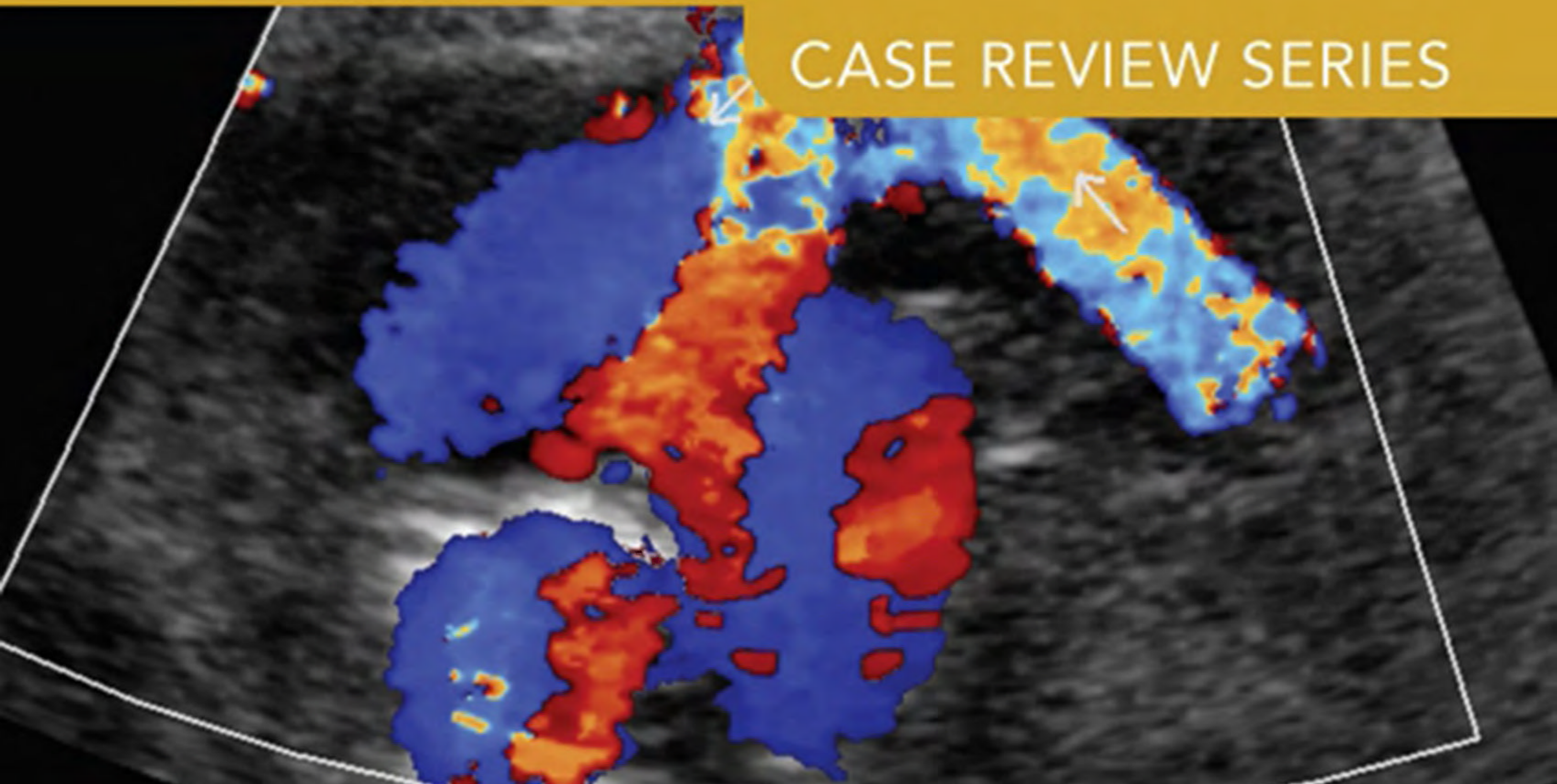
3RD EDITION

General & Vascular Ultrasound

CASE REVIEW SERIES



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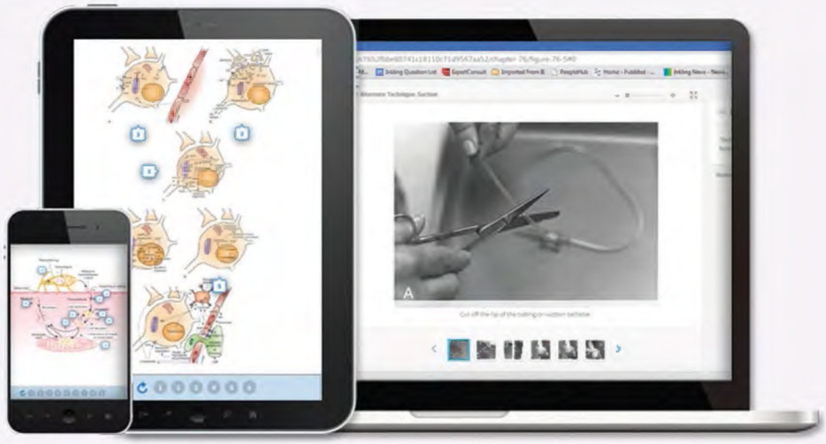

CASE REVIEW

General and Vascular Ultrasound

THIRD EDITION

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I would like to thank prior colleagues in my life who have helped mentor me to reach my goals in academic radiology. I would also like to acknowledge the faculty and residents, whom I hope I have mentored in achieving their goals on their road to success in academic endeavors.
I would like to dedicate this to all those who, throughout my life, have supported me in my endeavors, starting with my parents, my spouse, and, most importantly, my children and grandchildren, who bring me constant joy.

JPM

I would like to dedicate this case series to my family for their love, guidance, and support throughout my career. I would also like to dedicate this book to those who helped and guided me through medical school, residency, and fellowship. Finally, I would like to acknowledge my orthopedic and radiology colleagues with whom I have worked and done collaborative research; my life has been enriched by knowing and working with them.

SAT

To my family—Andrea, Claire, and Emma—and my father, mother, and brother.

LN

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I have been very gratified by the popularity and positive feedback that the authors of the **CASE REVIEW Series** have received on the publication of the editions of their volumes. Reviews in journals and online sites as well as word-of-mouth comments have been uniformly favorable. The authors have done an outstanding job in filling the niche of an affordable, easy-to-access, case-based learning tool that supplements the material in **The Requisites** series. I have been told by residents, fellows, and practicing radiologists that the **CASE REVIEW Series** books are the ideal means for studying for oral board examinations and subspecialty certification tests.

Although some students learn best in a noninteractive study book mode, others need the anxiety or excitement of being quizzed. The selected format for the **CASE REVIEW Series** (which consists of showing a few images needed to construct a differential diagnosis and then asking a few clinical and imaging questions) was designed to simulate the board examination experience. The only difference is that the **CASE REVIEW Series** books provide the correct answer and immediate feedback. The limit and range of the reader's knowledge are tested through scaled cases ranging from relatively easy to very hard. The **CASE REVIEW Series** also offers feedback on the answers, a brief discussion of each case, a link back to the pertinent **The Requisites** volume, and up-to-date references from the literature. In addition, we have recently included labeled figures, figure legends, and supplemental figures in a new section at the end of the book, which provide the reader more information about the case and diagnosis.

Because of the popularity of online learning, we have been rolling out new editions on the Web. We also have adjusted to the new Boards format, which will be electronic and largely case-based. We are ready for the new boards! The case reviews are now hosted online at https://expertconsult.inkling.com. The interactive test-taking format allows users to get real-time feedback, "pinch-and-zoom" figures for easier viewing, and links to supplemental figures and online references. Personally, I am very excited about the future. Join us.

David M. Yousem, MD, MBA

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I am happy to present the third edition of the **CASE REVIEW Series** on **General and Vascular Ultrasound,** Third Edition, by John McGahan, MD, Sharlene A. Teefey, MD, and Laurence Needleman, MD. The authors have updated the vascular and nonvascular U.S. cases with the latest knowledge and procedures being performed in 2015, emphasizing new uses in the musculoskeletal system. They have put greater emphasis on physics, artifacts, clinical evaluation, and treatment in line with what is expected of training radiologists by The Joint Commission as well as the Accreditation Council for Graduate Medical Education. This material has also been reformatted to enable online education. The third edition will certainly prepare residents and fellows for the newly formatted diagnostic radiology boards.

General and Vascular Ultrasound is one of the most popular in the **CASE REVIEW Series**. I am sure that this edition will continue that strong favorable history. Congratulations to the authors and to the readers who will benefit from their wisdom.

David M. Yousem, MD, MBA

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PREFACE

This is the updated third edition of the **CASE REVIEW Series** on **General and Vascular Ultrasound.** This case series uses a new multiple-choice question format and provides detailed explanations and discussions to bring the reader up-to-date medical knowledge. In this third edition, several new topics have been introduced, and some previous topics have been expanded. Cases include anatomy and cover intra-abdominal, retroperitoneal, pelvic, neck, scrotal, and peripheral vascular disease. Gray scale spectral and color Doppler usage is addressed for native vessels and transplanted organs. Ultrasound is a modality that requires an understanding not only of the anatomy and pathophysiology of the organ of interest but also of the physics and instrumentation of ultrasound. It is also important to have a sound understanding of flow dynamics in vessels and of the appearance of normal and abnormal waveforms. Thus there are case reviews discussing physics and artifacts, as well as duplex and color Doppler images of the peripheral vasculature. In recent years, ultrasound has exploded onto the field of musculoskeletal imaging. Therefore in this edition we added musculoskeletal ultrasound of some of the more common entities that might be encountered in a radiology practice. We hope you find these ultrasound case reviews and the accompanying discussions informative and that they enhance your practice.

John P. McGahan, MD

Sharlene A. Teefey, MD

Laurence Needleman, MD

ACKNOWLEDGMENTS

I would like to thank everyone who helped in the preparation of this textbook: Julie Ostoich-Prather for her work in helping me prepare some of the images for this text and my assistants who helped me with both typing and editing each of the case reports, including, among others, Hue To, Angela Michelier, and Veronica Conerly-Scott. Thanks to Katy Meert, Rae L. Robertson, and Robin Carter for their help in organizing and editing the final production of this work. Special thanks to Dr. David Yousem for the invitation to help on this edition of **General and Vascular Ultrasound.** Finally, and most important, I would like to thank every one of my trainees, fellows, and colleagues who have worked on this case series, including Dr. Brandon Doskcil, Dr. Priyanka Jha, Dr. Grant Holz, Dr. Gary Tse, Dr. Wonsuk Kim, Dr. Ellen Cheng, Dr. Pavan Khanna, Dr. Jennifer Chang, Dr. Shruthi Ram, Dr. Behrad Golshan, Dr. Michael Jin, Dr. Ruchi Chaudhari, Dr. Ethan Neufeld, and Dr. Ghaneh Fananapazir.

JPM

I would like to thank my teachers, especially Barry Goldberg, Eli Kazam, Alfred Kurtz, and Richard Wechsler. I thank the sonographers and vascular technologists at Thomas Jefferson University, especially Lauren Lown and the late Joe Darby, for their hard work (and excellent images, some of which are in this book). Thank you to Traci B. Fox, Maria Stanczak, and Sandeep Deshmukh for helping with some of these cases. Finally, thanks to all my colleagues and students who help me keep learning.

LN

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CONTENTS

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Opening Round

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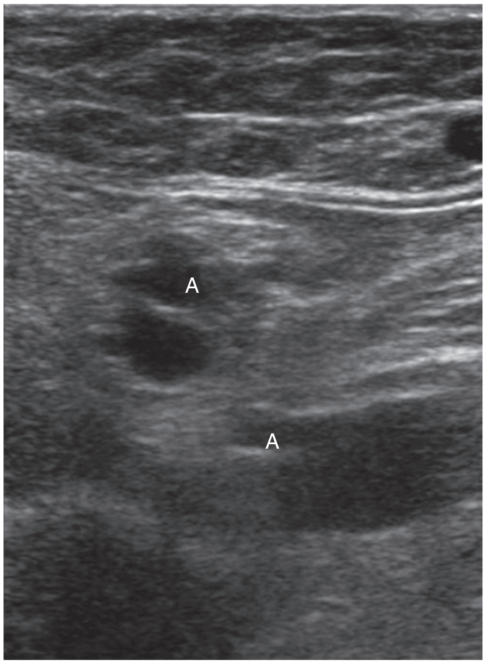

Figure 1-1

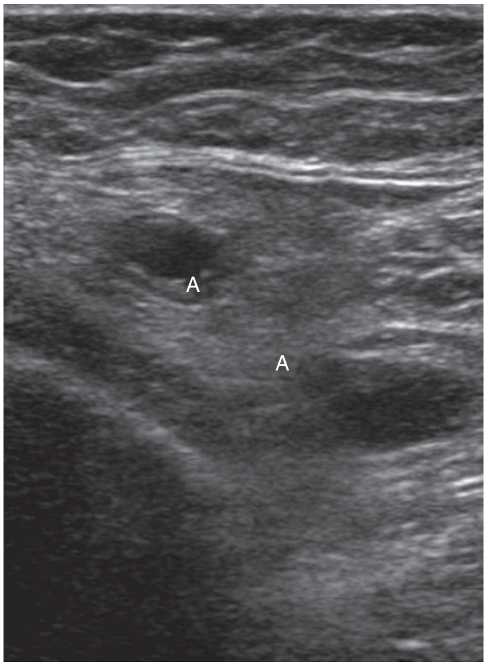

Figure 1-2

HISTORY: A 62-year-old man with lung cancer in the hospital for treatment presents with a swollen leg without pain. A lower extremity venous ultrasound was performed. Transverse images of the upper thigh, at the level of the proximal femoral and deep femoral veins, without and with compression were obtained.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Acute deep venous thrombosis (DVT)
   B. Residual venous thrombosis
   C. Recurrent DVT
   D. Superficial thrombophlebitis
2. What is the most common gray scale sign of acute DVT?
   A. Free-floating clot
   B. Continuous waveform
   C. Deformable filling defect
   D. Irregular filling defect
3. What does the management of uncomplicated acute femoral DVT include?
   A. Follow-up ultrasound at 1 week
   B. Thrombolysis
   C. Inferior vena cava (IVC) filter
   D. Anticoagulation
4. There is acute thrombosis in the left femoral vein and the posterior tibial vein. What does this indicate?
   A. A hypercoagulable state
   B. Normal natural history
   C. Vein-to-vein embolism
   D. Superficial thrombophlebitis

See Supplemental Figures section for additional figures and legends for this case.

CASE 1

Acute Deep Venous Thrombosis

1. **A.** The correct answer is acute DVT. The deep femoral vein is dilated and noncompressible (Fig. S1-2). This is a less common location for DVT than the femoral vein. The appearance is not of a residual venous thrombosis (scar). There is no evidence of prior DVT so the material is not recurrent. The femoral vein and the deep femoral veins are deep veins so there is no superficial thrombophlebitis.
2. **C.** The most common finding in DVT is of a noncompressible vein. The acute DVT, being soft, is deformable. While a free-floating clot is acute, it is seen less commonly. Residual venous thrombosis is irregular and the material is hard and nondeformable. A continuous waveform is a Doppler sign of obstruction, not a gray scale sign.
3. **D.** The vast majority of DVT above the knee is treated with anticoagulation. Thrombolysis and IVC filters are used in rarer complicated cases. Follow-up ultrasound without treatment is incorrect.
4. **B.** Multiple sites of DVT frequently occur together. Since the calf veins are the most frequent and the earliest site of DVT, identifying clots above and below the knee is not unusual. DVT in multiple sites does not indicate a hypercoagulable state. The clot above the knee occurs spontaneously; it is not an embolism from a more distal site. These veins are deep so there is no superficial thrombophlebitis.

Comment

Imaging Findings

The venous ultrasound exam consists of gray scale ultrasound and color duplex Doppler. The gray scale ultrasound component has an uncompressed cross-sectional view of the vein (Fig. S1-1) and a compressed view of the vein (Fig. S1-2). Normal veins will compress completely. If a vein does not compress, the study is abnormal (Figs. S1-2 and S1-4). The three reasons why the vein will not compress are acute DVT, residual material in the vein (residual venous thrombosis [scarring]), and inadequate compression. If the adjacent artery is distorted by the compression, the degree of compression is adequate.

The gray scale appearance of acute venous thrombosis has several characteristic findings. Although not as common, the identification of free-floating material inside the vein is pathognomonic. Acute clot tends to enlarge the vein (Figs. S1-1 and S1-3). When compressed, the acute thrombus is relatively soft and so it is deformable with compression (Fig. S1-2). Additionally, the surface of the material, better seen in long axis, is smooth. Echogenicity is often cited as a characteristic to differentiate acute from chronic material but, with modern machines, most acute clots tend to be heterogeneous (Fig. S1-3) and echogenicity is not generally helpful.

Anatomy

The major deep veins above the knee are the common femoral vein, femoral vein, and popliteal vein. The name “femoral vein” has replaced the term “superficial femoral vein” because the vein is part of the deep system. The common femoral vein becomes the external iliac vein above the inguinal ligament.

Treatment and Follow-up

Treatment for acute DVT in the iliac femoral and popliteal veins is generally anticoagulation. An IVC filter may be necessary in some if there is a contraindication to anticoagulation.

Follow-up ultrasound during anticoagulation is rarely warranted in the early period following treatment. Recommendations for follow-up are made if there is a change in clinical status that will require a change in therapy. However, a repeat ultrasound near the end of treatment (before anticoagulation is completed) can determine if there is residual scarring and may affect the length of treatment.

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Cross-reference

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CASE 2

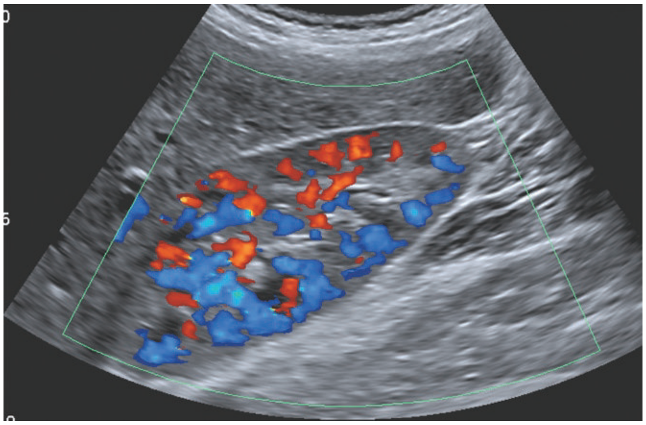

Figure 2-1

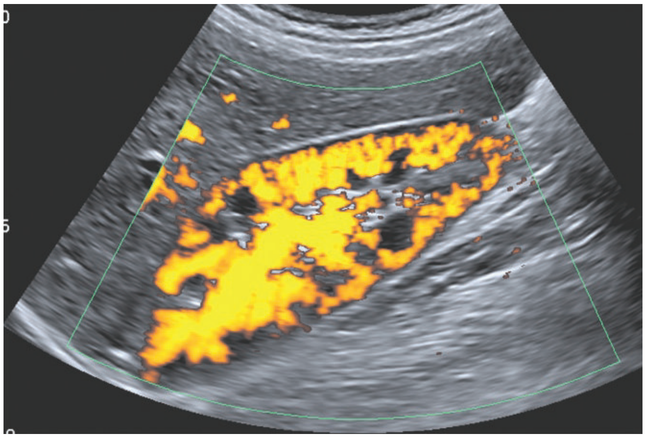

Figure 2-2

HISTORY: Two color images of the right kidney from a renal study for flank pain are shown.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented?
   A. Normal kidney
   B. Arteriovenous malformation
   C. Pyelonephritis
   D. Hydronephrosis
2. What is the main difference between color and power?
   A. Color uses Doppler, and power uses speckle tracking.
   B. Color uses frequency, and power uses amount of signal.
   C. Power uses red and blue, and color uses yellow.
   D. Power rejects venous flow, and color shows arterial and venous flow.
3. In regard to power, which of the following is false?
   A. It is more sensitive to perpendicular flow.
   B. It is more sensitive to fast flow.
   C. It is more sensitive to tissue motion.
   D. It is more sensitive to slow flow.
4. What is an advantage of color Doppler over power Doppler?
   A. Aliasing
   B. Directional information
   C. Detection of slow flow
   D. Can be used with spectral Doppler

See Supplemental Figures section for additional figures and legends for this case.

CASE 2

Power and Color Doppler

1. **A.** Figure S2-1 shows color through the kidney, but there is a paucity of color in the lower and upper poles. This is likely related to poor angle. The power Doppler in Figure S2-2 shows flow throughout the kidney and so confirms the absence of color was artifactual. Pyelonephritis can show an area or areas of diminished flow, but the power Doppler is normal. There is no local change in color to suggest arteriovenous malformation. There is no hydronephrosis.
2. **B.** The main difference between color and power is that color uses frequency; power uses amount of signal. Both methods use Doppler. Color Doppler uses two or four colors to encode information; power generally uses one color. Arterial and venous flow is colorized in both techniques.
3. **B.** Power and color are equally sensitive to fast flow, but power is more sensitive to slow flow. Power is more sensitive to flow at and near 90 degrees. It is also more sensitive to tissue motion that can create artifacts.
4. **B.** An advantage of color Doppler over power Doppler is directional information. Most modes of power do not present directional information. Both can be used with spectral Doppler. Aliasing is an artifact (Fig. S2-3) and may not be helpful. Power detects slow flow better than color Doppler.

Comment

Moving blood creates Doppler information. The information can be color Doppler encoded based on velocity and direction (Fig. S2-1) or power Doppler color assigned based on the amount (not the size) of the shifts (Fig. S2-2). The concentration of shifts affects the power Doppler color assignment and has a relation to the amount of moving blood. Power Doppler maps generally show shades of one color. Some newer power Doppler machines can encode direction, but this is not widely used.

The main advantage to power Doppler is improved signal-to-noise (Fig. S2-2). Noise is random but weak; noise can be distinguished from color information, and gain can be increased without fear of introducing too much false signal. Power is more sensitive to smaller, deeper vessels. Power Doppler is also less dependent on angle so vessels at 90 degrees fill better. Aliasing seen in color Doppler (Fig. S2-3) is not present in power, so lower pulse repetition frequencies can be used to detect slower flow. The single color used in power Doppler can help to define the edge of flow (Fig. S2-4).

In some instances the amount of flow (e.g., renal transplants) may be as important as determining venous or arterial flow, and power Doppler can give a better overview of normal or absent flow in some organs. The amount of flow is not quantitative and the presence of color is not equivalent to perfusion. Hyperemia and synovitis are detectable using power Doppler so it is frequently used to diagnose, assess, and monitor risk of relapse in rheumatological diseases.

The lack of directional information in power Doppler favors color Doppler when this is important. In instances where velocity information is helpful such as stenoses, color Doppler is favored over power. In practice, switching between the two modes is easy, and in some settings creating images in both modes can give added information beyond either one alone.

Power Doppler is subject to artifacts. The most common is flash created from transducer motion or moving objects. False flow may also be detected at edges with strong reflectors.

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Cross-reference

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CASE 3

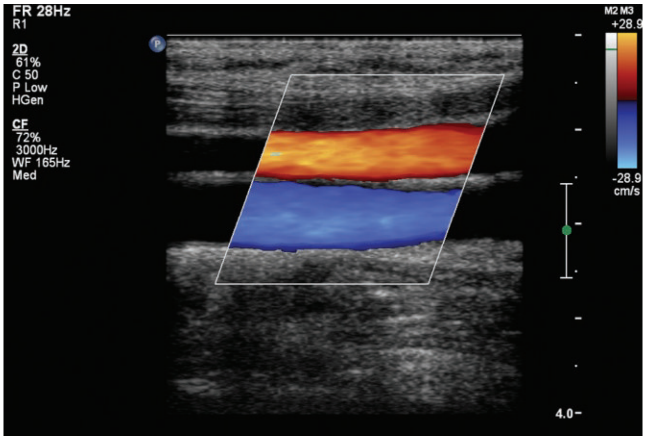

Figure 3-1

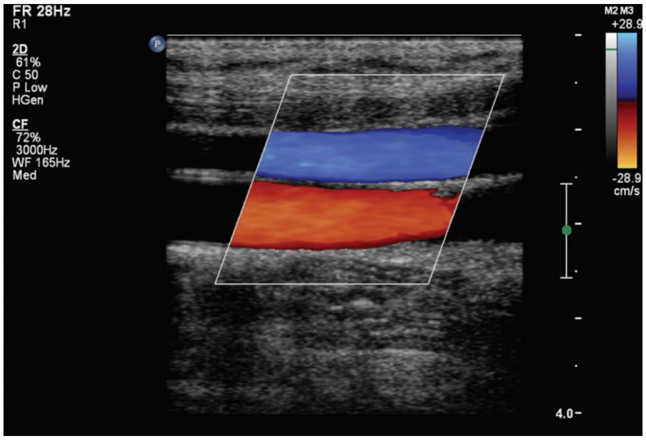

Figure 3-2

HISTORY: Two sagittal images from the jugular vein and common carotid artery in the neck were taken seconds apart.

1. What accounts for the change in color assignment between the two images?
   A. Transducer orientation
   B. Systole in one and diastole in the other
   C. Color box orientation
   D. Color map inversion
2. With regard to color Doppler examinations, which of the following is true?
   A. Red is always flow toward the transducer, and blue is away.
   B. Red is always arteries, and blue is veins.
   C. Red is always flow toward the head, and blue is toward the feet.
   D. None of the above.
3. With regard to spectral Doppler examinations, which of the following is true?
   A. Toward the transducer is above the baseline; away is below the baseline.
   B. Toward the transducer are positive Doppler shifts; away are negative Doppler shifts.
   C. Arteries are always above the baseline; veins are below the baseline.
   D. None of the above.
4. With regard to the direction of the color box, which of the following is true?
   A. It should never be set to perpendicular to the skin.
   B. It should be oriented so arteries are red.
   C. It should be oriented to optimize color filling.
   D. It should always give a single color direction in the vessel being examined.

See Supplemental Figures section for additional figures and legends for this case.

CASE 3

Flow Direction

1. **D.** The color map shows which color is assigned to toward, and which to away from the transducer. In these images, flow toward is red in Figure S3-1 and blue in Figure S3-2. The map is switched by a color invert control. A reversed transducer can cause this but it is not the cause in this case. The cardiac cycle may affect arterial and venous color, but typically not at the same time. Color box orientation was not changed in these images; both show the box to be oriented toward the head.
2. **D.** There is no standard in vascular sonography for color assignment. The color on the upper part of the color map is flow toward the transducer; the lower color is flow away from the transducer. An artery or vein may be red or blue based on the map and its direction.
3. **B.** In the spectrum, flow toward the transducer is always assigned positive Doppler shifts (either without a designation or designated with a positive sign). Flow away are negative shifts (designated by a minus sign). The spectrum may be inverted so flow toward the transducer may be above or below the baseline.
4. **C.** The direction of the color box should be oriented to optimize color filling. This is based on the vessel's Doppler angle to the transducer and a good angle may be perpendicular to the skin. The box direction should avoid a direction perpendicular to the vessel. Some vessels may be oriented in different directions in the scan, and a single color assignment is not possible.

Comment

The interpretation of a Doppler image begins with identifying where in the patient the image was taken. The orientation of the image (e.g., sagittal, longitudinal, oblique) and the location of the Doppler portion determine which vessels are evaluated. This lets the interpreter understand what to expect in normal. The image is then analyzed for the presence, direction, and characteristics of flow. If it is as expected, the image is normal; if not, it is abnormal and the abnormalities characterized.

The direction of flow is determined by analyzing the color image or spectral Doppler with respect to the direction of the ultrasound beam out of the probe relative to the vessel. The Doppler color box (Figs. S3-1, S3-2, and S3-3) and the Doppler line (Figs. S3-5 and S3-6) should be positioned to avoid striking vessels at 90 degrees (Fig. S3-4) because the Doppler shift will be absent or minimal and it may be difficult to characterize direction and the character of flow.

In evaluating direction, note how color is assigned to away or toward the transducer. In vascular imaging, there is no standard but some sonographers invert the color assignment so veins of interest are blue and arteries red.

The direction of the Doppler out of the transducer may be left to right, straight down or right to left. In evaluating the image, if one creates an imaginary line in the beam's direction to exit out of the transducer to the vessel under interrogation, flow toward or away on the image can be assigned.

A single vessel may have more than one direction in a large color box if the vessel travels across the box; they can be toward or away from the transducer in different parts of the image.

Two different arteries and veins may have flow in different directions (e.g., in the abdomen the splenic artery flows right to left and the hepatic artery left to right, or the portal and hepatic veins may flow in opposite directions).

The Doppler frequency spectrum labels flow toward the transducer as positive and flow away as negative velocities (e.g., −100 cm/s). Most interpreters prefer to look at arterial waveforms above the baseline, and inverting the waveform is usually done in arterial studies. Inversion is less common in venous examinations. The spectrum should be evaluated to see if the positive numbers are above or below the baseline. If below, the spectrum is inverted; somewhere near the spectrum a notation indicating it is inverted (e.g., Inv) will be present (Fig. S3-5). Not recognizing an inverted waveform can produce errors.

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Cross-reference

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CASE 4

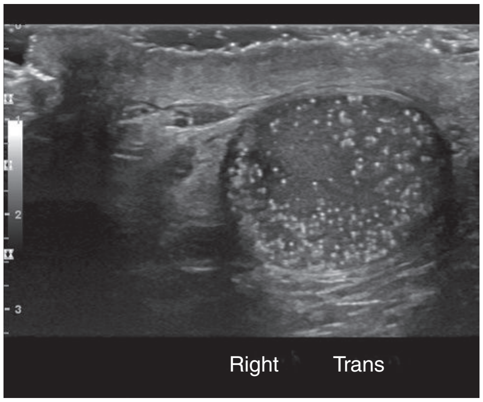

Figure 4-1

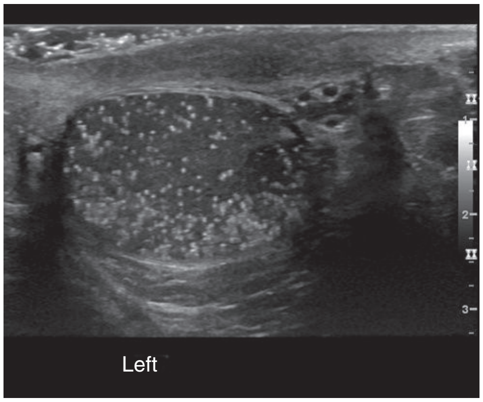

Figure 4-2

HISTORY: A 28-year-old male presents with testicular pain. Images of the right and left testes were obtained.

1. Which one of the following would be included in the differential diagnosis for the imaging findings presented in Figures 4-1 and 4-2?
   A. Testicular trauma
   B. Germ cell neoplasm
   C. Orchitis
   D. Calcium deposition in seminiferous tubules
   E. Testicular torsion

2. Which one of the following is a false statement concerning this entity?
   A. There is a conclusive relationship between testicular microlithiasis (TM) and the eventual development of testicular malignancy.
   B. There is an increased prevalence of testicular tumors in patients with TM.
   C. The incidence of TM in most studies of sonography of the scrotum is in the range of 5%.
   D. The tumors associated with TM are germ cell tumors.

3. What number of echogenic foci on at least one sonographic image of the testicle would be the most common criterion for the diagnosis of TM?
   A. 3
   B. 5
   C. 10
   D. 25

4. Concerning the recommendation for a patient with TM, which of the following is not recommended?
   A. Annual sonographic exam
   B. Annual physical examination
   C. Prophylactic orchiectomy
   D. Self-examination of the testes

See Supplemental Figures section for additional figures and legends for this case.

CASE 4

Classic Testicular Microlithiasis

1. **D.** This particular entity is TM. This is due to calcium deposition in the seminiferous tubules.
2. **A.** There is no proof within the literature that a testicular malignancy will develop from TM. At the time of diagnosis of TM, there is a noted increase prevalence of testicular tumors.
3. **B.** Although this definition may be arbitrary, the most common definition of classic microlithiasis is having five or more echogenic foci on one sonographic image of the testicle.
4. **C.** No one advocates prophylactic orchiectomy. There are advocates within the literature of all other choices.

Comment

Differential Diagnosis

Differential for these images is very small. This appearance is that of classic microlithiasis (Figs. S4-1 and S4-2). Calcifications may occur with a number of different testicular neoplasms or can be secondary to testicular infarction and/or trauma. However, those calcifications are usually denser, more focal, and have quite a different appearance from classical microlithiasis as seen in this case.

Ultrasound Findings

Ultrasound finding of TM is defined as five or more echogenic foci on a single image of a testis. Certainly, this definition is somewhat arbitrary, but this has been described as classic microlithiasis. Typically, the distribution of calcifications is diffuse and usually bilateral (Figs. S4-1 and S4-2).

Prognosis/Management

TM refers to laminated calcium deposits within the lumen of the seminiferous tubule. Patients with microlithiasis have an increased incidence of testicular malignancy compared to those without TM. These patients often have associated risk factors, including cryptorchidism, Klinefelter syndrome, and Down syndrome, to name a few.

There have been a number of different management schemes proposed for patients with TM. Some have felt that the risk of neoplasms in patients with TM is so high that screening computed tomography of the chest, abdomen, and pelvis is recommended. This is a more extreme recommendation. Most would not agree with this specific recommendation. Some advocate annual sonographic examination and many would consider this as the standard follow-up. However, no study has shown that performing annual sonographic examination will definitely increase detection or decrease morbidity of germ cell tumors. Also, no study has shown a definitive survival benefit of surveillance sonography of patients with TM. Most would encourage periodic self-examination and sonography for any detected abnormality. Others have suggested annual follow-up physical examination without sonography. Certainly, instruction in self-examination seems simple and appropriate. Annual physical exam and/or sonography could be considered. Final consensus would depend on a long-term study or follow-up of patients with TM. A recent study with 30 patients with TM, followed for an average of 19 months, showed there was no tumor development in this group.

References

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Cross-reference

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CASE 5

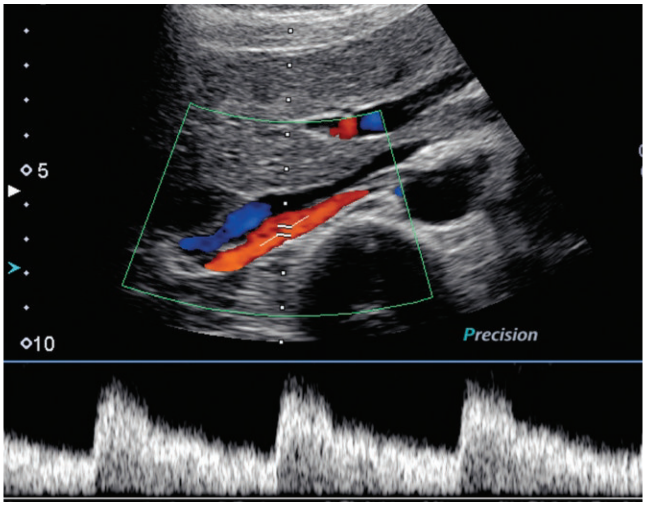

Figure 5-1

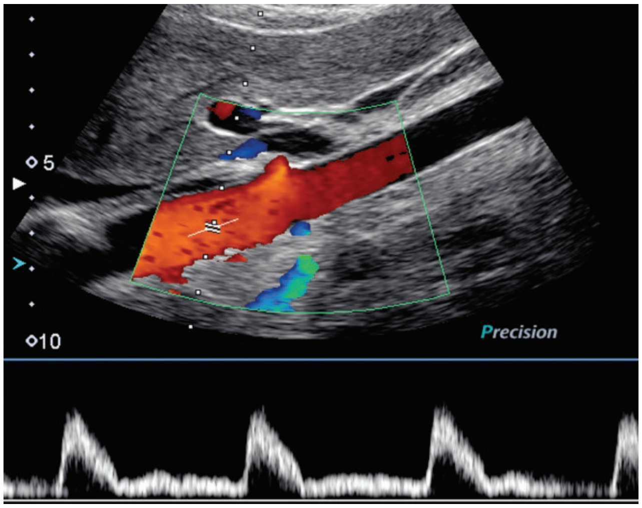

Figure 5-2

HISTORY: Two spectral Doppler waveforms from a renal artery duplex study are shown. Figure 5-1 is of the mid right renal artery and Figure 5-2 is of the aorta.

1. Regarding the two vessels, which of the following is true?
   A. The right renal artery in Figure 5-1 is abnormal due to pathologic spectral broadening.
   B. The aorta in Figure 5-2 is abnormal due to pathologic spectral broadening.
   C. Both arteries have laminar flow.
   D. Neither artery has laminar flow.

2. What does spectral broadening describe?
   A. The presence of multiple different velocities in the spectrum along a particular time in the vertical axis
   B. Turbulent flow
   C. Laminar flow
   D. Abnormal flow

3. Where is spectral broadening not seen?
   A. After stenoses
   B. At bifurcations
   C. At aneurysm
   D. In plug flow

4. Pathologic spectral broadening has all of the following except
   A. The whiteness of the envelope (peak velocity) is greater than the window (lower velocities).
   B. The average velocity is near the baseline.
   C. The edge of the envelope is not well defined.
   D. Forward and reverse flow may be present.

See Supplemental Figures section for additional figures and legends for this case.

CASE 5

Spectral Broadening

1. **C.** Both arteries have laminar flow. The renal artery flow profile is parabolic so normal spectral broadening is present. The aorta has plug flow so spectral broadening is absent.
2. **A.** Spectral broadening describes the presence of multiple different velocities in the spectrum along a particular time in the vertical axis. It may be present in normal and abnormal flow and is seen in laminar flow that is parabolic as well as turbulent or disturbed flow.
3. **D.** Spectral broadening is not seen in plug flow. All of the blood in the center of the vessel is flowing in one direction with nearly one velocity (Fig. S5-2). Any change in vessel size or direction can create spectral broadening.
4. **A.** Pathologic spectral broadening has the whiteness of the envelope (peak velocity) to be equal to or less than the window (lower velocities).

Comment

The spectral Doppler is a graphical display of the Doppler shifts detected (Figs. S5-1 and S5-2). The fastest red blood cells create the signals that form the outer edge of the spectrum. This is called the envelope. The signals from lower velocity flow appear underneath the envelope, and this area is called the window (Fig. S5-1). If all the blood is moving at one velocity the window is empty (Fig. S5-2). If lower velocities are present, there are signals filling in the window (Fig. S5-1). The presence of high and low velocities in the spectrum is called spectral broadening. Spectral broadening is a description of a waveform; it occurs in normal (Fig. S5-1) and abnormal vessels (Fig. S5-3).

Spectral broadening may also be created by technical factors such as too much gain or an improper sample volume size (Figs. S5-4 and S5-5).

Normal Spectral Broadening

Blood travels in layers, and multiple layers are typically evaluated in the sample volume. In straight large arteries, all of the blood is flowing in one direction and is laminar. In smaller vessels, the center stream moves fastest, and each layer moves more slowly until there is slow or absent flow at the vessel wall. A spectral Doppler from this vessel will have all velocities represented, filling in the window, and be spectrally broadening.

As vessels turn and at bifurcations the blood does not stay in well-defined layers, and it travels in a variety of directions until the vessel straightens. The different directions of flow also create faster and slower velocities and so waveforms in these normal areas are also spectrally broadened. Some areas, such as at the carotid bifurcation where the vessel widens (the carotid bulb), may be mistaken for diseased vessels if the normal spectral broadening is not appreciated.

Laminar Flow

Laminar flow is where the flow is straight and the layers flow parallel to one another. Normal small vessels are laminar and demonstrate normal spectral broadening. Large straight arteries also demonstrate laminar flow but without spectral broadening. All of the blood in these vessels is traveling at one velocity except near the vessel wall. A spectrum from the center of these vessels shows one velocity and no filling in of the window (Fig. S5-2).

Abnormal Spectral Broadening

Spectral broadening also occurs in regions of pathologic flow disturbances, typically related to mild and severe stenoses. Beyond milder stenosis, eddy currents are created after the obstruction. This multidirectional flow with lower and higher velocities demonstrates abnormal spectral broadening.

Poststenotic disturbed flow and turbulence are characterized by more pronounced spectral broadening (Fig. S5-3). As the blood exits the narrowed stenosis, it begins to travel in different directions and at different velocities, creating spectral broadening. The envelope may be poorly defined. Additionally, blood may be spinning, creating simultaneous forward and reverse flow.

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CASE 6

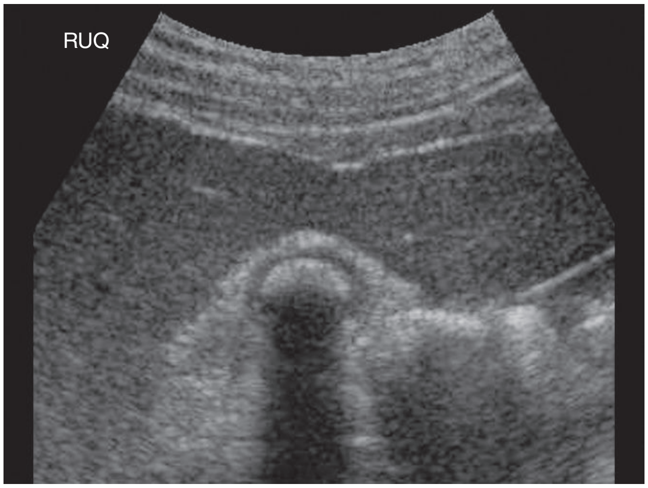

Figure 6-1

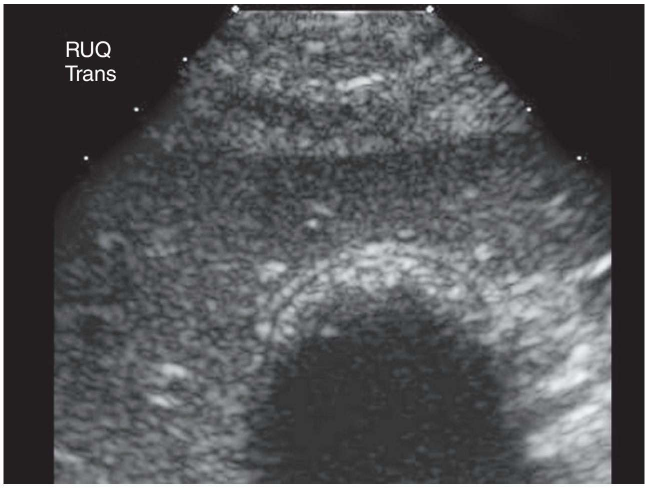

Figure 6-2

HISTORY: A 38-year-old male presents with right upper quadrant pain.

1. Which one of the following would be included in the differential diagnosis for the imaging findings presented?
   A. Emphysematous cholecystitis
   B. Gallstones
   C. Acute acalculous cholecystitis
   D. Porcelain gallbladder
2. Cholesterol stones constitute approximately what percentage of gallstones?
   A. 20%
   B. 40%
   C. 75%
   D. 95%
3. Which one imaging feature would NOT be compatible with a diagnosis of gallstones?
   A. Mobility on patient repositioning
   B. Posterior acoustic shadowing
   C. Vascularity on Doppler ultrasound
   D. Highly reflective anterior surface
4. Which one of the following is NOT a risk factor associated with gallstone formation?
   A. Advanced age
   B. Female gender
   C. Pima Indian ethnicity
   D. Parenteral nutrition

See Supplemental Figures section for additional figures and legends for this case.

CASE 6

Wall-Echo-Shadow Sign

1. **B.** Gallstones, biliary sludge, and mild gallbladder wall thickening are present. There is no dirty shadowing (curvilinear gas in the gallbladder wall) suggestive of emphysematous cholecystitis, or dense posterior acoustic shadowing of the gallbladder wall suggestive of porcelain gallbladder.
2. **C.** Approximately 75% of gallstones are cholesterol stones. Approximately 25% are calcium-bilirubinate stones. Many stones are mixed.
3. **C.** Vascularity within an echogenic structure in the gallbladder would indicate perfused soft tissue and be concerning for gallbladder carcinoma or polyp.
4. **B.** Female gender, not male, is associated with gallbladder formation. Women are thought to be more at risk due to estrogen's effect on the liver, causing it to remove more cholesterol from the blood and secrete it in the bile.

Comment

Ultrasound Findings

The principal ultrasound imaging features of gallstones are (1) highly reflective anterior surface; (2) posterior acoustic shadowing; and (3) mobility on patient repositioning. They may also demonstrate twinkle artifact on Doppler imaging; however, this is a less reliable and nonspecific finding. If a large gallstone occupies the gallbladder, the wall-echo-shadow (WES) sign may be encountered (Figs. S6-1 and S6-2). This sign describes visualization of the gallbladder wall, an echo representing the highly reflective anterior surface of the gallstone, and the posterior acoustic shadow of the large gallstone. The WES sign should be contrasted against the imaging findings of porcelain gallbladder, in which only a highly echogenic wall with dense posterior acoustic shadowing is seen.

Differential Diagnosis

Major differential considerations for gallstones include sludge balls and gallbladder polyps. Sludge balls can be mobile like gallstones but, unlike gallstones, would not typically cast a posterior acoustic shadow or demonstrate a highly reflective anterior surface. Sludge balls also tend to be larger than most gallstones. A small sludge ball would be difficult to distinguish from a gallstone, as small gallstones less than 5 mm do not tend to shadow. Gallbladder polyps are protrusions of soft tissue adherent to the gallbladder wall and do not move or shadow like gallstones. They tend to be hypovascular, so lack of vascularity on Doppler imaging would still be consistent with this diagnosis. When the WES sign is present, it is confusing, as the lumen of the gallbladder is not seen. In these cases, only the wall of the gallbladder is seen and it is often thickened (Figs. S6-1 and S6-2). The gallstone or stones are seen that cast an acoustic shadow.

Prognosis

Gallstones are extremely common, especially in middle-aged, obese females. They are frequently also asymptomatic and in that case require no specific management. Gallstones can present with several complications, including biliary colic due to passing of small stones through the cystic duct, acute cholecystitis, and chronic cholecystitis. Rarely, gallstones near the neck of the gallbladder can compress the common bile duct causing function obstruction, a clinical entity known as Mirizzi syndrome. Laparoscopic cholecystectomy is the most frequent definitive treatment for these ailments.

Reference

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 33–39.

CASE 7

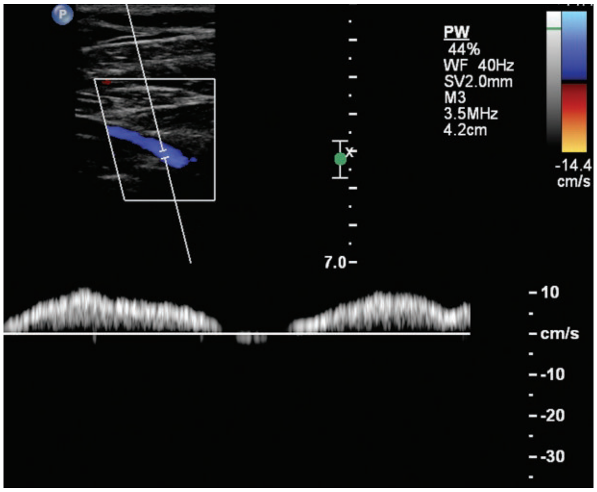

Figure 7-1

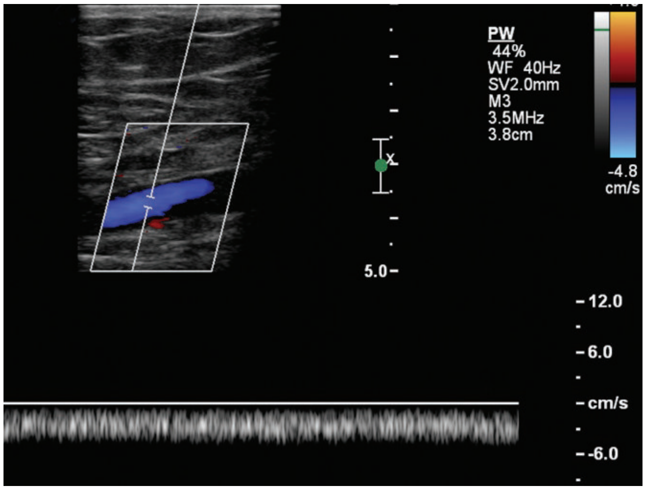

Figure 7-2

HISTORY: A 49-year-old presents with persistent leg swelling 9 months after an acute deep venous thrombosis (DVT). As part of the lower extremity venous ultrasound, spectral and color Doppler images of the left and right common femoral veins (CFVs) were obtained.

1. Regarding the CFV waveforms, which of the following is true?
   A. Both the CFV in the left image and the CFV in the right image are abnormal.
   B. The CFV in the left image is normal, and the CFV in the right image is abnormal.
   C. The CFV in the left image is abnormal, and the CFV in the right image is normal.
   D. Both CFV waveforms are normal.

2. Regarding venous ultrasound studies for a single symptomatic leg, which of the following is true?
   A. Unilateral DVT studies require bilateral venous waveforms from the common femoral or iliac vein.
   B. Unilateral DVT studies require bilateral waveforms from the femoral or popliteal vein.
   C. Unilateral DVT studies are confined to one leg only.
   D. Unilateral DVT studies require pulsatile changes to document a normal waveform.

3. What is the most common spectral Doppler finding in femoral DVT?
   A. Increased pulsatility in the CFV
   B. Decreased pulsatility in the CFV
   C. Increased phasicity in the popliteal vein
   D. Decreased phasicity in the popliteal vein

4. A left CFV Doppler waveform is continuous. What are possible causes for this? (Choose all that apply.)
   A. Left iliac vein occlusion
   B. Cervical cancer
   C. Normal CFV
   D. Inferior vena cava (IVC) thrombosis

See Supplemental Figures section for additional figures and legends for this case.

CASE 7

Lower Extremity Venous Obstruction

1. **B.** The CFV that varies is a normal phasic variation (Fig. S7-1). A small amount of reversed flow can be normal in the CFV. The CFV that is flat is abnormal and called a continuous waveform (Fig. S7-2).
2. **A.** In all studies, at a minimum, bilateral waveforms from the pelvis or thigh, either the common femoral or iliac veins, are required. The rationale is to detect symmetry of the waveforms. Normal common femoral waveforms show phasic waveforms from respiration. Pulsatile waveforms can be seen in the CFV from the cardiac cycle but are not seen in the majority of patients. Excessive pulsatility may be seen with cardiac dysfunction.
3. **D.** Obstruction in the femoral vein will cause loss of phasicity in the vein distal to it, in this case the popliteal vein. The CFV is proximal to the femoral vein, and the common waveform does not change from more distal disease.
4. **A, B, and D.** Any process that obstructs flow can create a continuous signal. This may be DVT above the site of the Doppler sample, scarring in the vein, or extrinsic obstruction. The normal CFV signal is never continuous.

Comment

Duplex Doppler for venous disease consists of color Doppler and spectral Doppler.

Color Doppler

When DVT is present, the color Doppler demonstrates a filling defect. Color Doppler shows flow around the edge of most acute clots. The flow around the edge of clots seen on color Doppler is analogous to the contrast flowing around the clot in contrast venography. Acute clot may sometimes be completely occlusive without color or spectral Doppler.

Care must be made when evaluating color Doppler because a filling defect can be falsely created by too little gain. Alternatively, a subtle filling defect may be obscured if excessive color from too much gain overwrites the clot.

Normal and Abnormal Spectral Doppler Waveforms

In the normal vein of the lower extremity the velocity of the venous signal will vary during breathing. This normal variation is called phasicity (Fig. S7-1).

Spectral Doppler is generally performed distal to a filling defect to evaluate for obstruction by the filling defect. When obstruction is present, the phasic variation is blunted or completely absent. When there is no change during breathing, the waveform is described as continuous (Figs. S7-2 and S7-4). When there is complete obstruction, no flow is present (Fig. S7-6). When patients are in congestive heart failure or with elevated right heart pressure, the phasic variation may be excessive.

Differential Diagnosis

The presence of a blunted or continuous waveform indicates there is obstruction above the level that the Doppler was obtained from. For instance, if the CFV indicated obstruction, it may be at the iliac or IVC level. If the obstruction is from the IVC, both CFVs will be obstructed. If only one iliac waveform is blunted, that iliac is obstructed.

The etiology of obstruction may be an acute DVT (Fig. S7-6), scarring from prior DVT (Fig. S7-3), or extrinsic compression from a mass (Fig. S7-5).

In the presence of asymmetrical common femoral or iliac vein waveforms further investigation may be warranted. Ultrasound of the pelvic veins and adjacent tissues are performed by some, but not all, labs to determine if pelvic disease is causing the blunted signal. If venous ultrasound is not performed or is indeterminate, other modalities such as magnetic resonance (MR) or computed tomography (CT) of the pelvis should be considered. The etiology for the abnormal signal can generally be determined using CT or MR.

Treatment

Treatment is based on the etiology of the obstruction.

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Cross-reference

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CASE 8

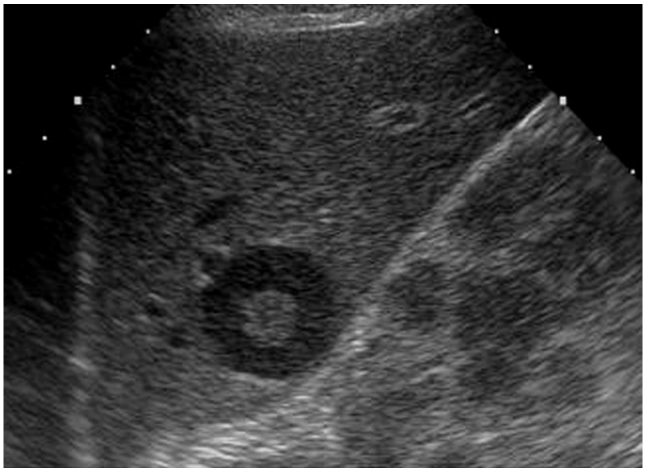

Figure 8-1

Figure 8-2

HISTORY: A 34-year-old female presents with right upper quadrant abdominal pain.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented in Figure 8-1? (Choose all that apply.)
   A. Metastases
   B. Hepatocellular carcinoma
   C. Abscess
   D. Lymphoma
2. What is the lesion in Figure 8-1 most likely to be?
   A. Benign neoplasm
   B. Malignant secondary liver tumor
   C. Infectious mass
   D. Malignant primary liver tumor
3. Which of the following benign etiologies could also have this appearance?
   A. Hepatic angiomyolipoma
   B. Focal nodular hyperplasia
   C. Hemangioma
   D. Biliary hamartoma
4. Which of the following liver metastases is most likely to have this imaging appearance?
   A. Melanoma
   B. Breast cancer
   C. Renal cell carcinoma
   D. Medullary thyroid cancer

See Supplemental Figures section for additional figures and legends for this case.

CASE 8

Hepatic Target Lesions

1. **A, B, and D.** The differential diagnosis includes metastases, hepatocellular cancer, lymphoma, and an abscess. Abscesses usually have more peripheral echogenic region. An abscess with this pattern would be considered less likely. The best answer for this target lesion is a metastasis.
2. **B.** Target lesions are much more likely to be malignant. Although, much less likely, benign etiologies may also occasionally have this appearance.
3. **B.** Focal nodular hyperplasia can occasionally have the appearance of a target lesion. However, this is uncommon.
4. **B.** Hypovascular liver metastases, from colon and breast carcinoma, are more likely to have the imaging appearance of a target lesion. The patient in this case was diagnosed with metastatic breast cancer. The remainder of the choices listed are typically hypervascular metastases and do not present as "target" or "bull's-eye" lesions.

Comment

Differential Diagnosis

The lesions shown in Figure S8-1 have an isoechoic or hyperechoic center and a hypoechoic rim. This appearance is referred to as a target lesion, and the great majority of these lesions are malignant. Liver metastases are most common, but hepatocellular carcinoma, lymphoma, and abscess can also have this appearance and should be considered in the differential diagnosis in the proper clinical setting.

Ultrasound Findings

It is very uncommon to see target lesions from benign etiologies. Hepatic adenomas and focal nodular hyperplasia may appear as target lesions, but they are much less common than hepatic metastases. Hemangiomas are extremely common liver tumors, but it is rare for them to have a hypoechoic rim. They typically have a "reverse" target appearance, being hyperechoic, but with an iso- to hypoechoic center.

Management

Target lesions typically arise from metastases from colon, breast, and lung cancers, among other primary malignancies. A contrast computed tomography or contrast magnetic resonance imaging of the abdomen may be useful (Fig. S8-2). The hypoechoic rim of the target lesion usually represents a viable tumor and should be the area of interest for percutaneous biopsies. Further management will depend on the etiology of the target lesion.

References

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Cross-reference

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Acknowledgments

Special thanks to Pavan Khanna, MD, for preparation in this case.

Figure 9-1

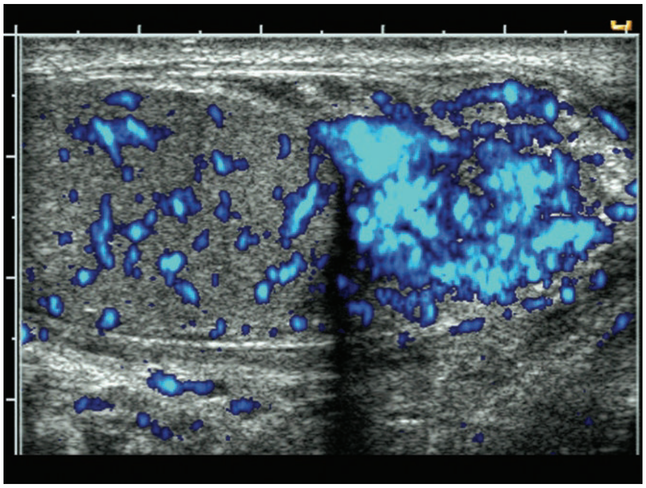

Figure 9-2

HISTORY: A 22-year-old male presents with scrotal pain.

1. Which one of the following would be the most likely in the differential diagnosis of an enlarged extra testicular mass in Figure 9-1?
   A. Adenomatoid tumor
   B. Bowel containing inguinal hernia
   C. Epididymitis
   D. Spermatocele
   E. Epididymal head cyst
2. Which part of the epididymis is epididymitis least likely to enlarge?
   A. Focal enlargement of the head
   B. Focal enlargement of the tail
   C. Diffuse
   D. Focal enlargement of the body
3. Which of the following findings is NOT seen with epididymitis?
   A. Skin thickening
   B. Testicular swelling
   C. Hydrocele
   D. Para-aortic adenopathy
4. Concerning bacterial epididymitis and sequelae of epididymitis, all of the following statements are true EXCEPT:
   A. May result in a scrotal abscess
   B. May result in testicular infarct
   C. Usually resolves spontaneously
   D. Usually occurs in younger postpubertal men

See Supplemental Figures section for additional figures and legends for this case.

CASE 9

Epididymitis

1. **C.** Epididymitis is the most likely diagnosis. However, an adenomatoid tumor is the second most common extratesticular benign solid tumor of the scrotum and could be considered. Also, an inguinal hernia could be considered for an extratesticular mass. The inguinal canal would need to be scanned in real time.
2. **D.** This is the least likely of the listed locations. Focal enlargement of the head is the most common location.
3. **D.** This is a common finding with germ cell tumors of testis and not with epididymitis. All the others are features of epididymitis.
4. **C.** Not true, as most cases are bacterial in origin and require antibiotic treatment.

Comment

Differential Diagnosis

The differential diagnosis of an enlarged epididymis is fairly narrow. Epididymitis is the most likely diagnosis in this case. An adenomatoid tumor is the second most common benign tumor of the epididymis. Lipomas of the cord are the most common benign extratesticular mass. A bowel containing inguinal hernia can protrude into the scrotal sac. However, an enlarged and hyperemic epididymis is most commonly epididymitis (Figs. S9-1 and S9-2). The most common cause of scrotal pain in young adults is epididymo-orchitis. Gray scale ultrasound combined with color Doppler are the prime imaging modalities to make this diagnosis. The most common cause of acute scrotal pain in a child is torsion of a testicular appendage such as the appendix of the epididymis or the appendix of the testis. Reactive changes such as a hydrocele and epididymal head enlargement with torsion of appendage may mimic epididymis. Testicular torsion must be considered in the differential in a younger male.

Ultrasound Findings

The head of the epididymis is usually swollen; sometimes there is diffuse swelling of other portions of the epididymis (Fig. S9-3). Rarely only the tail is swollen, which can be overlooked. There is increased color flow in the epididymis (Figs. S9-2 and S9-4). There may be a hydrocele or pyocele in severe cases (Fig. S9-3). There is often skin thickening. The infection often involves the testis with resultant orchitis, which causes an enlarged and hyperemic testis. There may be resultant testicular abscess or even infarction. Contrast-enhanced ultrasound has been advocated to establish the diagnosis, but it is probably rarely needed to make this diagnosis.

Prognosis/Management

The American College of Radiology has developed "appropriate criteria" for evaluation of acute onset of scrotal pain. They have rated ultrasound with Doppler the highest rating and the first test that should be utilized for scrotal pain without trauma and without a mass. They rate ultrasound as a 9 on a scale where 7, 8, and 9 are usually the best test. For instance, they would rate technetium 99m scrotal scintigraphy as a 4, based on a scale where 4, 5, and 6 may be appropriate. Magnetic resonance imaging (MRI) with contrast is rated less useful than either one of these modalities. Prognosis is usually good if diagnosed and treated early with antibiotics. If left untreated, a scrotal or testicular abscess may occur with eventual loss of the testis.

References

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Remer EM, Casalino DD, Arellano RS, et al. ACR appropriateness criteria® acute onset of scrotal pain – without trauma, without antecedent mass. *Ultrasound Q*. 2012;28(1):47–51.

Cross-reference

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CASE 10

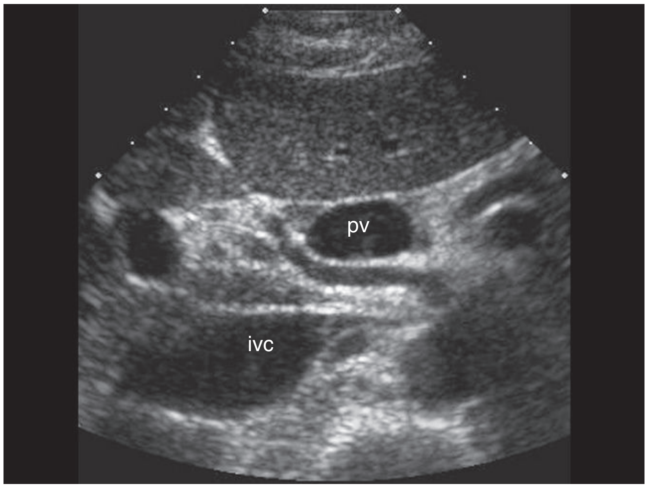

Figure 10-1

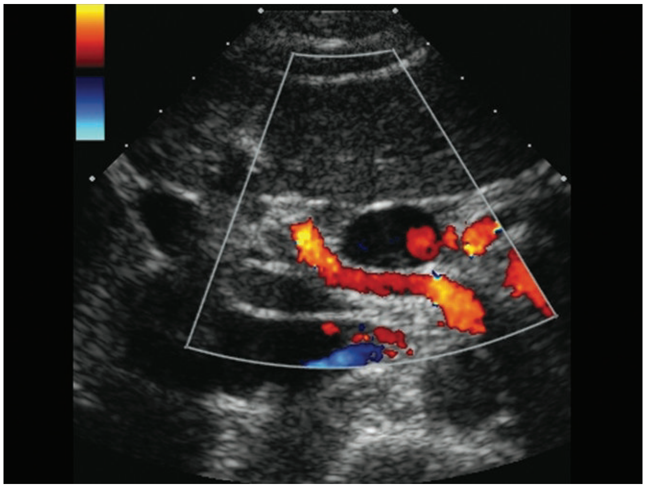

Figure 10-2

HISTORY: A 56-year-old female presents with possible biliary obstruction.

1. In Figure 10-1 of a transverse image of the upper abdomen, the tubular structure identified posterior to the portal vein (PV) most likely represents which of the following?
   A. A normal common bile duct
   B. A dilated common bile duct
   C. Proper hepatic artery
   D. Replaced right hepatic artery (RHA)

2. According to the Michel classification, which one of the following is the most common variant of hepatic arterial variations?
   A. Replaced left hepatic artery (LHA) from the left gastric artery (LGA)
   B. Replaced RHA from the superior mesenteric artery (SMA)
   C. Accessory of hepatic artery from the LGA
   D. Entire hepatic trunk arising from the SMA

3. Which one of the following hepatic arterial variants would be important to recognize for tumor resection of the right lobe of the liver?
   A. Replaced LHA from the LGA
   B. Replaced RHA from the SMA
   C. Accessory LHA from LGA
   D. The common origin of the celiac axis and the SMA

4. What is the third most common hepatic artery variant?
   A. The common origin of the celiac axis and the SMA
   B. Accessory LHA from the LGA
   C. Accessory right and LHA
   D. Replaced right and LHA

See Supplemental Figures section for additional figures and legends for this case.

CASE 10

Replaced Right Hepatic Artery

1. **D.** This is the most accurate diagnosis where the replaced hepatic artery lies posterior to the portal vein.
2. **B.** This occurs in 11% of cases. Replaced LHA from the LGA is a close second.
3. **B.** It is important to recognize the RHA originating from the SMA for resection of the right hepatic lobe. It is always important to note other variations, but of these, this is the most important variation for right hepatectomy.
4. **B.** In most series, this is the third most common variant. A replaced LHA arising from the LGA is the second most common variant.

Comment

Differential Diagnosis

Differential diagnosis of this case could include any tubular structure that lies between the portal vein in the inferior vena cava. In this case, this corresponds to RHA that originates from the superior mesentery artery (Figs. S10-1 and S10-2). Other common hepatic artery variants include the proper hepatic artery dividing early, with one artery traveling posterior to the portal vein and the other branch traveling anterior to the portal vein. It is important to use color flow to identify arterial anatomy and not mistake a tubular structure for a common bile duct. There are other structures that could be considered in the differentials, but if color flow (Fig. S10-2) or pulse Doppler is utilized, the arterial waveform can be identified.

Ultrasound Findings

Ultrasound findings in these cases are dependent on both gray scale and color flow findings. Certainly, there are a number of different hepatic artery variants. Most commonly the RHA and the LHA arise from the common hepatic artery in 55% of cases. A replaced RHA from the SMA is the most common variant (11%). A replaced LHA from the LGA is the next most common. There can also be an accessory LHA arising from the LGA. By performing color Doppler ultrasound, the tubular structure in this case can be identified as a vascular structure rather than a dilated common duct. Pulsed Doppler can show an arterial waveform.

Prognosis/Management

It is important to recognize hepatic arterial variants for a number of different reasons. For instance, if a surgical procedure is contemplated, it is important to recognize hepatic, venous, and biliary anatomy before surgery. Such variants may be detected with ultrasound or computed tomography. Furthermore, it is important in liver transplantation to recognize if, in fact, there was a need to transplant two versus one hepatic artery. Certainly, if there are anatomical variants in the donor's liver, it may make it very difficult to surgically anastomose small or accessory arteries. In planning a surgery, it is very important to recognize different anatomical variants that may affect that surgery.

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Cross-reference

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CASE 11

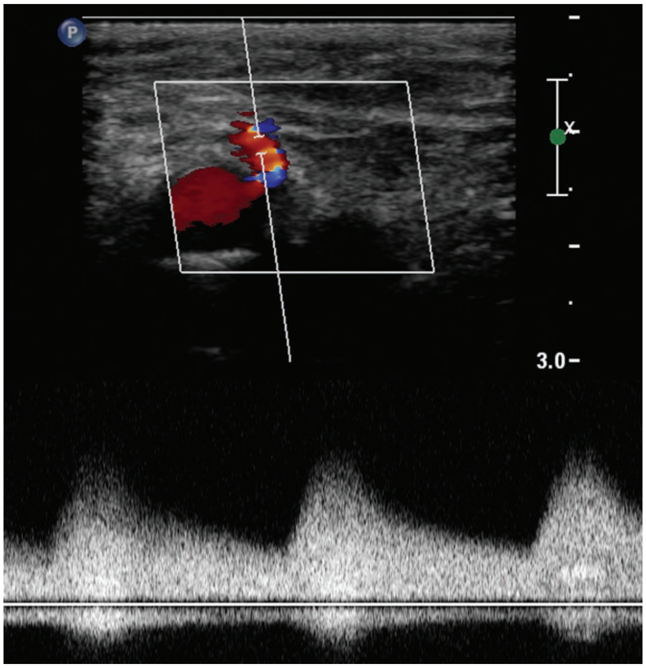

Figure 11-1

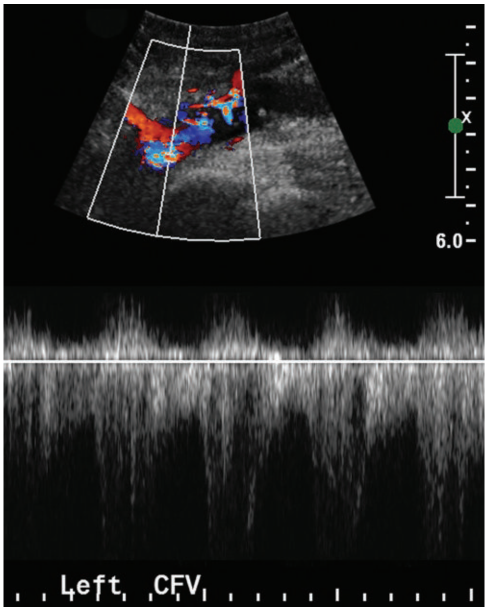

Figure 11-2

HISTORY: These images of vessels in the groin represent two patients with the same entity. Both had recent cardiac catheterization with postoperative bruits.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Pseudoaneurysm
   B. Arterial stenosis
   C. Arteriovenous fistula (AVF)
   D. Tricuspid regurgitation

2. What does treatment for this entity include?
   A. Anticoagulation
   B. Angioplasty
   C. Endovascular procedure
   D. Thrombin injection

3. Regarding AVFs, which of the following is true?
   A. They frequently occur in nonpenetrating trauma.
   B. They frequently cause claudication from steal physiology.
   C. They frequently occlude spontaneously.
   D. They frequently occur in contiguous vessels.

4. Regarding perivascular tissue vibrations (color bruit), which of the following is true?
   A. The turbulence in an AVF creates a color bruit.
   B. Color bruits are more common in pseudoaneurysms than AVFs.
   C. Color bruits are always seen when audible bruits are heard.
   D. Color bruits are more common in arterial stenoses than AVFs.

See Supplemental Figures section for additional figures and legends for this case.

CASE 11

Arteriovenous Fistula

1. **C.** The presence of a high velocity, low pulsatile waveform outside the artery (Fig. S11-1) indicates an AVF. A small vessel adjacent to the artery may be a branch, but this waveform is not of a normal artery. There is not a to and fro sign to indicate a pseudoaneurysm. The vein waveform shows periodic increased velocity in the proper direction indicating arterialization of the waveform (Fig. S11-2).
2. **C.** Treatment of AVF can include ultrasound-guided compression repair, surgical repair, or endovascular occlusion. Thrombin injection is contraindicated as this may produce an embolism. Anticoagulation and angioplasty are not indicated.
3. **D.** AVFs are more typical in contiguous vessels where a penetrating object crosses through the artery and vein leaving a connection behind. Occasionally a tract is created between a noncontiguous artery and vein as in Figure S11-1. AVFs are more frequent in penetrating trauma. They are usually asymptomatic but can rarely cause steal. While they can close spontaneously, most remain patent without treatment.
4. **A.** Perivascular tissue vibrations are caused by tissue movement from adjacent turbulence. They are more common in AVFs than pseudoaneurysms or stenosis. They may or may not correspond to audible bruits.

Comment

Presentation

After penetrating trauma, needle sticks, and catheterization, a connection between an artery and vein may be created (AVF). The most common sign is a bruit over the area. In rare cases, the AVF may steal blood and produce claudication.

Most commonly, the penetrating needle crosses a contiguous artery and vein, such as the common femoral artery and vein in the femoral sheath or the brachial artery and vein. On occasion the vein is not contiguous with the artery and the AVF has a tract between the two.

Ultrasound Findings

Spectral Doppler signals in AVF are typical. High velocity continuous forward flow from the artery to the vein is seen. This is due to the persistent high arterial venous pressure gradient between the two. The feeding artery may also show diminished pulsatility (Fig. S11-3) while the artery below the AVF returns to normal pulsatility (Fig. S11-4). The draining vein may be arterialized, with high velocity flow during arterial systole (Fig. S11-2).

The region of the fistula is often detected by a color bruit sign from turbulence around the AVF (Fig. S11-5). The feeding artery is usually patent although coexistent dissections, pseudoaneurysms, or occlusions can occasionally be found after trauma. A fluid collection is usually absent.

Treatment

In the absence of symptoms, AVF need not be treated. They can be ligated surgically or the connection covered by a stent. Thrombin injection is contraindicated because the material can flow into the venous system and cause an embolism.

References

Kelm M, Perings SM, Jax T, et al. Incidence and clinical outcome of iatrogenic femoral arteriovenous fistulas: implications for risk stratification and treatment. *J Am Coll Cardiol.* 2002;40(2):291–297.

Rubens DJ, Bhatt S, Nedelka S, Cullinan J. Doppler artifacts and pitfalls. *Radiol Clin North Am.* 2006;44(6):805–835.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 284.

CASE 12

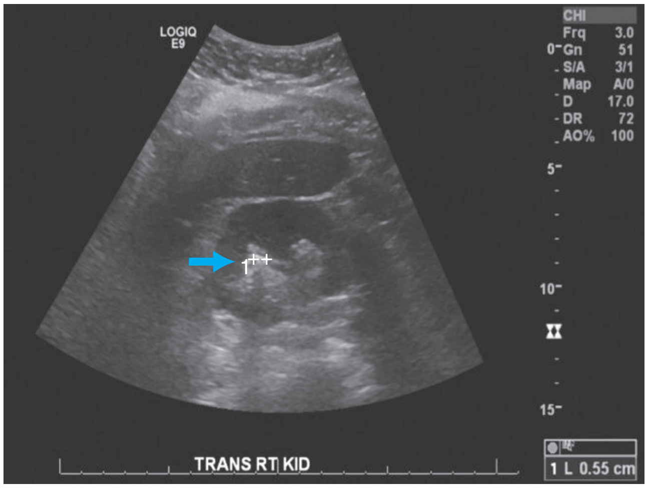

Figure 12-1

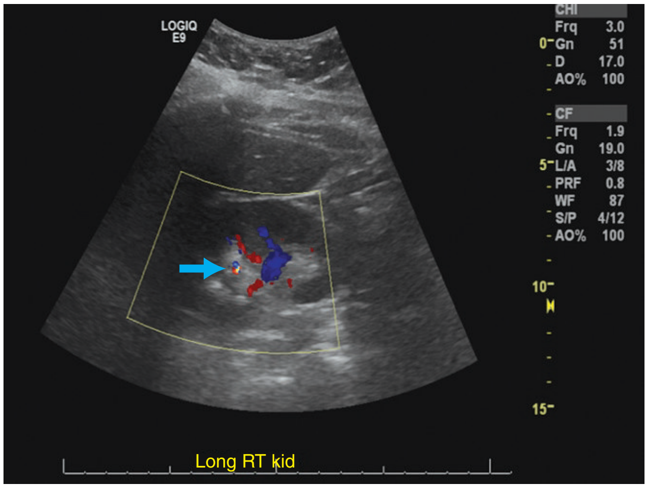

Figure 12-2

HISTORY: A 63-year-old female presents with right sided abdominal and flank pain.

1. Which one of the following would be included in the differential diagnosis for the imaging findings presented in Figure 12-1?
   A. Renal sinus fat
   B. Medullary nephrocalcinosis
   C. Renal stones
   D. Vascular calcifications

2. What is the name of the artifact demonstrated in Figure 12-2?
   A. Reverberation artifact
   B. Twinkle artifact
   C. Aliasing
   D. Mirror image artifact

3. Which one of the following conditions does NOT predispose to the condition shown in Figures 12-1 and 12-2?
   A. Crohn's disease
   B. Myeloproliferative disorders
   C. Renal tubular acidosis (RTA)
   D. Cystinuria

4. What technique can be employed to confidently demonstrate shadowing from an echogenic renal focus?
   A. High frequency transducer
   B. Adjusting focal depth
   C. Both A and B
   D. Use of color Doppler

See Supplemental Figures section for additional figures and legends for this case.

CASE 12

Renal Ureteral Stones

1. **C.** Figure S12-1 demonstrates an echogenic shadowing focus with shadowing most consistent with a renal stone. Other less likely possible differentials are vascular calcifications and medullary nephrocalcinosis.
2. **B.** Twinkle artifact is a color ring down artifact on color Doppler imaging noted posterior to the echogenic focus that helps diagnose and identify renal stones. It appears as a rapid alteration of color immediately behind a stationary focus such as a renal stone.
3. **C.** Many conditions can predispose to renal stones, including gout, Crohn's disease, myeloproliferative disorders, chemotherapy, and a metabolic disorder such as cystinuria. RTA is a metabolic disorder and is a cause for medullary nephrocalcinosis.
4. **C.** Posterior acoustic shadowing can be better demonstrated by adjusting the focal depth and focal zone at the level of the stone and by using a higher frequency transducer. Increased attenuation of sound waves with a higher frequency transducer can accentuate shadowing. Color Doppler is used to identify the twinkle artifact.

Comment

Differential Diagnosis

Differential diagnosis for an echogenic renal focus includes renal stones, sinus fat, vascular calcifications, and medullary nephrocalcinosis. Most renal stones are composed of calcium (phosphate or oxalate). These will have associated acoustic shadowing (Fig. S12-1), as will bladder stones (Fig. S12-3). Other less common components include struvite (magnesium-ammonium-phosphate) or apatite (calcium phosphate), uric acid, and cystine. Vascular calcifications appear as linear, parallel, closely spaced reflectors. They may have shadowing. Medullary nephrocalcinosis presents as diffusely increased echogenicity of medullary pyramids. Sonographic findings may develop before any discernible calcification is seen on radiographs or computed tomography. With advanced disease, shadowing can develop in the pyramids, rather than within the collecting system, which helps differentiate from renal stones. Refractive shadowing is seen with renal sinus fat due to differences in speed of sound between soft tissue, fat, and fluid, without a definite echogenic focus.

Ultrasound Findings

Imaging features of renal calculi depend more on their size than composition. Stones larger than 5 mm are more confidently diagnosed compared to smaller stones. Demonstrating shadowing may be limited with smaller stones. Improving imaging techniques such as adjusting focal depth and focal zone and using a higher frequency transducer can aid in demonstrating shadowing. Doppler imaging may demonstrate twinkle artifact, a short color ring down artifact, seen posterior to the stones (Figs. S12-2 and S12-4). This is alternating color posterior to a stone that decreases in size more posterior to the stone.

Conditions Predisposing to Renal Stones

Low fluid intake and high intake of proteins predisposes to renal stones. Most calcium stones occur idiopathically without associated metabolic abnormalities. Uric acid stones are seen in patients with gout, Crohn's disease, myeloproliferative disorders, and on chemotherapy. Cystine stones are seen with the rare metabolic disorder cystinuria. Struvite (magnesium-ammonium-phosphate) or apatite (calcium phosphate) stones are seen with infections with urea-splitting bacteria such as *Proteus, Pseudomonas, Staphylococcus aureus*, and *Klebsiella*. Further management depends on the clinical context and size of the stones. Treatment options include observation, pain management, lithotripsy, and decompression of collecting system with nephrostomy, in case of obstruction and/or infection. Nephrolithotomy may be used to fragment and then remove the stones. Medical management may be needed, depending of the underlying etiology of the stones.

Reference

Rubens DJ, Bhatt S, Nedelka S, Cullinan J. Doppler artifact and pitfalls. *Radiol Clin North Am*. 2006;44(6):805–835. Review.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 126–131.

Acknowledgment

Special thanks to Priyanka Jha, MD, for preparation of this case.

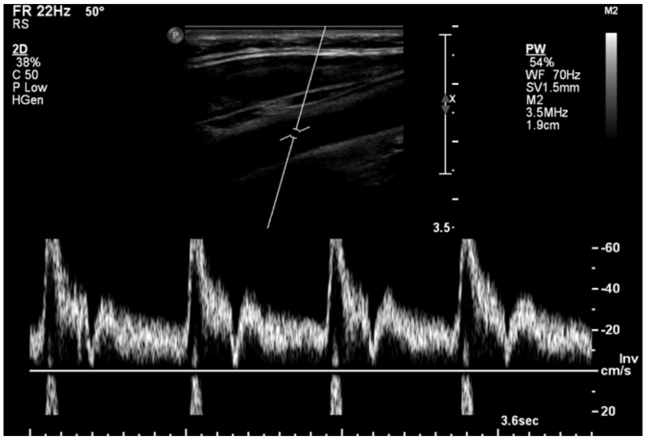

Figure 13-1

HISTORY: A waveform is taken from a normal common carotid artery.

1. What is the peak systolic velocity in Figure 13-1?
   A. 60 cm/s
   B. 80 cm/s
   C. 50 cm/s
   D. Not measurable
2. What is the cause of the artifact?
   A. Too high a scale
   B. Too large an angle
   C. Too high a velocity
   D. Too low a Doppler frequency
3. Which is a way to decrease aliasing?
   A. Increase the scale
   B. Decrease the angle
   C. Decrease the gain
   D. Increase the frequency
4. What does aliasing cause?
   A. Spectral broadening
   B. Nyquist limit
   C. Signal loss
   D. Wraparound

See Supplemental Figures section for additional figures and legends for this case.

CASE 13

Spectral Aliasing

1. **D.** Not measurable due to aliasing. The velocity is greater than 60 cm/s, which is the velocity at which the aliasing begins. Cutting and pasting the aliased to the nonaliased velocity is possible, but the aliasing wraps around to the incorrect direction and then back to the normal direction, which makes estimating this way difficult.
2. **C.** The artifact is aliasing and it is caused by too high a velocity for the sampling rate. Although aliasing is related to scale, angle, and Doppler frequency, these settings reduce or eliminate aliasing.
3. **A.** Aliasing can be decreased or eliminated by increasing the scale, which increases the pulse repetition frequency (PRF). Other ways are to increase the Doppler angle and decrease the Doppler frequency. Gain does not affect aliasing.
4. **D.** Aliasing causes wraparound where part of the signal appears on the other side of the spectrum. Aliasing does not cause spectral broadening or signal loss. Aliasing is present when the velocity of the blood exceeds the Nyquist limit, but aliasing does not cause it.

Comment

Spectral aliasing appears in an artifact in which the wrong direction or wrong velocity is displayed on the spectral display (Figs. S13-1 and S13-3). Faster velocities are incorrectly represented due to wraparound as the fast moving blood is represented at the other side of the spectrum (Fig. S13-3). If the aliasing is severe enough, the signal can cross through the wrong direction and reappear in the correct direction albeit with incorrect velocity (arrow in Fig. S13-1). If unrecognized, the wrong velocity may be measured or spectral broadening may be misdiagnosed (Fig. S13-4). Some modern machines can recognize aliasing and can eliminate it with auto-optimization but it is important to recognize the technical parameters that create and overcome aliasing.

Aliasing is caused by a mismatch between the velocity of blood, a large Doppler shift, and an inadequate sampling rate. The magnitude of the Doppler shift varies based on the Doppler setting. Aliasing can be reduced or eliminated by lowering the Doppler shift or increasing the sampling rate.

Overcoming Spectral Aliasing

The most common control to eliminate aliasing is to increase the scale (Fig. S13-2), which typically increases the PRF. The sampling rate can also be speeded up by sampling at a lower depth. The shallower signal returns more rapidly to the transducer and a higher PRF is possible.

The Doppler shift the machine detects can affect aliasing as well. Because the Doppler shift is dependent on the transducer frequency, lowering the Doppler frequency lowers aliasing. The Doppler shift also decreases with increasing angle, so using a higher Doppler angle will have less aliasing. However, increasing the Doppler angle should be used with care because moving toward a Doppler angle of greater than 70 degrees may introduce other errors in measurement.

Changing the baseline does not affect the overall amount of aliasing but can reduce aliasing in the direction that the diagnostic signal comes from (the opposite side of the waveform will alias correspondingly more).

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Cross-reference

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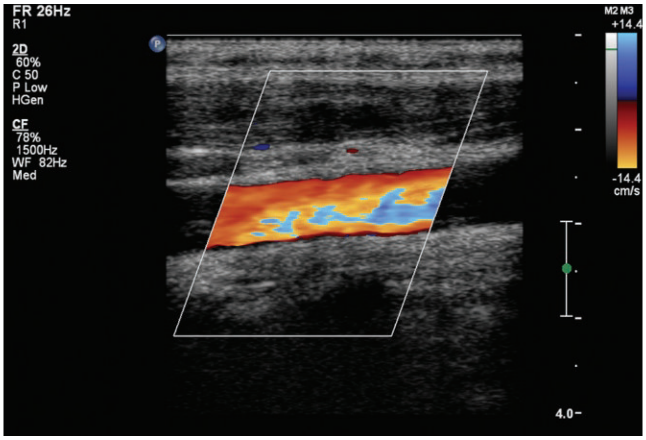

Figure 14-1

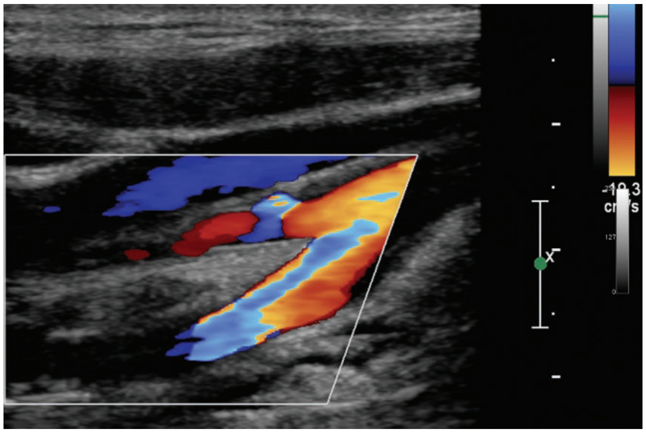

Figure 14-2

HISTORY: Figure 14-1 shows the common carotid artery of one patient. Figure 14-2 shows the bifurcation of the common, internal, and external carotid artery of another patient. The jugular vein is above the artery. The internal carotid artery is the deeper vessel beyond the bifurcation.

1. What does the blue in the common carotid artery in Figure 14-1 and internal carotid in Figure 14-2 represent?
   A. Eddy current
   B. Stenotic jet
   C. Turbulence
   D. Aliasing

2. What is the cause of this?
   A. Phase shift from moving blood
   B. Mismatch of sampling rate and velocity of what is sampled
   C. Noise
   D. Turbulent flow that is seen beyond a stenosis

3. How can aliasing be reduced or eliminated?
   A. Decreasing pulse repetition frequency
   B. Increasing the Doppler frequency
   C. Increasing the Doppler angle
   D. Switching to a curved array transducer

4. Regarding aliasing, which of the following is true?
   A. Decreasing gain increases the artifact.
   B. The artifact is more common in spectral than color Doppler.
   C. The artifact is related to Reynold's number.
   D. The artifact may be a pathfinder to faster moving blood.

See Supplemental Figures section for additional figures and legends for this case.

CASE 14

Color Aliasing

1. **D.** The blue in these arteries represents aliasing. The common carotid in Figure S14-1 is straight and doesn't have eddy currents. Similarly, there is good color filling and there is no stenosis to cause a jet in the internal carotid in Figure S14-2. Higher velocity rather than turbulence causes the change in color. The incorrectly assigned color changes are almost always due to an artifact in blood moving too fast to record the correct velocity.

2. **B.** Aliasing occurs when the sampling rate is inadequate to correctly measure the velocity of the blood being sampled. Faster flow, and even normal velocity flow, will alias if the sampling rate is too low. Aliasing is not caused by turbulence or noise. Doppler signals are related to phase shifts, but they are not related to aliasing.

3. **C.** Aliasing can be reduced or eliminated by increasing the Doppler angle, which reduces the Doppler frequency shift and makes it easier to measure without aliasing. Decreasing the transducer Doppler frequency has a similar effect on aliasing. Increasing, not decreasing, the pulse repetition frequency improves aliasing. This is typically done by increasing the scale. A curved array transducer has no effect on aliasing.

4. **D.** Color aliasing shows the sites of faster flow and is helpful to localize the sample volume in stenotic vessels. The artifact is more common in color Doppler. Turbulence, not aliasing, is related to Reynold's number. Aliasing is related to the Nyquist limit. Gain is not related to aliasing.

Comment

Color aliasing is an artifact in which the color assigned to a vessel or part of a vessel is incorrect due to too high a velocity for the sampling rate of the color Doppler (Figs. S14-1 and S14-2). This is the most common artifact in color. It is pervasive because sampling rates to create color Doppler are significantly lower than in spectral Doppler because multiple pulses are required to create a color Doppler. Moreover, the Doppler information is created for a box of tissue instead of the small spectral Doppler sample in the range gate.

The color map shows how faster and slower velocities are represented and which colors are assigned to each direction. The simplest color map has one color in each direction (typically red and blue). Black is no flow, and the color goes from a dark shade to a light shade as the velocity increases.

In a relatively straightforward case, the aliased color will move through the colors and shades on the color map. In aliasing, the aliased color goes from the light shade of one color to the light shade of the inverse color and then to the darker shade of the inverse color. In a color map of four colors, aliasing goes from blue to cyan to yellow to red or the reverse.

A very common color map is four colors, with blue or red being the lower velocities and cyan and yellow being the faster velocities. In a color map of four colors, aliasing goes from blue to cyan to yellow to red or the reverse (e.g., the internal carotid artery in Fig. S14-2).

Aliased color may change smoothly from color to color in layers. In more severe aliasing, forward and reverse colors may appear less organized, as if the colors were dropped onto the image (called a mosaic appearance).

Aliasing is an artifact but it can be helpful as a pathfinder. The fastest moving blood in the color image will be aliased. Because elevated velocity is the hallmark of stenosis and the highest velocity measured to calculate the degree of stenosis, the aliased area can help localize the site more quickly.

References

Nelson TR, Pretorius DH. The Doppler signal: where does it come from and what does it mean? *AJR Am J Roentgenol Am Roentgen Ray Soc*. 1988;151(3):439–447.

Rubens DJ, Bhatt S, Nedelka S, Cullinan J. Doppler artifacts and pitfalls. *Radiol Clin North Am*. 2006;44(6):805–835.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 26–27.

CASE 15

Figure 15-1

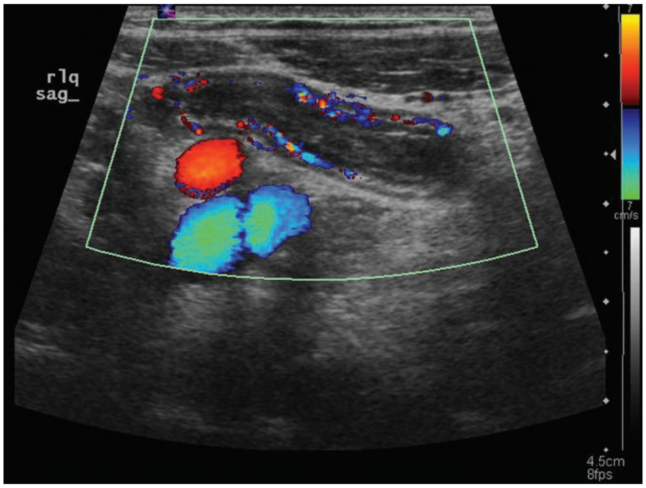

Figure 15-2

HISTORY: A 25-year-old female presents with right lower quadrant pain and these ultrasound images.

1. Which one of the following would be included in the differential diagnosis for the imaging findings presented in Figures 15-1 and 15-2? (Choose one.)
   A. Crohn's disease involving the appendix
   B. Acute appendicitis
   C. Inflamed Meckel's diverticulum
   D. Acute diverticulitis
   E. Epiploic appendagitis
2. Concerning the ultrasound diagnosis of acute appendicitis, which of the following has the lowest odds ratio (lowest probability) of predicting acute appendicitis?
   A. Thickened periappendiceal fat
   B. Increased appendiceal diameter
   C. Presence of an appendicolith
   D. Presence of free fluid
3. What is the most common decade of life for having acute appendicitis?
   A. First decade
   B. Second decade
   C. Third decade
   D. Fourth decade
4. Which of the following is a false statement regarding the appendix or acute appendicitis?
   A. The normal appendix has three concentric hyperechoic rings.
   B. Acute appendicitis may lead to a gangrene appendix.
   C. Acute appendicitis may lead to an appendiceal abscess.
   D. Acute appendicitis does not resolve spontaneously.

See Supplemental Figures section for additional figures and legends for this case.

CASE 15

Acute Appendicitis

1. **B.** There is a thickened blind ending tubular structure most consistent with appendicitis. This may also be secondary to Crohn's appendicitis. While much less common, in a different location, and often larger, acutely inflamed Meckel's diverticulum could be considered in the differential. This diverticulum arises from the ileum, proximal to the ileal-cecal valve.
2. **D.** This has the lowest odds ratios (lowest probability) of predicting acute appendicitis. Free fluids are nonspecific and can be due to a number of etiologies.
3. **B.** The second decade (age 11 to 20) is the most common decade for acute appendicitis. However, acute appendicitis can occur in any age group.
4. **D.** In some cases, acute appendicitis may resolve spontaneously with or without antibiotic treatment.

Comment

Differential Diagnosis

Differential diagnosis of right lower quadrant pain includes acute appendicitis, diverticulitis with a redundant sigmoid, inflammatory or infectious bowel disease, and ovarian etiologies in females. Ultrasound is very helpful in diagnosing acute appendicitis or excluding some of these etiologies.

Ultrasound Findings

A classical description of acute appendicitis on ultrasound includes a noncompressible, blind ending, fluid-filled, tubular structure with a diameter of greater than 6 mm (Fig. S15-1). In a recent study, the sonographic findings that have the highest rate of predicting and supporting the diagnosis of acute appendicitis include echogenic surrounding fat, complex fluid, an appendicolith, loss of stratification of the appendiceal wall, and increased diameter of the appendix. While a diameter of 6 mm has been used as a cut-off value in diagnosis of acute appendicitis, some have shown that up to a quarter to a third of normal patients have an appendiceal diameter of greater than 6 mm. Thus, some argue a greater cross-sectional diameter should be used as the cut-off in predicting acute appendicitis. The abnormal appendix is usually not compressible. There may be hyperemia of the acutely inflamed appendix (Fig. S15-2).

Prognosis/Management

The aim of imaging is to decrease the negative appendectomy rate. If the clinical exam is equivocal, then ultrasound may be helpful in establishing this or another diagnosis. If the ultrasound exam is equivocal, or the patient is larger, then computed tomography (CT) is useful.

Acute appendicitis may spontaneously resolve and may reoccur or may progress to perforation and abscess formation. Laparoscopic removal is the treatment of choice. Ultrasound or CT may be used to detect complications of appendicitis including a periappendiceal abscess.

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Cross-reference

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CASE 16

Figure 16-1

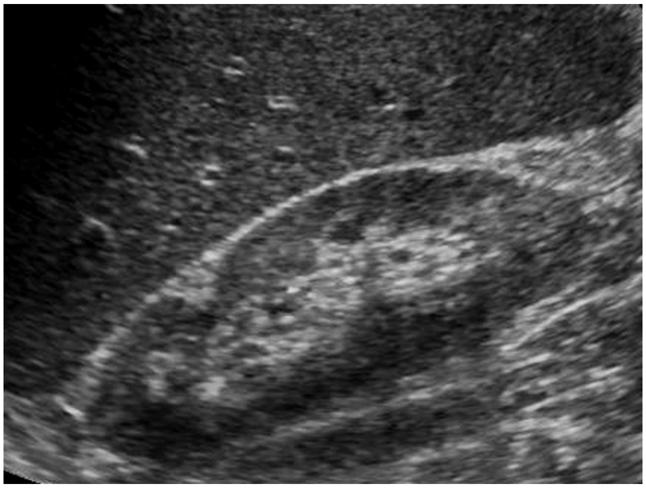

Figure 16-2

HISTORY: A 36-year-old male presents with a left scrotal varicocele, and ultrasound of the left kidney was performed.

1. Which one of the following would be included in the differential diagnosis for the imaging findings presented in Figure 16-1? (Choose only one.)
   A. Lymphoma
   B. Renal cell carcinoma (RCC)
   C. Renal pseudotumor
   D. Focal pyelonephritis
2. Concerning this entity, all of the following are correct EXCEPT:
   A. Usually occurs in the left kidney.
   B. Usually has similar echo-texture as the rest of the renal parenchyma.
   C. Has increased color or power Doppler compared to the rest of the renal parenchyma.
   D. In some cases, computed tomography (CT) or magnetic resonance imaging (MRI) may be necessary to exclude a renal mass.
3. Which of the following is the most likely differential diagnosis for the anterior echogenic region of the right kidney shown in Figure 16-2?
   A. An angiomyolipoma
   B. A renal infarct
   C. A junctional parenchymal defect
   D. An RCC
4. Which of the following is FALSE regarding the junctional parenchymal defect shown in Figure 16-2?
   A. Usually occurs on the left side.
   B. It usually occurs in the junction of the upper and middle third of the kidney.
   C. In this location, there is communication with the renal sinus fat.
   D. This defect is at the point of fusion of the upper and lower portion of the kidney.

See Supplemental Figures section for additional figures and legends for this case.

CASE 16

Normal Anatomical Variants of the Kidney

1. **C.** Certainly a renal pseudotumor, such as a "dromedary hump," could give this appearance. However, renal masses, such as lymphoma or an RCC, could be considered. There are a variety of appearances of focal pyelonephritis on ultrasound, and it could have this appearance.
2. **C.** Color or power Doppler of that segment should be similar to the rest of the renal parenchyma (Fig. S16-3), and the vessels should not be displaced. MRI or CT may be needed in some equivocal cases.
3. **C.** This is a typical location and appearance for a junctional parenchymal defect (Fig. S16-2).
4. **A.** This is not a true statement as it is more commonly identified on the right side.

Comment

Differential Diagnosis

The differential diagnosis in Figure S16-1 is fairly broad. On ultrasound images, the differential could include a focal mass such as metastases, primary renal tumor, or lymphoma. Even an abscess or focal pyelonephritis could be considered within the differential. A hemorrhagic cyst may be considered in the differential but is less likely. In this case, this is a "dromedary hump" or "splenic hump" caused by impression from the spleen.

Ultrasound Findings

Ultrasound features of a "dromedary hump" include a bulge at the lateral border of the mid-pole of the left kidney. The echotexture of the hump is similar to the rest of the kidney. However, in some cases (such as this case), the hump may be quite prominent and may appear hypoechoic. Usually, color Doppler ultrasound or power Doppler ultrasound demonstrates normal color compared with the rest of the renal parenchymal. The vascularity to this portion of the kidney is similar to other portions of the kidney as illustrated in Figure S16-3, but, in some cases, it may be more difficult to make this distinction. Contrast enhancement ultrasound has been advocated to demonstrate normal color contrast enhancement of this region of the kidney compared to other portions. If contrast-enhanced ultrasound is not available, either contrast CT and/or MRI may be utilized (Fig. S16-4). Other anatomical pitfalls may be encountered as identified in Figure S16-2. This is a junction parenchymal defect that was caused by fusion of the upper and lower portions of the kidneys. It is usually triangular in appearance, better identified, and more medial within the kidney. It appears echogenic as there is connection to the echogenic renal sinus fat.

Prognosis/Management

Management for Figure S16-1 (dromedary hump) would be first to perform power or color Doppler ultrasound. If there still is an equivocal diagnosis, contrast-enhanced ultrasound is recommended. If this does not clearly demonstrate that this is a normal variant, then contrast-enhanced CT (Fig. S16-4) and/or MRI may be needed. A junctional parenchymal defect will always occur in the same location and have the same appearance (Fig. S16-2).

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 103–104.

CASE 17

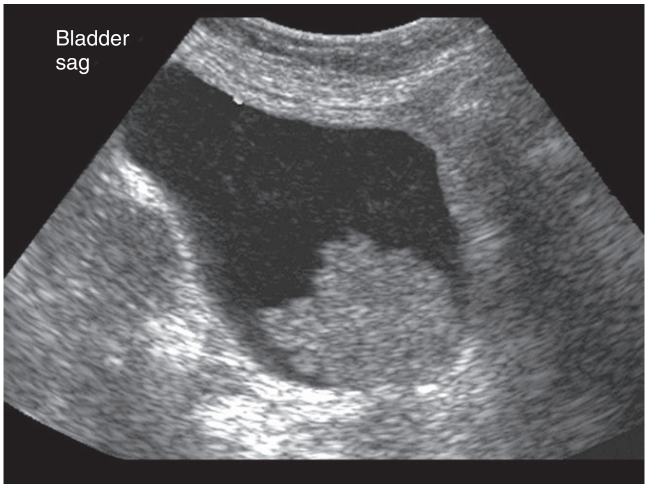

Figure 17-1

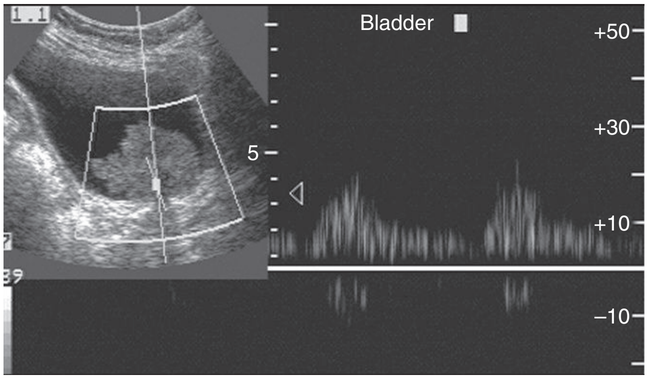

Figure 17-2

HISTORY: This 72-year-old male presented with longitudinal ultrasound of the bladder seen in Figures 17-1 and 17-2.

1. Which one of the following should be included in the differential diagnosis for the imaging findings presented in this case? (Choose one.)
   A. Hematoma
   B. Enlarged prostate protruding into the bladder base
   C. Fungus balls
   D. Bladder calculi
   E. Bladder cancer
2. What is the most common type of bladder cancer?
   A. Squamous cell carcinoma (SCC)
   B. Adenocarcinoma
   C. Transitional cell carcinoma (TCC)
   D. Metastatic cancer to the bladder
3. All are true concerning TCC EXCEPT:
   A. TCC has approximately equal occurrence in men and women.
   B. Hematuria is a common presenting complaint in patients with TCC of the bladder.
   C. Cystoscopy is more sensitive than sonography in identifying TCC.
   D. Treatment from bladder cancer varies greatly by the stage of the cancer.
4. Which of the following is NOT true regarding ultrasound features of bladder cancer?
   A. Contrast-enhanced ultrasound has shown an increased detection rate of TCC compared to noncontrast ultrasound.
   B. Ultrasound is very helpful in staging bladder cancer.
   C. A typical sonographic feature of bladder cancer would include a polypoid mass or masses protruding into the bladder lumen.
   D. Color Doppler or pulse Doppler is helpful in diagnosing bladder cancer.

See Supplemental Figures section for additional figures and legends for this case.

CASE 17

Transitional Cell Carcinoma of the Bladder

1. **E.** Bladder cancer; a hematoma or a fungus ball may present as a lobulated mass within the bladder lumen and would be considered within the differential. Bladder cancer would have increased color flow and is the best answer. An enlarged prostate would be contiguous with the prostate and could be considered.
2. **C.** TCC accounts for approximately 95% of all bladder cancers—squamous cell approximately 5%.
3. **A.** This is a false statement as TCC occurs approximately three times more frequently in women than men.
4. **B.** Ultrasound is mainly used for diagnosis of bladder cancer in patients with hematuria or other symptomatology. Cystoscopy, magnetic resonance imaging (MRI), or computed tomography (CT) are used for staging.

Comment

Differential Diagnosis

The differential of a mass in the bladder could include a benign prostatic hypertrophy or prostatic cancer, which could protrude into the bladder lumen. The continuity of this mass and the prostate can be identified by sonography. Filling defects such as blood clots from the bladder or the kidneys will present as an echogenic mass within the bladder. Filling defects such as calculi do occur within the bladder but have echogenic focus with acoustic shadowing. Bladder cancer would appear as an echogenic mass, as in this case.

Ultrasound Findings

Sonographic features of TCC of the bladder would include a lobulated mass that arises from the wall of the bladder (Fig. S17-1). In patients with a very trabeculated bladder, it may be difficult to separate this trabeculation from an early TCC. Certainly in these cases cystoscopy should be performed. TCC, unlike blood clots, would have increased color flow (Fig. S17-2). TCC detection is enhanced with the use of ultrasound contrast. Ultrasound is not typically used for staging of these tumors; staging is better performed with cystoscopic exam and/or CT and/or MRI.

Prognosis/Management

TCCs occur more frequently within the bladder than within the kidneys or ureters. SCCs do occur within the bladder and are usually from chronic irritation. SCCs account for approximately 5% of all bladder cancers. Bladder adenocarcinomas may arise after long-term radiation or inflammation and can occur in urachal diverticula or urachal remnants. There is a wide number of predisposing factors for TCC including the use of cigarettes, various dyes or dye cleaners, drinking water with high levels of arsenic, and history of recurrent infections, especially those caused by schistosomiasis haematobia.

Urinalysis will detect hematuria, and then ultrasound can be used as a screening exam. However, if there is a strong suspicion of tumor, then cystoscopic exam of the bladder is performed. In cases in which cystoscopic exam is negative, then examination of the upper tracts may be performed with CT urography. Biopsy of the bladder tumors is not performed percutaneously but through the cystoscope. Treatment will vary and depend on the stage of the tumor. Low-grade tumors usually are treated by transurethral resection and intravessicular treatments, including bacillus Calmette-Guerin. More invasive tumors, such as stage 3 or 4 tumors, are treated with radical cystectomy, nodal dissection, as well as chemotherapy with or without radiation. Prognosis is dependent on the stage of the cancer at detection and the pathologic grade of the tumor.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 167–169.

CASE 18

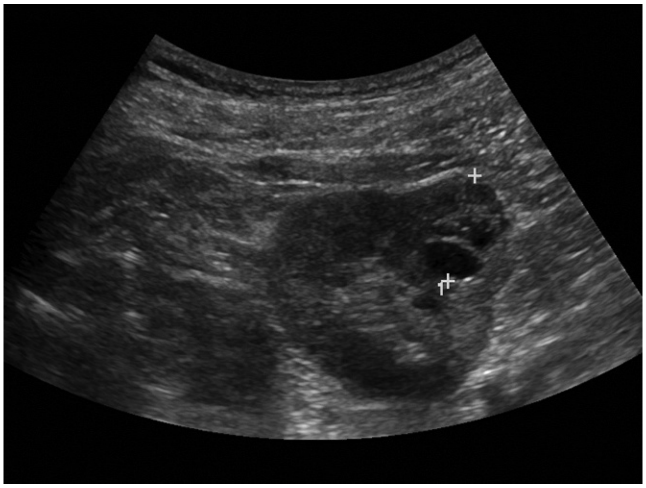

Figure 18-1

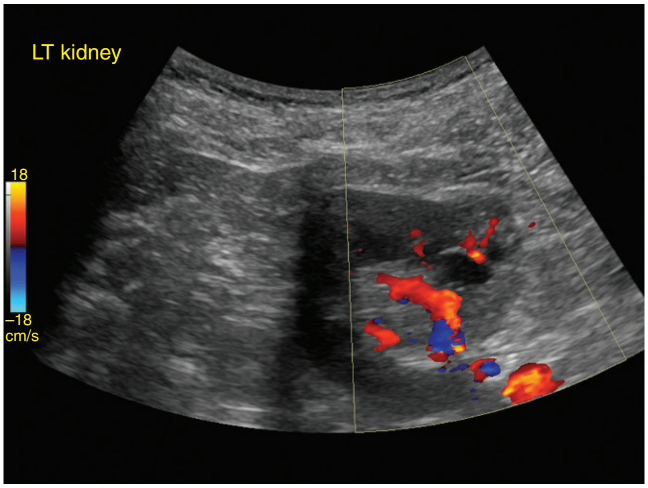

Figure 18-2

HISTORY: A 43-year-old male with a history of chronic pancreatitis presents with persistent abdominal pain. Computed tomography (CT) demonstrates an incidental 1.8 cm heterogeneously enhanced hypodense lesion in the inferior pole of the left kidney. Ultrasound images of the left kidney were obtained.

1. What should be included in the differential diagnosis for Figures 18-1 and 18-2? (Choose all that apply.)
   A. Multilocular cystic nephroma
   B. Cystic renal cell carcinoma (RCC)
   C. Complex renal cyst
   D. Renal angiomyolipoma
   E. Renal lymphoma
2. What is the Bosniak classification for this lesion?
   A. Category I
   B. Category II
   C. Category IIF
   D. Category III
   E. Category IV
3. What is the malignant risk of this lesion based on the Bosniak IV classification?
   A. 0%
   B. 10%
   C. 25%
   D. 50%
   E. 90%
4. What is the recommended treatment for this lesion?
   A. No further work-up is required.
   B. Repeat ultrasound in 6 months
   C. Magnetic resonance imaging
   D. Surgical resection

See Supplemental Figures section for additional figures and legends for this case.

CASE 18

Bosniak Renal Cyst

1. **A, B, and C.** Multilocular cystic nephroma, a very complex cyst, or a cystic RCC could be considered within the differential. Renal angiomyolipomas are usually solid echogenic masses. Renal lymphomas are usually hypoechoic solid renal masses or have diffuse renal involvement.
2. **E.** Color flow, thick septa, solid elements, and irregular margins are suggestive of a category IV. However, one could make a strong case for this being a category III lesion.
3. **D.** Category IV has a malignant potential of approximately 90%.
4. **D.** Surgical excision, cryoablation, or radiofrequency ablation (RFA) is recommended for category IV lesions. Biopsy is recommended, but cystic RCC and multilocular cystic nephroma often have similar histologic features.

Comment

Differential Diagnosis

The differential diagnosis in this case includes a complex cyst, a cystic RCC, and a multilocular cystic nephroma. A complex cyst such as a Bosniak III or Bosniak IV cyst is considered. Certainly, cystic RCCs would have this appearance. Multilocular cystic nephromas occur in a bimodal distribution and have multiple septations. Angiomyolipomas are usually echogenic masses and would not be considered. Lymphomas are more often diffuse and/or focal hypoechoic masses.

Ultrasound/CT Findings

The Bosniak classification system was originally described in 1986 using CT findings to determine the malignant risk and guide management of incidental renal cysts. Although CT remains the primary diagnostic in evaluation of renal masses, ultrasonography is extremely helpful for simple cyst identification and assessment of internal flow. The Bosniak system consists of four categories based on triphasic CT findings, ranging from simple to complex cysts. Category I cysts are characterized as simple cysts without thick walls, septa, calcifications, or solid components. Category II cysts are less than 3 cm in diameter with some abnormal CT features including hyperattenuation (>20 Hounsfield units), less than 1 mm septation, and fine calcifications within the septum or wall. Category IIF lesions are more complex cysts with multiple thin septum, slightly thick walls, calcification or cysts greater than 3 cm, but no contrast enhancement. Category III lesions have uniform wall thickening/nodularity, thick or irregular calcifications, and thick septa on contrast enhancement. Lastly, category IV lesions have solid enhancing elements, large cystic components, and irregular margins. This case could be considered a Bosniak III or IV lesion (Figs. S18-1, S18-2, and S18-3).

Prognosis and Management

Category I lesions have no malignant potential. As a result, category I requires no further follow-up. Category II lesions have malignant risk of less than 3%. Category IIF identifies more complex lesions with a malignant risk of 5% to 10% but are not necessarily suspicious enough to warrant surgical exploration. They require short-term follow-up (3-month, 6-month, or 12-month intervals). Category III and IV lesions have the malignant potential of approximately 50% and 90%, respectively. Therefore, surgical excision, RFA, or cryoablation (Fig. S18-4) is recommended for category III and IV lesions. Biopsy for category III lesions is controversial due to the similar histologic features of cystic RCC and multilocular cystic nephroma. Some RCCs may appear cystic.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 109–111.

Acknowledgment

Special thanks to Ellen Cheang, MD, for preparation in this case.

CASE 19

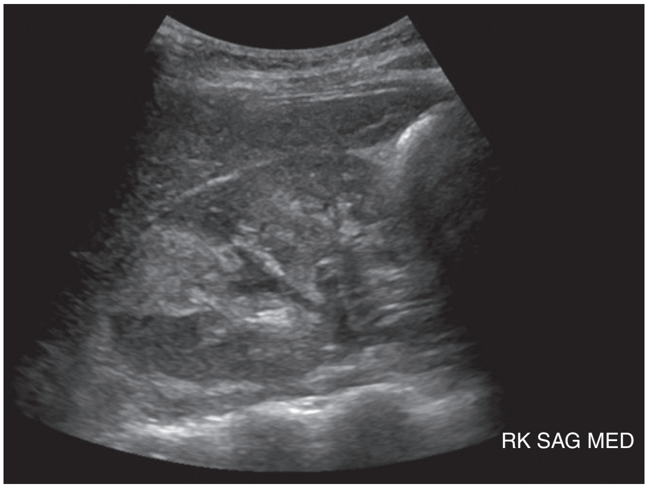

Figure 19-1

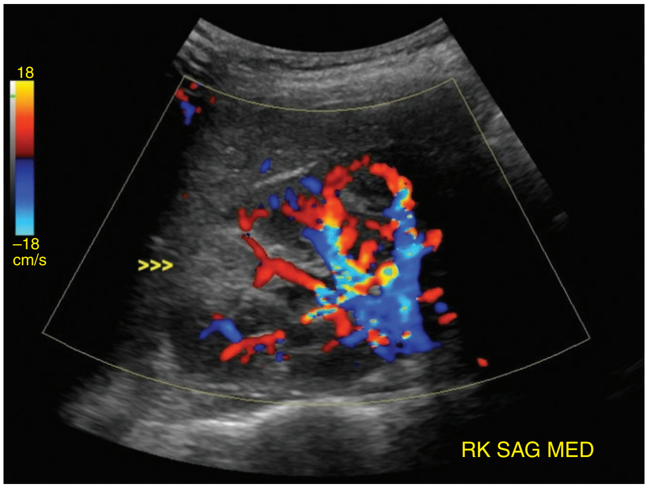

Figure 19-2

HISTORY: A 26-year-old female, 20 weeks pregnant, presents with right flank pain and urinary tract infection.

1. Which of the following would be the most likely diagnosis for the imaging findings presented?
   A. Normal kidney
   B. Pyelonephritis
   C. Fungal infection
   D. Acute tubular necrosis
2. Which is a serious complication of acute pyelonephritis, usually associated with poorly controlled diabetic women?
   A. Emphysematous pyelonephritis
   B. Renal necrosis
   C. Renal atrophy
   D. Renal infarct
3. Which of the following statements concerning acute bacterial pyelonephritis is FALSE?
   A. *Escherichia coli* represents the most common offending pathogen.
   B. Diagnosis of acute pyelonephritis in adults is primarily a clinical diagnosis based on key findings of history, physical exam, and laboratory values.
   C. Ascending infection occurs less commonly than hematogenous spread.
   D. In most patients, the early stages of an infected kidney on ultrasound imaging appears normal.
4. The primary role of sonography in evaluating patients with pyelonephritis is to rule out complications. All of the following are possible complications of pyelonephritis EXCEPT:
   A. Renal abscess
   B. Obstruction
   C. Perinephric abscess
   D. Hematoma

See Supplemental Figures section for additional figures and legends for this case.

CASE 19

Acute Bacterial Pyelonephritis

1. **B.** There is an echogenic region with a lack of color flow seen in Figures S19-1 and S19-2, which corresponds to a region of pyelonephritis. Fungal infection could be considered but is usually more diffuse than this process, which is more focal.
2. **A.** There can be a number of serious complications of acute pyelonephritis, including abscess formation and emphysematous pyelonephritis, particularly in diabetics.
3. **C.** Ascending infections from bladder to the kidney are more common than hematogenous spread.
4. **D**. A hematoma would be an unlikely finding in acute pyelonephritis, but all the others could occur.

Comment

Differential Diagnosis

Differential considerations include renal trauma, neoplasm, abscess, and infarct. Follow-up imaging after treatment may be prudent to exclude a neoplastic process.

History would be important to exclude renal trauma. An abscess may be a sequela of focal pyelonephritis. Usually a neoplasm would be more vascular than a focal area of pyelonephritis, which is usually avascular. If there is any doubt, a follow-up ultrasound would be obtained. Renal infarct would appear as a vascular region within the kidney.

Acute pyelonephritis is an infection of the renal parenchyma and collecting system. The majority of the cases are caused by an ascending infection from the lower urinary tract. *E. coli* is the most common pathogen in cases resulting from ascending infection, while *Staphylococcus aureus* is the most common offending pathogen from hematogenous seeding. Pyelonephritis is a clinical diagnosis, and imaging is usually reserved for patients with severe symptoms or those who have failed to respond to antibiotics.

Ultrasound Findings

Gray scale sonographic findings include renal enlargement, loss of corticomedullary differentiation, and decreased visualization of renal sinus fat (Figs. S19-1 and S19-3). Color Doppler evaluation may demonstrate focal areas of decreased perfusion (Fig. S19-2). Pyelonephritis alters the renal parenchyma echogenicity on ultrasound, resulting in areas that have decreased or increased echogenicity. In many cases, the renal ultrasound may appear normal. A complication of focal pyelonephritis is a renal abscess. A renal abscess typically appears as a rounded, hypoechoic, thick-walled, complex lesion. Layering of the internal fluid collection may also be present. If gas is present within the abscess cavity, "dirty shadowing" can be seen. Occasionally, these may be mistaken for cysts. Computed tomography (CT) is also helpful in making this distinction (Fig. S19-4).

Emphysematous pyelonephritis is an uncommon, severe necrotizing form of acute pyelonephritis. Gas formation in the renal parenchyma characterizes this infection, which typically affects poorly controlled diabetic women. CT is the preferred modality for evaluating patients with emphysematous pyelonephritis as it is more sensitive for the detection of gas collections.

Xanthogranulomatous pyelonephritis is a chronic inflammatory disease in which the renal parenchyma is replaced with lipid-laden macrophages as part of the pathologic response to the inflammatory process. It most commonly results from long-standing obstructive nephropathy and nephrolithiasis. It can present as diffuse, segmental, or focal and is typically unilateral.

Evaluation/Treatment

Precontrast and postcontrast CT is the modality of choice in evaluating acute pyelonephritis in such a patient population, because ultrasound can miss mild cases of pyelonephritis and can underestimate perinephric extension of a renal abscess.

Treatment is usually centered on hydration, rest, and antibiotic therapy. Urinalysis with culture and sensitivity is helpful to detect a specific organism and drug sensitivity. Oral antibiotics are usually the treatment of choice unless there is a complication, in which case intravenous antibiotics may be needed. Smaller renal abscesses usually resolve spontaneously without further therapy while a large renal abscess may require percutaneous drainage.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 124–126.

Acknowledgments

Special thanks to Heather Early, MD, and Ghaneh Fananapazir, MD, for preparation of this case.

CASE 20

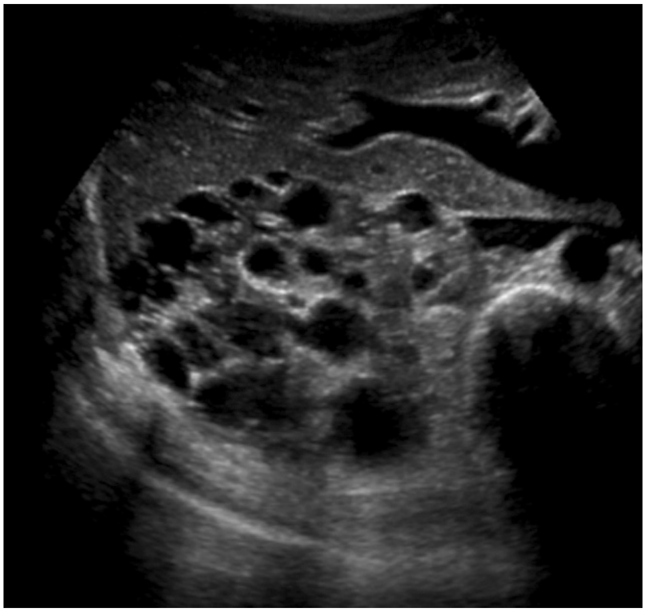

Figure 20-1

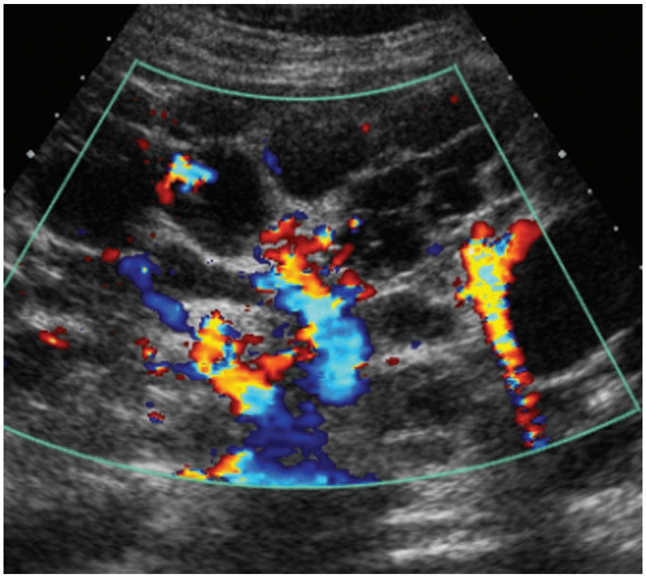

Figure 20-2

HISTORY: A 34-year-old female presents with a new rise in creatinine. Images of her kidneys were obtained.

1. Which of the following is the most likely diagnosis for the ultrasound findings identified in the renal ultrasounds in Figures 20-1 and 20-2? (Choose one.)
   A. Autosomal dominant polycystic kidney disease (ADPKD)
   B. Von Hippel-Lindau
   C. Tuberous sclerosis
   D. Angiomyolipoma

2. Concerning ADPKD, all are true statements EXCEPT:
   A. An important aspect of treatment is controlling hypertension.
   B. Although the kidneys are affected more than any other organ, cysts can develop in the liver, pancreas, and spleen, usually causing no symptoms.
   C. ADPKD typically presents in children with symptoms of hypertension, hematuria, and urinary tract infections.
   D. Ten percent of patients have intracranial aneurysms.

3. ADPKD:
   A. Causes a significantly increased risk of RCC (renal cell carcinoma).
   B. Is the most common hereditary cause of end stage renal failure.
   C. Has the classic appearance of a "bunch of grapes."
   D. Has a normal contralateral kidney and ureter.

4. Which of the following is NOT a therapy for ADPKD?
   A. Antihypertensives
   B. Low salt diet
   C. Anticoagulants
   D. Laparoscopic cyst decortications

See Supplemental Figures section for additional figures and legends for this case.

CASE 20

Autosomal Dominant Polycystic Kidney Disease

1. **A.** ADPKD has the typical appearance identified in Figures S20-1 and S20-2. Von Hippel-Lindau and tuberous sclerosis can also present with multiple bilateral renal cysts but usually have other associated characteristic findings.
2. **C.** Patients with ADPKD typically present in the fourth or fifth decade of life with symptoms related to hypertension, hematuria, or urinary tract infections.
3. **B.** ADPKD is the most common hereditary cause of end stage renal failure.
4. **C.** There is no association with ADPKD and increased clotting. All of the other options could be part of the therapeutic regimen for ADPKD.

Comment

Differential Diagnosis

The differential diagnosis for multiple bilateral renal cysts includes those cysts occurring with von Hippel-Lindau disease and tuberous sclerosis, acquired uremic cystic disease, and patients on dialysis. In acquired uremic cystic disease and in dialysis patients, the kidneys are usually small, distinguishing them from the enlarged kidneys of ADPKD. With von Hippel-Lindau disease, central nervous system tumors, retinal angiomas, pheochromocytomas, and solid renal masses due to RCC are often seen. These other findings are absent in ADPKD. Tuberous sclerosis commonly involves central nervous system tubers, subependymal nodules, and giant cell astrocytomas, as well as dermatologic findings such as adenoma sebaceum that are not seen with ADPKD. Renal lymphoma can produce renal masses that are hypoechoic and may simulate cysts, but patients usually have a history of lymphoma—careful scanning shows these are not cysts.

Ultrasound Findings

Ultrasound is the procedure of choice for the workup of ADPKD, and it is an ideal modality for screening patients' families. Most children with ADPKD have normal sonographic findings at birth. Multiple, bilateral renal cysts of varying sizes located in the renal cortex are identified in time in these patients (Figs. S20-1 and S20-2). In older patients with progressive disease, the kidneys are usually enlarged. Low-level internal echoes, fluid levels, and solid nodular internal structures can often be seen due to hemorrhage into renal cysts or infection. Sequential examinations usually demonstrate an increase in cyst size over a period of years, resulting in calyceal distortion and irregularity of the renal outline. Cyst wall calcification and renal stones are also commonly visualized sonographically. Cysts of the liver, pancreas, and spleen may help to confirm the diagnosis of ADPKD. Autosomal recessive polycystic kidney disease presents with hyperechoic, enlarged kidneys in utero or the newborn. The cysts are usually too small to be depicted on ultrasonographic images; however, small discrete macroscopic cysts are occasionally seen, with sparing of the peripheral cortex. These are seen in a different population and may be seen in utero on into childhood.

Prognosis/Management

Two genetic defects cause ADPKD, with the Type 1 defect resulting in an earlier age of onset of end stage renal disease compared to the Type 2 defect. The prognosis of patients with ADPKD spans a range, from renal failure in childhood to a normal lifespan with no apparent symptoms. Typically, ADPKD causes progressive renal dysfunction, resulting in renal failure by the fourth to sixth decades. Risk factors for progression include large kidneys, several episodes of hematuria, frequent urinary tract infections, hypertension, black racial background, and male sex.

The goal of treatment is to control symptoms and prevent complications. Controlling hypertension is the most important part of treatment. Urinary tract infections should be treated quickly with antibiotics. Cysts that are painful and infected, that have internal hemorrhages, or cause a urinary tract obstruction may need to be drained. These may be seen on computed tomography or magnetic resonance imaging (Figs. S20-3 and S20-4). Laparoscopic cyst decortication can also be used to relieve symptoms and improve function. In end stage disease, dialysis or a kidney transplant may be needed. Another cause of mortality in ADPKD is subarachnoid hemorrhage from intracranial aneurysms. Patients also have associated cardiovascular problems, including bicuspid aortic valve, mitral valve prolapse, and aortic dissection.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 167–169.

Acknowledgment

Special thanks to Grant Holz, MD, for preparation in this case.

CASE 21

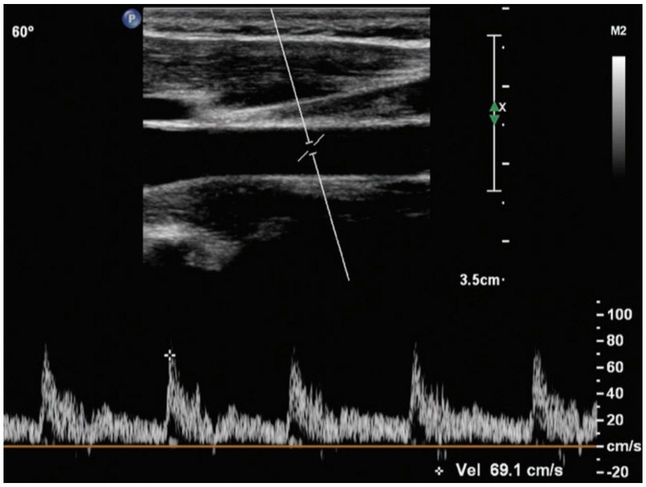

Figure 21-1

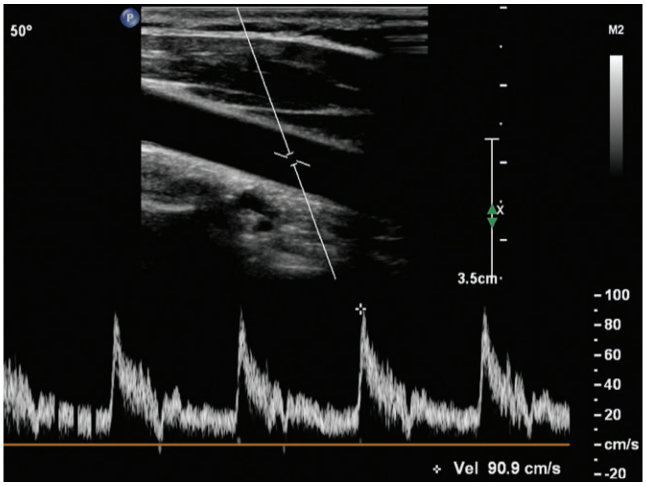

Figure 21-2

HISTORY: Spectral Doppler of the peak systolic velocity in the common carotid artery with different settings are shown.

1. Which of the following peak systolic velocities was correctly measured?
   A. Figure 21-1
   B. Figure 21-2
   C. Both Figure 21-1 and Figure 21-2
   D. Neither Figure 21-1 nor Figure 21-2
2. In regard to the angle indicator, which of the following is true?
   A. It should be set to 60 degrees.
   B. It should be set to 0 degrees.
   C. It changes the scale and measurement.
   D. It should be set to 120 degrees.
3. In regard to the angle indicator, which of the following is true?
   A. It must be placed in the vessel the same way in follow-up studies.
   B. It must always be at 60 degrees to the vessel wall.
   C. It must always be lined up with the color flow.
   D. It cannot report a velocity above 70 degrees.
4. In regard to peak systolic velocities, which of the following is true?
   A. They occur 70 ms from the onset of systole.
   B. They are measured in kilohertz.
   C. They are calculated based on an angle of 0 degrees if the angle indicator is not set.
   D. They are not subject to error if the Doppler angle is set below 70 degrees.

See Supplemental Figures section for additional figures and legends for this case.

CASE 21

Doppler Angle

1. **B.** Figure S21-2 uses a Doppler angle of 50 degrees, which is acceptable. Figure S21-1 has the angle indicator in the wrong direction. It is not parallel to the vessel wall. A Doppler angle of 60 degrees would be acceptable if the image that was adjusted so 60 degrees is parallel to the vessel.

2. **C.** The angle indicator changes the scale and affects the velocity measurements. It is typically set parallel to the walls of the vessel or along the direction of color flow. Some laboratories scan at 60 degrees to the vessel wall, but this is not necessary. Angles at, or less than, 60 degrees to the vessel wall are acceptable if the indicator is properly set.

3. **A.** The angle indicator must be placed in the vessel the same way in follow-up studies. Otherwise, different angles may create a different result based on a different protocol rather than a true change in the patient. The method of assigning the angle may be based on a fixed angle, a range of angles (e.g., below 60 degrees parallel to the vessel wall), or lined up with the color as long as the angle is below 60 degrees. Angles above 60 degrees to the vessel wall and certainly above 70 degrees are not acceptable to measure velocities. However, the machine will report an incorrect velocity.

4. **C.** Peak systolic velocities are calculated based on an angle of 0 degrees if the angle indicator is not set. All velocity measurements are in centimeter per second and occur at a variable amount of time after systole begins. All velocity measurements are subject to error, the error increases substantially above 70 degrees.

Comment

After determining if flow is present and its direction, the velocity of blood flow is evaluated. If a Doppler cursor is not assigned, the machine assumes a Doppler angle of 0 degrees. The Doppler angle is assigned by aligning the angle correction cursor (also called angle indicator line or flow indicator) along the color flow direction or parallel to the vessel walls (Fig. S21-2).

Currently a Doppler angle equal to or less than 60 degrees is acceptable and used in many laboratories (Fig. S21-3). Historically a Doppler angle of 60 degrees was a standard for carotid imaging (Fig. S21-3). With more modern machines that have greater ability to steer the Doppler, smaller angles are possible. Some labs continue to scan carotids at one consistent angle because it produces fewer errors between studies.

Angles other than 60 degrees are necessary in some vessels that do not have a straight course. The Doppler angle will correctly vary from place to place in the vessel. For example, when imaging the right main renal artery from an anterior approach, the artery travels initially toward and then away from the transducer. The artery can even be scanned from a lateral or posterior approach, and from this orientation it may head right toward the transducer with a zero Doppler angle.

Angle Measurement Errors

All measurements have errors. There are two main errors associated with angle correction: assigning the incorrect angle (Fig. S21-1) and using an angle that is too high (Fig. S21-4).

If the angle correction cursor is not placed correctly, the wrong angle and the wrong velocity will be assigned. Some, wrongly believing that the angle correction cursor must be placed at 60 degrees, incorrectly set the cursor at that value regardless of the actual direction of the flow on the image (Fig. S21-1).

The angle correction cursor is an estimate of the actual direction of flow. For larger Doppler angles, a small mistake in assigning the Doppler angle makes a large error in the velocity calculation. For this reason, angles at, or less than, 60 degrees are recommended. Velocity measurements should not be used if the Doppler angle is at, or greater than, 70 degrees (Fig. S21-4). A signal at such a large angle indicates the vessel is patent but the velocity should not be reported.

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Cross-reference

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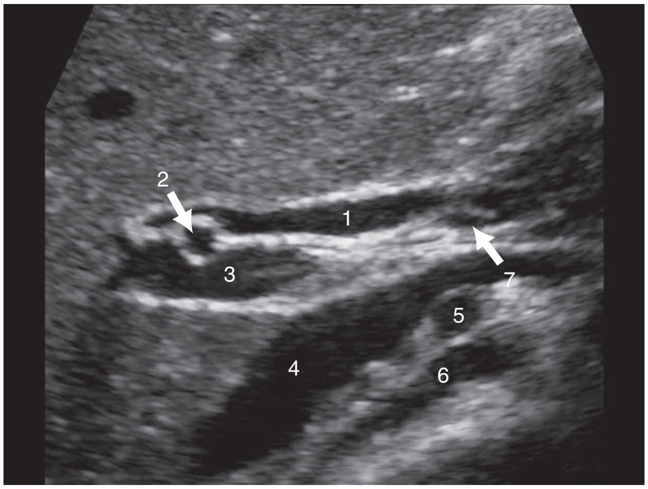

Figure 22-1

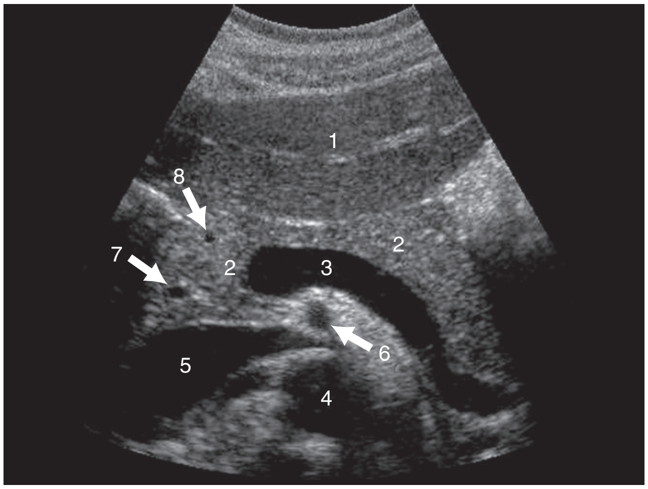

Figure 22-2

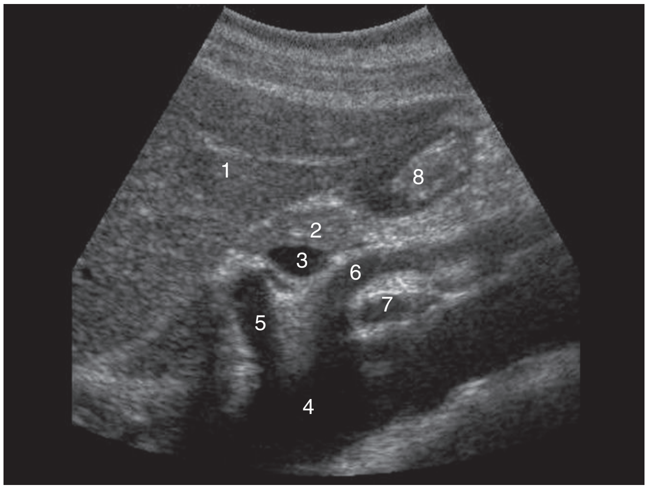

Figure 22-3

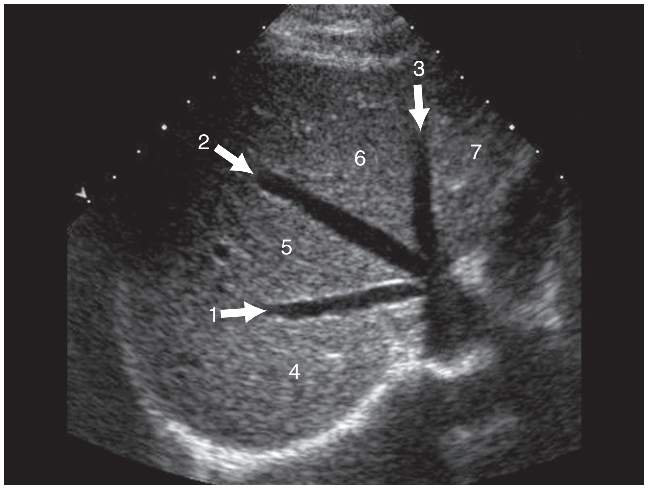

Figure 22-4

HISTORY: A 24-year-old male presented with upper abdominal pain, and these images were obtained.

1. In Figure 22-1, the longitudinal ultrasound of the porta hepatis, structure #2, represents the:
   A. Inferior vena cava.
   B. Right portal vein.
   C. Celiac axis.
   D. Common bile duct (CBD).
   E. Right hepatic artery.
2. In Figure 22-2, transverse image, the normal structure #8 corresponds to the:
   A. CBD.
   B. Pancreatic duct.
   C. Gastroduodenal artery (GDA).
   D. Superior mesenteric artery (SMA).
3. In Figure 22-3 of a longitudinal midline plane, the normal structure #7 corresponds to the:
   A. Portal vein.
   B. Celiac axis.
   C. Left renal vein.
   D. Superior mesenteric artery.
4. On the transverse view of the upper abdomen in Figure 22-4, which segment of the liver is identified as #6?
   A. Segment 2
   B. Segment 4A
   C. Segment 8
   D. Segment 7

See Supplemental Figures section for additional figures and legends for this case.

CASE 22

Normal Anatomy of the Upper Abdomen

1. **E.** Most commonly, the right hepatic artery is anterior to the portal vein as in this case. However, if the right hepatic artery originates from the SMA, it will be located posterior to the portal vein.
2. **C.** The GDA lies in the head of the pancreas. The CBD is structure 7. The SMA is structure 6.
3. **C.** The left renal vein lies between the SMA (#6) and the aorta (#4) (Fig. S22-3). The left renal vein may be compressed between the SMA and the aorta in the "nutcracker" syndrome.
4. **B.** Segment 4A corresponds to label #6; it lies between the main hepatic vein (#2) and the left hepatic vein (#3) (Fig. S22-4). Label 5 corresponds to segment 8 of the liver.

Comment

Differential Diagnosis

It is important to recognize normal structures in the liver so these structures are not confused with potential anomalies or abnormalities. Ultrasound is excellent in visualization of normal arterial and venous anatomy. Doppler waveforms are important to differentiate arterial and venous structure and are better described in other cases.

Ultrasound Findings

Ultrasound is an excellent tool to define normal anatomy of the upper abdomen as seen in Figures S22-1, S22-2, S22-3, and S22-4.

Prognosis/Management

There is no specific management question in this case. In the liver, the right hepatic artery usually lies between the anterior located CBD and the posterior located portal vein (Fig. S22-1). However, there are anatomical variations. A replaced right hepatic artery lies posterior to the portal vein. The hepatic artery may bifurcate early and have one branch lying anterior and the other branch posterior to the portal vein. Also important is the fact that the portal vein may be mistaken for the CBD. Thus, it is important to use color Doppler to identify arterial and venous structures or to identify structures such as bile ducts without any flow.

It is important to recognize normal pancreatic anatomy. On transverse images of the pancreas, confluence of the portal vein and the splenic vein (label 3 in Fig. S22-2) defines the posterior border of the pancreas. For other tubular structures within the pancreas that need to be defined so they are not confused with their anatomical variants or pathologic states, see Figure S22-2. On longitude images, the left renal vein lies between the superior mesentery artery and the aorta (Fig. S22-3).

It is important to recognize normal hepatic veins because they define segmental anatomy of the liver as developed by Couinaud. This segmental anatomy is better discussed in a separate case in this series. The middle hepatic vein divides the right and the left lobe of the liver. The right hepatic vein divides the right lobe into an anterior segment (segments 5 and 8) and the posterior segment (segments 6 and 7). Likewise, the left hepatic vein divides the left lobe into the medial segment (segments 4A and 4B) and the lateral segment (segments 2 and 3). Sometimes there are hepatic venous variants with fusion of various hepatic veins such as the left and middle hepatic vein, or there may be an accessory right hepatic vein. It is important to note normal structures and their location as it aids recognition of the surgical anatomy of the liver as developed by Couinaud.

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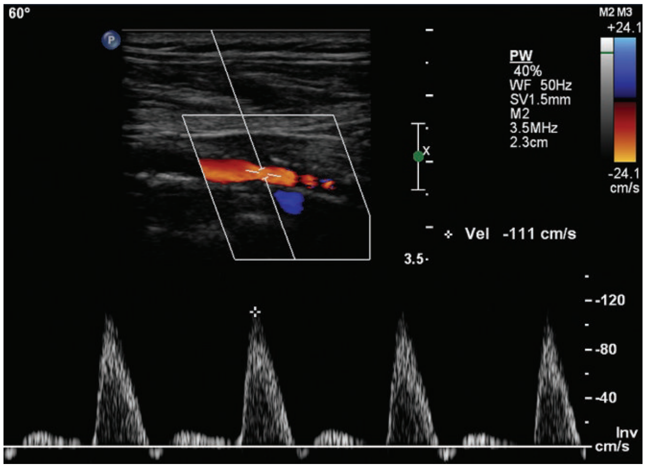

Figure 23-1

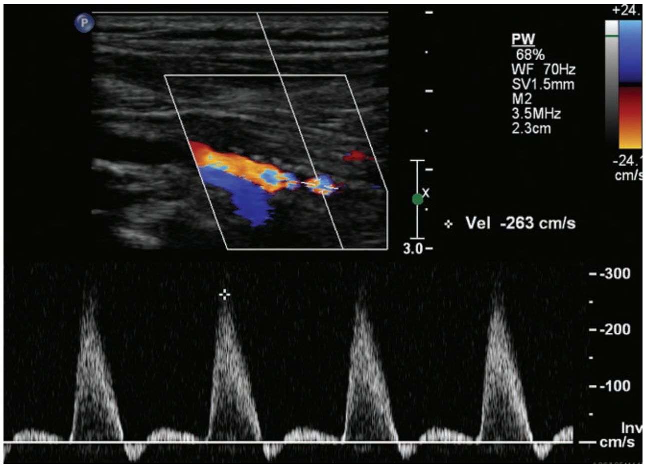

Figure 23-2

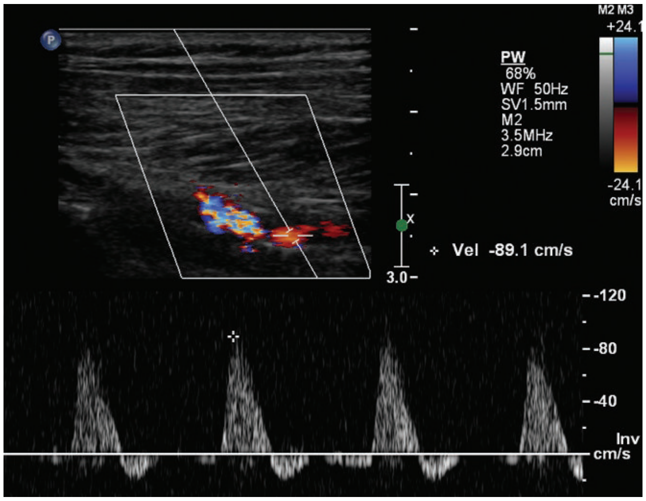

Figure 23-3

HISTORY: A 72-year-old man with hypertension and diabetes has calf pain after walking two blocks. It resolves quickly with rest. There was a duplex ultrasound of the lower extremity arteries including duplex images of the proximal to distal popliteal artery.

1. What is the degree of popliteal artery stenosis?
   A. 1% to 20%
   B. 20% to 50%
   C. 50% to 99%
   D. Occlusion
2. Which is a sign or symptom of peripheral artery disease?
   A. Medial ankle ulcer
   B. Pulsatile common femoral pulses
   C. Delayed pulse at popliteal artery
   D. Leg pain at end of the day
3. What is the duplex velocity ratio to distinguish a hemodynamically significant lesion?
   A. 2:1
   B. 3:1
   C. 1:3
   D. Ratios are not used for peripheral artery duplex.
4. What is the most common color Doppler sign of a stenotic lesion?
   A. Color bruit
   B. Flow reversal
   C. Aliasing
   D. Collateral artery

See Supplemental Figures section for additional figures and legends for this case.

CASE 23

Peripheral Artery Stenosis

1. **C.** There is narrowing and focal high velocity indicating a stenosis above 50% (Fig. S23-2).
2. **C.** Delayed pulse at the popliteal artery may be detected in peripheral artery disease when the stenosis is proximal to the artery. A medial ankle ulcer is more typical of chronic venous insufficiency. A pulsatile common femoral pulse is normal. Leg pain at the end of the day is more typical of venous disease.
3. **A.** The duplex velocity ratio to distinguish a hemodynamically significant lesion is 2:1 to indicate a stenosis above 50%. The ratio is calculated as the peak systolic velocity in the stenosis divided by the peak systolic velocity in the normal artery before the stenosis.
4. **C.** The most common color Doppler sign of a stenotic lesion is aliasing. A color bruit indicates a stenotic lesion that causes enough turbulence to be seen in the adjacent tissue, but it is less common than aliasing. Flow reversal is a finding in normal arteries. Collateral arteries may be seen but are less common than narrowing and aliasing.

Comment

Overview

Peripheral artery disease may present with claudication, rest pain, or ischemia. Arterial duplex Doppler is used to localize and grade stenosis. Frequently there are multiple sites of stenosis. The examination consists of inflow, femoropopliteal, and outflow (calf) arteries.

Normal Peripheral Artery Waveform

The normal peripheral arterial waveform has a rapid upstroke and acute downstroke with a short reversal (Fig. S23-1). Typically there is another forward component. This is described as a multiphasic waveform. Some describe the number of forward and reverse components, so a forward-back-forward signal is triphasic. However, it is the presence of the reverse component, not the number of phases, that is most important to diagnose normal.

Duplex Doppler of Peripheral Artery Stenosis

An arterial stenosis demonstrates three duplex findings: plaque on gray scale ultrasound, narrowing by color Doppler (Fig. S23-4), and typical spectral Doppler findings. The spectral Doppler findings are focal increase in the velocity of blood relative to the velocity in the normal vessel before it (Figs. S23-1 and S23-2) and decreased velocity and disturbed flow after the stenosis. Spectral broadening and/or turbulence should be detected beyond the stenosis (Fig. S23-3). In runoff vessels, low velocity may be seen.

Grading of Peripheral Artery Stenosis

Because the normal velocities of the peripheral arteries differ from one another, an absolute elevated velocity indicating a stenosis is not used in most laboratories. Instead, a ratio of the highest velocity to the velocity before the stenosis is used. The most common cut point for abnormal is a ratio of 2 to indicate a greater than 50% stenosis. This degree of stenosis is typically pressure reducing. Some groups also subdivide stenotic vessels into 50% to 75% stenosis with a ratio of 2 to 3.9 and greater than 75% stenosis with a ratio greater than 4. Occlusions have no flow by color and spectral Doppler.

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CASE 24

Figure 24-1

Figure 24-2

HISTORY: The patient is a 40-year-old with liver function abnormalities. Two gray scale images of the liver taken seconds apart are part of an abdominal examination.

1. Regarding Figures 24-1 and 24-2, what is the difference between the two images?
   A. Fatty liver is artifactually eliminated in Figure 24-2.
   B. Time gain compensation (TGC) correction displays a normal liver in Figure 24-2.
   C. Gain increases overall echogenicity in Figure 24-2.
   D. Shadowing is eliminated by better frequency in Figure 24-2.

2. Regarding increasing the ultrasound frequency, which of the following is true?
   A. It increases the attenuation of the sound beam.
   B. It has no effect on the attenuation of the sound beam.
   C. It is commonly associated with increased acoustic output.
   D. It increases the noise in the image.

3. Regarding the TGC, which of the following is true?
   A. It affects patient exposure.
   B. It can compensate for shadowing.
   C. It should make the image uniform from top to bottom.
   D. It cannot make a normal liver echogenic.

4. Regarding gain, which of the following is true?
   A. It affects scatters but not specular reflectors.
   B. It affects the ultrasound as it enters the patient.
   C. Increasing gain increases patient exposure.
   D. It can produce noise if set too high.

See Supplemental Figures section for additional figures and legends for this case.

CASE 24

Time Gain Compensation and Attenuation

1. **B.** The liver is normal. An incorrect TGC did not amplify the distal signals enough and the deeper liver looked artifactually dark. The gain and frequency were not adjusted.
2. **A.** Increasing the ultrasound frequency increases the attenuation of the sound beam. This must be compensated for by changing the TGC or gain. An increase in acoustic output may or may not be needed. Noise is not generally affected by the frequency.
3. **C.** The TGC should make the image uniform from top to bottom. It amplifies the returning signal so it does not affect patient exposure. Shadows have no information in them so the TGC cannot compensate for shadowing. An improper TGC can artifactually increase the echogenicity of an organ if it is set too high.
4. **D.** Gain can produce noise if set too high. It affects scatters and specular reflectors. It affects the ultrasound that returns to the transducer so increasing gain does not increase patient exposure. Acoustic power affects patient exposure.

Comment

As sound travels through the body, attenuation occurs. If no correction is made, then the image will get progressively darker with depth. The higher the frequency of sound, the more attenuation that occurs, and the less the beam is able to penetrate (Fig. S24-1).

An appropriately gained image will have uniform brightness across the entire image at all depths (Fig. S24-1). The TGC is a signal processor function that allows the operator to adjust the amplitudes of the *returning* signal so the far field echoes can be independently adjusted while the other echoes are left alone (Fig. S24-2).

It is important to note that no additional power is being put into the patient as a result of adjusting the TGC, as TGC adjustments are made after the signal has returned from the patient. Adjusting the TGC instead of increasing the acoustic power is an important part of patient safety and the ALARA (as low as reasonably achievable) principle.

After TGC adjustments, if the far field is too dark because of inadequate penetration, the operating frequency should be lowered. Increasing the TGC only makes the echoes brighter; it does not create better penetration where there is a shadow.

If the entire image is too dark or too bright, the overall gain should be adjusted. The overall gain adjusts the received signal amplitudes so that all are increased or decreased, regardless of depth. The TGC individual settings permit the operator to adjust brightness at different depths, while the overall gain adjusts the brightness of the entire image. If there is not enough signal and these controls have been optimized, the acoustic power could then be increased.

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Cross-reference

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Acknowledgments

Special thanks to Traci B. Fox, EdD, RT(R), RDMS, RVT, for preparation in this case.

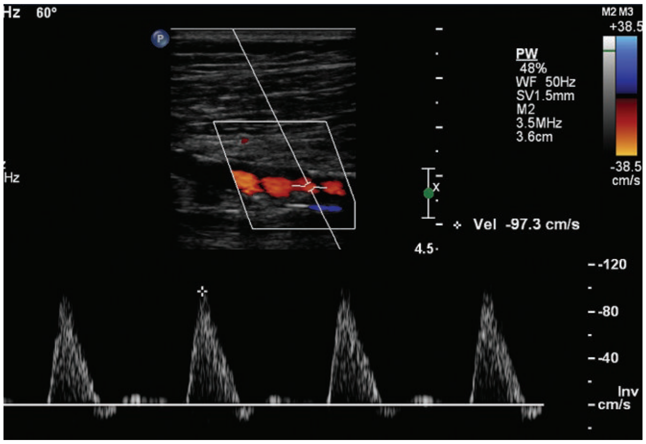

Figure 25-1

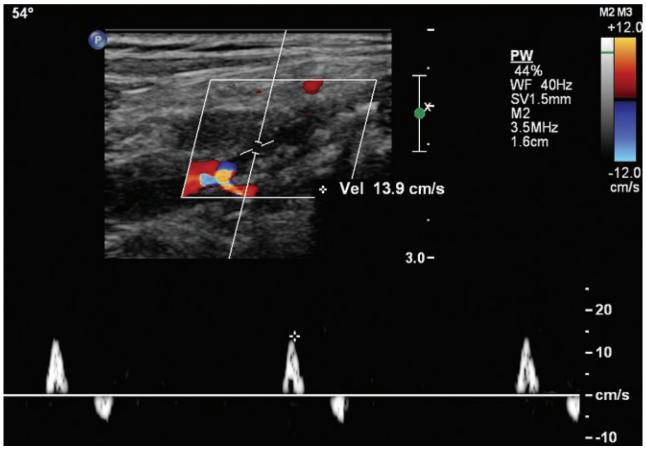

Figure 25-2

HISTORY: A 73-year-old male presents with ½ block claudication. A duplex arterial study was performed. Images from the superficial femoral artery (Fig. S25-1) and proximal popliteal artery (Fig. S25-2) are shown.

1. What is the degree of stenosis in the superficial femoral artery (Fig. 25-1)?
   A. None
   B. Mild
   C. 50% to 75%
   D. 50% to 99%
2. What does the waveform in the proximal popliteal artery (Fig. 25-2) indicate?
   A. No significant stenosis
   B. Significant stenosis proximal to the site of the waveform
   C. Significant stenosis proximal at the site of the waveform
   D. Significant stenosis distal to the site of the waveform
3. What is the velocity in the popliteal artery in Figure 25-2?
   A. Low
   B. Normal
   C. High
   D. Incorrectly measured
4. In regard to the reverse component of flow in a peripheral artery spectral waveform, which of the following is true?
   A. It is due to the Doppler angle.
   B. It is artifactual.
   C. It is created by reflected waves from distal vessels.
   D. It is lost as a result of peripheral edema.

See Supplemental Figures section for additional figures and legends for this case.

CASE 25

Thump (Staccato) Waveform and Indirect Signs of Arterial Stenosis

1. **B.** The degree of stenosis in the superficial femoral artery is mild. There is mild plaque and narrowing in color. The velocity is not elevated, and the waveform shape is normal multiphasic.

2. **D.** The waveform in the proximal popliteal artery (Fig. S25-2) indicates a significant stenosis distal to the site of the waveform. The waveform has an equally sharp upstroke and downstroke with little diastolic flow except for a tiny amount in mid diastole.

3. **A.** The velocity in the popliteal artery in Figure S25-2 is low. Although there is variation in the normal velocities in the leg, no vessel should be below 35 cm/s, and so a peak velocity under 20 is always low. The waveform measurement was performed correctly.

4. **C.** The reverse component of flow in a peripheral artery spectral waveform is created by reflected waves from distal vessels. The reversal is real and not affected by the Doppler angle. Edema does not affect the shape of the arterial waveform in any substantial way.

Comment

The normal peripheral arterial waveform has a rapid antegrade upstroke, a somewhat slower downstroke that produces an acute angle at the apex, and a diastolic reversed component with lower velocity (Fig. S25-1). After this waveform there may be a smaller antegrade component or several back and forth components, each smaller than the last. The forward-reverse-forward waveform is described as triphasic. The reverse component is most important and therefore many simply describe the normal waveform as multiphasic. Some normal patients do not have the third antegrade component. In some other normal patients, particularly young patients with compliant vessels, the back and forth in diastole is more pronounced and may produce four or more distinct phases.

Arteries before high grade stenoses or occlusions may have a characteristic stump-thump waveform (Fig. S25-2). Other names for this are thumps, knocking, or staccato waveforms. The thump is most apparent if the sample is close to the abnormal segment. In a thump, the upstroke is preserved but the downstroke is immediate, producing a short burst of forward flow. There is frequently no reverse component, but a small reverse component may be present. The reverse may be immediately after the forward component or not, and it is of short duration and has lower velocity than the antegrade component. Despite being in two directions, this should not be mistaken for a normal multiphasic waveform.

The waveform in a significant stenosis has elevated velocity, with forward flow through the cardiac cycle (Fig. S25-3).

Arteries distal to significant stenoses may display the parvus tardus (weak and slow) waveform (Fig. S25-4). There are three hallmarks of the parvus tardus waveform: forward flow throughout the cardiac cycle (monophasic continuous waveform), a slow upstroke and slow time to peak velocity, and increased amount of diastolic flow compared with the normal waveform. In peripheral arteries, the change is dramatic because the normal reverse component is lost. The reverse component comes from reflected waves created by the antegrade wave striking and being reflected from the resistant arteriolar circulation. If the antegrade pulse is weaker, for example, from a pressure reducing lesion, the reflection is weak or absent, and the waveform stays antegrade through the cardiac cycle.

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Cross-reference

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CASE 26

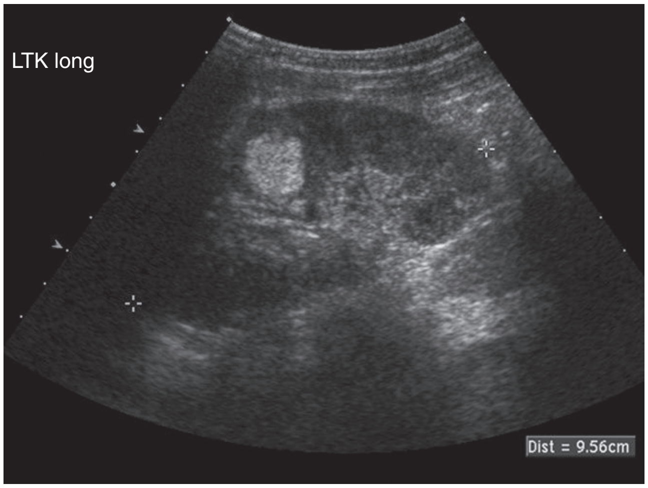

Figure 26-1

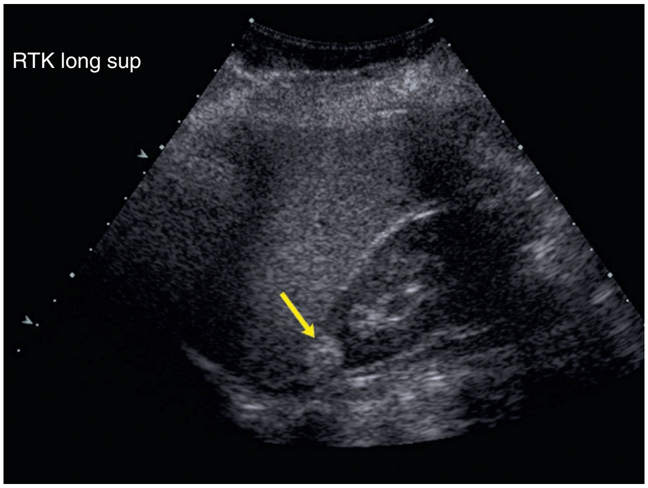

Figure 26-2

HISTORY: Two different patients present with abdominal pain, and images of their kidneys are obtained.

1. Which one of the following would be included in the differential diagnosis for the ultrasound findings identified in the renal ultrasounds in Figures 26-1 and 26-2? (Choose all that apply.)
   A. Renal cell carcinoma (RCC)
   B. Hemorrhagic renal cyst
   C. Renal abscess
   D. Angiomyolipoma (AML)
2. Which of the following is NOT true regarding renal AMLs?
   A. In the majority of cases, AMLs appear as a homogeneous, well-defined cortical mass and have the same echogenicity as perirenal fat.
   B. A small percentage of AML may appear anechoic to perirenal fat.
   C. Both cystic elements and calcifications are common features of AML.
   D. Some AMLs have acoustic shadowing.
3. Which one of the findings below would NOT be associated with tuberous sclerosis (TS)?
   A. Renal cysts
   B. Cardiovascular lesions such as atrial myxomas
   C. Subependymal giant cell astrocytomas
   D. Retinal hamartomas
4. Which of the following is NOT true regarding TS?
   A. There is increased risk of developing RCC.
   B. May develop pulmonary lymphangioleiomyomatosis.
   C. If large in size, greater than 4 cm, there is a risk of hemorrhage.
   D. The triad of manifestations of TS includes mental retardation, seizures, and cutaneous lesions.

See Supplemental Figures section for additional figures and legends for this case.

CASE 26

Angiomyolipoma

1. **A and D.** AML has the typical appearance identified in Figures S26-1 and S26-2. While rare, RCC may appear echogenic and is a potential pitfall in this case.
2. **C.** Having either cystic regions or calcification within a mass would be an unusual feature for an AML. Most AMLs are as echogenic as perirenal fat, and approximately 20% have some acoustic shadowing.
3. **B.** The most common cardiac lesion with TS is a cardiac rhabdomyoma, which often occurs in utero (Fig. S26-4).
4. **A.** Von Hippel-Lindau is associated with RCC and not TS.

Comment

Differential Diagnosis

The differential diagnosis is fairly narrow. AMLs appear as smooth, very echogenic lesions compared with the renal parenchyma. They will have the same echo texture as the perirenal fat and perinephric fat. However, in less than 10% of cases, RCCs may appear hyperechoic compared to the renal cortex. Thus, RCC is the main differential diagnosis. Medullary nephrocalcinosis or focal calcifications may appear very echogenic, but both often are more focal with acoustic shadowing, as in the case of renal stones or calcifications.

Ultrasound Findings

The majority of cases of AMLs appear as homogeneous hyperechoic masses with similar echotexture to the rest of the renal sinus fat. There are a small percentage of cases in which the tumors are less echogenic than fat but more echogenic than renal parenchyma. In 5% to 10% of cases, there is no fatty component or minimal fatty component to an AML. These cases will not appear as an echogenic mass. Approximately 20% of AMLs do have mild acoustic shadowing as identified in Figures S26-1 and S26-2. This shadowing may be due to a mixture of fat and other elements within the AML. AMLs may be single or multiple.

If associated with TS, there can be multiple other findings. Most AMLs occur sporadically in adults. A small percent are associated with TS. In these cases, there will be other manifestations of TS such as mental retardation, seizures, and cutaneous lesions. TS is associated with a number of different abnormalities including hamartomas that occur elsewhere in the body, such as cerebral cortical subependymal nodules, retinal hamartoma, and cardiac rhabdomyoma (Fig. S26-4). In patients affected with TS, there is also an increased number and frequency of renal cysts in infancy and childhood.

Prognosis/Management

The prognosis is dependent on underlying disease. In patients with TS, the prognosis is usually dependent on the other sequelae of TS. These would include development of significant lesions such as subependymal giant cell astrocytomas and progression of other aspects of TS.

AML's prognosis is excellent. However, there is the risk of hemorrhage of an AML greater than 4 cm. Thus, in these cases, partial nephrectomy or catheter embolization can be considered. It is important to distinguish AML from RCC if there is any doubt. A computed tomography scan demonstrating that the lesion is fat, such as illustrated in Figure S26-3, will establish the diagnosis of AML. Magnetic resonance imaging may also be useful in these cases. Differentiating AML with minimal fat from RCC may be difficult. Biopsy may be needed in some cases.

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CASE 27

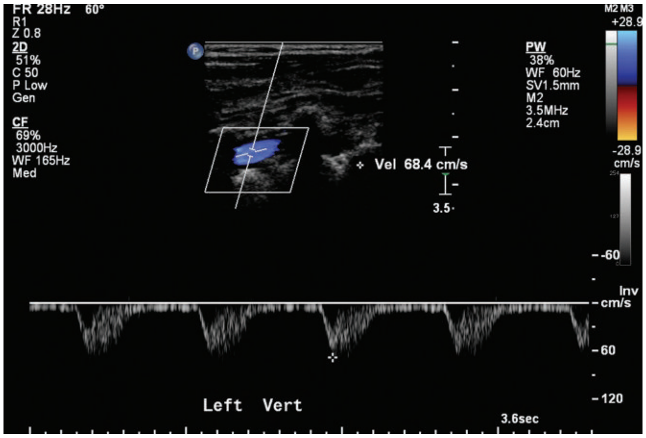

Figure 27-1

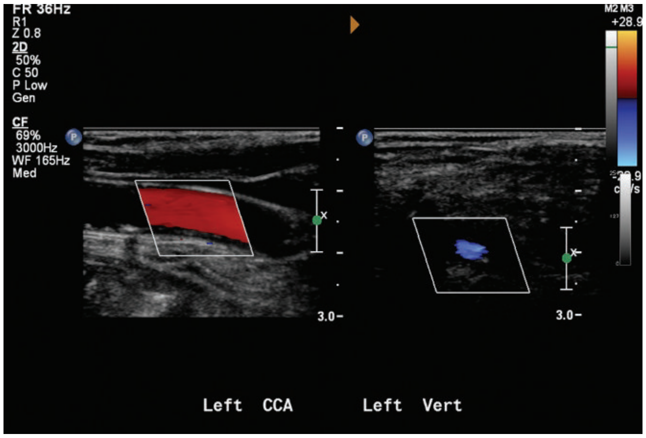

Figure 27-2

HISTORY: A 67-year-old man presents with asymmetrical pulses. Images were obtained during duplex evaluation of the cerebrovascular arteries.

1. How can the vertebral artery (Fig. S27-1) be described?
   - A. Flowing in the wrong direction
   - B. Abnormally pulsatile
   - C. Tardus parvus
   - D. Stenotic
2. What is the most likely site of obstruction?
   - A. Right vertebral artery
   - B. Left vertebral artery
   - C. Left subclavian artery
   - D. Innominate artery
3. What is the most common symptom of subclavian steal?
   - A. Stroke
   - B. Dizziness
   - C. Hand tiredness
   - D. Transient ischemic attack (TIA)
4. Which of the following is FALSE regarding the vertebral arteries?
   - A. One artery may be smaller on one side than another.
   - B. The normal arterial waveform shape resembles the external carotid artery.
   - C. Obstruction in the feeding artery can lead to reversed flow.
   - D. External carotid artery collaterals can reestablish distal flow in an obstructed vertebral artery.

See Supplemental Figures section for additional figures and legends for this case.

CASE 27

Subclavian Vertebral Steal Syndrome

1. **A.** The vertebral artery is reversed during all of the cardiac cycle (Fig. S27-1). It is flowing in the opposite direction of the common carotid artery and flowing toward the feet on the spectral Doppler and color Doppler image (Fig. S27-2).
2. **C.** Left subclavian artery obstruction will produce flow reversal in the ipsilateral vertebral artery. Right-sided vertebral or innominate obstructions will not cause retrograde left vertebral artery flow. A proximal left vertebral lesion can cause reverse flow more distally in the vertebral artery, but this is rare.
3. **C.** Patients with subclavian steal generally have no symptoms. When they do, arm tiredness or claudication is most common. Vertebrobasilar symptoms such as dizziness are rarer, as are strokes or TIAs.
4. **B.** The normal vertebral artery waveform is similar to the internal carotid artery because it supplies the brain. The vessels may be asymmetrical in size. Because the two vertebral arteries form the basilar, flow can be reversed in one side, fed by the other. The vertebral artery does have branches in the neck, so external carotid collateralization is possible in vertebral artery obstruction.

Comment

Etiology

Subclavian steal occurs when a subclavian artery stenosis lowers post stenotic pressure and the vertebral artery becomes a collateral vessel to the subclavian. Vertebral artery flow reverses. The most common etiology is atherosclerosis.

Other Causes

There are other unusual (nonatherosclerotic) causes. These include large vessel vasculitis, right-sided aortic arch and isolated left subclavian artery, thoracic outlet syndrome, and others.

Symptoms

Most patients are asymptomatic. In the minority, there is arm claudication with exercise-induced arm pain or heaviness. Even less common are vertebrobasilar TIAs, typically with upper extremity exercise. Not all vertebrobasilar symptoms are caused by the steal but may have other etiologies. A coronary subclavian steal phenomenon may be present if a stenosis occurs in the subclavian artery before an internal mammary artery (IMA) bypass graft and can cause angina or infarction.

Because patients with subclavian steal have underlying atherosclerotic disease, they are at risk for cardiovascular mortality and morbidity.

Duplex Findings

The vertebral artery demonstrates retrograde flow during the entire cardiac cycle, indicating a complete steal (Figs. S27-1 and S27-2). In a partial steal, retrograde flow may be present in only part of the cardiac cycle. Complete steals are more likely with complete or more severe subclavian obstruction. The peripheral subclavian artery is beyond the most common site of stenosis, but it is the site that is typically imaged. The blunted peripheral subclavian (Fig. S27-3) loses the typical multiphasic waveform (Fig. S27-4) with loss of the normal reverse component. The abnormal waveform is described as monophasic continuous or tarsus parvus. Arm pressures are generally asymmetrical with the affected side being 20 or more mm Hg below the normal side.

Treatment

Coronary subclavian steals need treatment. The majority of other steals do not unless IMA bypass is planned or patients have burdensome symptoms. Endovascular repair is usually adequate, but long occlusions, or those with adverse anatomy, may require surgical repair. Duplex Doppler ultrasound is accurate to diagnose and follow most patients. Magnetic resonance angiography or computed tomography angiography, while also diagnostic, are not necessary in the vast majority of cases unless specific information is needed prior to surgery, for example, mapping of the subclavian lesion.

Reference

Potter BJ, Pinto DS. Subclavian steal syndrome. *Circulation*. 2014;129(22):2320–2323.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 263.

CASE 28

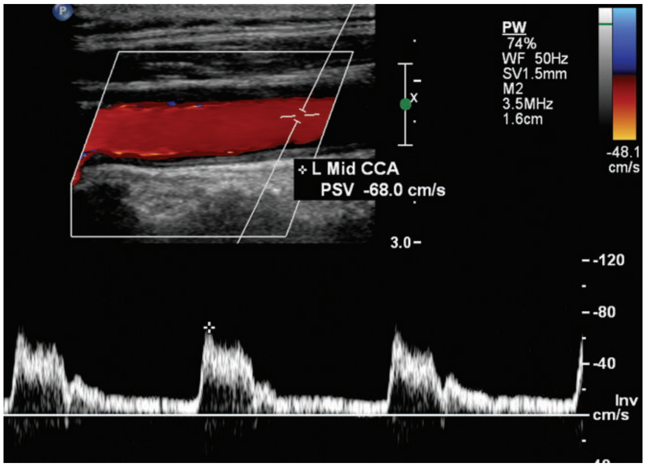

Figure 28-1

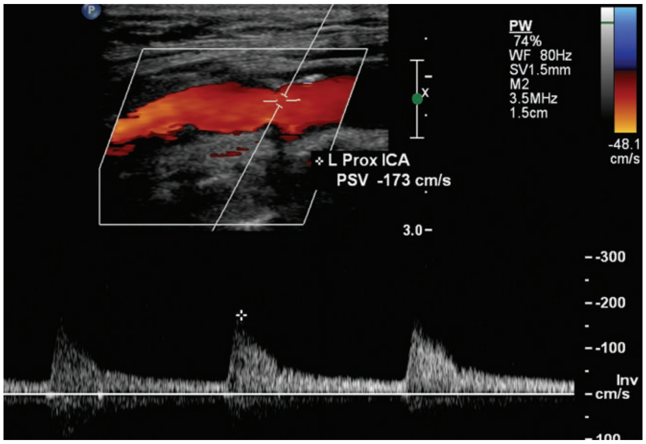

Figure 28-2

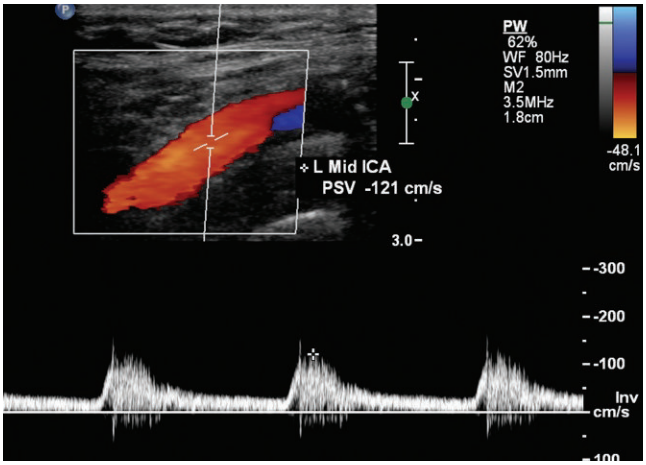

Figure 28-3

HISTORY: The patient is a 64-year-old having carotid ultrasound prior to coronary artery bypass graft surgery.

1. What is the degree of stenosis?
   A. 1% to 49% diameter reduction
   B. 50% to 69% diameter reduction
   C. 70% diameter reduction to near occlusion
   D. 80% diameter reduction
2. What is the change in velocity from the proximal to the mid internal carotid artery (ICA)?
   A. It is noise.
   B. It is not significant.
   C. It is indicative of stenosis.
   D. There is no change in velocity. The mid ICA is improperly measured.
3. What is the spectrum in the mid ICA?
   A. It is laminar.
   B. It is turbulent.
   C. It is flowing in the wrong direction.
   D. It is overgained.
4. Regarding treatment of ICA stenosis, which of the following is true?
   A. Carotid endarterectomy is recommended for patients with a stroke and a 40% stenosis.
   B. Medical therapy is superior to carotid endarterectomy.
   C. Medical therapy is superior to carotid artery stenting.
   D. Carotid occlusion is a contraindication to carotid endarterectomy.

See Supplemental Figures section for additional figures and legends for this case.

CASE 28

Internal Carotid Artery Stenosis

1. **B.** 50% to 69% diameter reduction is correct. The peak systolic velocity (PSV) increases significantly more than the common carotid artery (CCA) velocity; the ICA velocity is over 125 cm/s and velocity drops beyond the stenosis.
2. **C.** The change in velocity from the proximal to the mid ICA is significant, and it is indicative of stenosis. Velocity increases inside the stenosis and drops off beyond the stenosis. Noise can produce spectral broadening throughout the cardiac cycle. There is a small area in early systole that is higher than the measurement, but it is above and below the baseline (simultaneous forward and reverse flow) that is part of the poststenotic turbulence.
3. **B.** The spectrum in the mid ICA is turbulent. It has irregularities at the edge (picket fencing) with forward and reverse components. It is not laminar flow, which has no simultaneous forward and reverse component. Increased gain can cause some filling in of the spectrum; it cannot create reverse flow if it is not there. The spectrum is inverted and the color and spectral direction indicate correct direction away from the transducer and toward the head.
4. **D.** Carotid occlusion is a contraindication to carotid endarterectomy. Symptomatic patients with greater than a 50% to 69% diameter reduction are indicated to undergo revascularization when performed in a center with perioperative morbidity and mortality less than 6%. Medical therapy is recommended for all patients, but operative procedures can be more effective for selected patients with stenosis.

Comment

ICA Velocity

The velocity in the normal proximal internal carotid is generally lower than the mid-distal CCA because there is less volume (the external carotid artery takes some of the common carotid flow) and the carotid bulb has a wider cross section than the CCA. The diagnosis of internal carotid stenosis relies on the identification of focal velocity elevation (Fig. S28-2) at the site of stenosis (Fig. S28-4) compared with the unaffected CCA (Fig. S28-1).

ICA Velocity in Stenoses

In stenoses, the velocity goes up in the narrowed segment (Fig. S28-2). PSV increases first and then diastole goes up in more severe stenoses. For 50% to 69% stenosis, as in this case, velocities must be elevated above the CCA velocity and the PSV is greater than 125 cm/s (up to 229 cm/s). Stenoses above 70% have a velocity above 230 cm/s.

ICA Waveforms Beyond the Stenosis

As the vessel widens beyond the stenosis, the waveform shape changes to the disturbed flow that occurs after stenosis (Fig. S28-3). The velocity decreases as the lumen widens (Fig. S28-3), and blood flow becomes disordered as well. As the red blood cells travel in different directions with different velocities, and with circular vortices, the spectral Doppler demonstrates spectral broadening. This appears as filling of the spectrum because low and high velocities are represented. Moreover, although most flow is forward, some reversed flow is also noted due to circular flow. The waveform may also demonstrate transient peaks described as a picket fence appearance (Fig. S28-3).

References

Grant EG, Benson CB, Moneta GL, et al. Carotid artery stenosis: gray-scale and Doppler US diagnosis—Society of Radiologists in Ultrasound Consensus Conference. *Radiology*. 2003;229:340–346.

Kernan WN, Ovbiagele B, Black HR, et al. Guidelines for the prevention of stroke in patients with stroke and transient ischemic attack: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*. 2014;45:1–15.

von Reutern G-M, Goertler M-W, Bornstein NM, et al. Grading carotid stenosis using ultrasonic methods. *Stroke*. 2012;43(3):916–921.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 247.

Figure 29-1

Figure 29-2

HISTORY: A 25-year-old presents with abnormal renal function tests.

1. Which of the following would be included in the differential diagnosis for a unilateral process of an enlarged right kidney as shown in Figure 29-1? (Choose all that apply.)
   A. Renal vein thrombosis
   B. Renal lymphoma
   C. Acute pyelonephritis
   D. Acute arterial infarction
   E. Multicystic dysplastic kidney
2. If this was a bilateral renal enlargement, which of the following could the differential diagnosis include? (Choose all that apply.)
   A. Glomerulonephritis
   B. Amyloidosis
   C. Chronic diabetic nephropathy
   D. Renal lymphoma
3. After the treatment of a unilateral process involving the right kidney, which of the following would the differential diagnosis include for the findings shown in Figure 29-2? (Choose all that apply.)
   A. Radiation nephritis
   B. Chronic pyelonephritis
   C. Renal ischemia
   D. Amyloidosis
4. If the appearance of the kidney in Figure 29-2 is a bilateral process without history, which of the following would the differential diagnosis include? (Choose all that apply.)
   A. Old age
   B. Chronic diabetes
   C. Chemotherapy
   D. Chronic pyelonephritis

See Supplemental Figures section for additional figures and legends for this case.

CASE 29

Renal Parenchymal Disease

1. **A, B, and C.** Certainly, renal vein thrombosis would be considered within the differential of the unilaterally enlarged kidney without a specific mass. Color Doppler of the renal vein would be important for this diagnosis. Acute pyelonephritis usually involves one portion of the kidney but may be a more global process and could be considered. When lymphoma involves the kidney, it is usually a bilateral process, but it could be a unilateral process.
2. **A, B, and D.** There are a number of different manifestations of lymphoma involving the kidneys, but one of these would be unilateral or bilateral renal enlargement. Acute glomerulonephritis is one of the common causes of renal enlargement without specific differentiating ultrasound features. Amyloidosis may be primary or secondary to a number of etiologies but in the acute phase may present as symmetrical renal enlargement.
3. **A, B, and C.** Given the enlarged kidney progression to a small kidney, radiation would be considered most likely in the differential. Without this history, renal ischemia or chronic infection would be considered.
4. **A, B, C, and D.** Any chronic insult, including chemotherapy, diabetes, or bilateral chronic pyelonephritis, could cause small kidneys and would be considered within the differential. With age there is renal atrophy.

Comment

Differential Diagnosis

There is a broad differential for unilateral renal enlargement. Space occupying masses, such as renal tumors or cysts and hydronephrosis, are well identified by ultrasound. Renal infection or unilateral diffuse tumor like lymphoma could be considered (Fig. S29-1). Renal vein thrombosis should be excluded by careful Doppler examinations of the renal vein on the affected side.

The differential for diffuse bilateral renal enlargement could include acute bladder outlet obstruction with associated hydronephrosis or other entities, such as autosomal dominant polycystic disease. Both of these would be easily identified by ultrasound. However, there are generalized renal diseases that cause bilateral renal enlargement, including acute glomerulonephritis and Wegener's granulomatosis, to name a few. These kidneys may range in size from normal to markedly enlarged. Acute tubular necrosis may also cause enlargement of the kidneys depending on the etiology. Acquired immune deficiency syndrome-related nephropathy may cause renal enlargement. Unfortunately, ultrasound may not be helpful in distinguishing among many of these entities.

Either unilateral or bilateral small kidneys are usually indicative of a chronic process (Fig. S29-2). However, renal agenesis may be present at birth. Unfortunately, ultrasound often is not helpful to distinguish the exact etiologies of the unilateral/bilateral small kidneys. These processes can result from a variety of chronic diseases such as diabetes or glomerulonephritis.

Ultrasound Findings

Ultrasound findings are helpful in distinguishing different etiologies of enlarged kidneys. Careful scanning of the bladder, ureters, and collecting systems for any evidence of hydronephrosis is important. The kidneys are examined for any specific masses, whether cystic or solid, that may cause renal enlargement. Careful evaluation of the renal vein and the inferior vena cava (IVC) is important to exclude renal vein or IVC thrombosis. This will cause either unilateral or bilateral enlargement depending on the site of the thrombus. Looking for extrarenal abnormalities such as retroperitoneal adenopathy, which may obstruct the renal vein or ureter and cause renal enlargement, is important.

Prognosis/Management

Treatment is dependent on exact etiology of the unilateral or bilateral renal enlargement. Computed tomography or magnetic resonance imaging may be helpful to document the abnormality or detect the etiology of renal enlargement.

References

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Rodriguez-de-Velasquez A, Yoder IC, Velasquez PA, Papanicolaou N. Imaging the effects of diabetes on the genitourinary system. *Radiographics*. 1995;15(5):1051–1068.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 131.

CASE 30

Figure 30-1

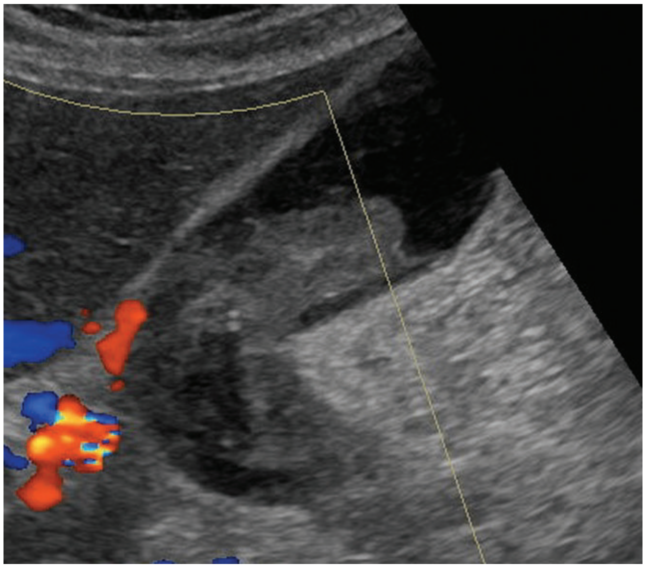

Figure 30-2

HISTORY: A patient presents with right upper quadrant pain; images show the gallbladder with the patient supine (Fig. 30-1) and upright (Fig. 30-2).

1. Choose the one best answer that would be included in the differential diagnosis for the imaging findings presented.
   A. Gallbladder carcinoma
   B. Blood clot
   C. Tumefactive biliary sludge
   D. Gallbladder polyp
2. All of the following are associated with an increased incidence of tumefactive biliary sludge EXCEPT:
   A. Rapid weight loss.
   B. Critical illness.
   C. Octreotide usage.
   D. High protein diet.
3. What can the components of tumefactive biliary sludge include? (Choose all that apply.)
   A. Hemosiderin
   B. Mucus
   C. Calcium bilirubinate
   D. Cholesterol crystals
4. What is the management for an asymptomatic patient with incidentally discovered tumefactive biliary sludge? (Choose all that apply.)
   A. Nonemergent cholecystectomy
   B. Expectant management
   C. Percutaneous cholecystostomy
   D. Repeat sonography in 1 to 2 weeks

See Supplemental Figures section for additional figures and legends for this case.

CASE 30

Tumefactive Biliary Sludge

1. **C.** The nonshadowing, echogenic gallbladder mass without internal vascularity may be either tumefactive sludge or sludge and cholelithiasis, which is the best answer. A gallbladder hematoma could be considered.
2. **D.** High protein diet is not associated with gallbladder sludge. Risk factors for development of tumefactive sludge include pregnancy, rapid weight loss (particularly in the obese), critical illness involving the use of total parenteral nutrition, certain drugs (e.g., ceftriaxone and octreotide), and following gastric bypass surgery. It is also associated with bone marrow or solid organ transplantation.
3. **B, C, and D.** Cholesterol monohydrate crystals, mucus, and calcium bilirubinate crystals are all components of biliary sludge.
4. **B and D.** Asymptomatic patients may be treated expectantly. In equivocal cases, repeat sonography may be performed after a delay in order to document resolution or decrease in the size of the sludge.

Comment

Differential Diagnosis

The differential diagnosis of tumefactive biliary sludge is fairly narrow and includes polypoid gallbladder carcinoma or a polyp. Tumefactive sludge may be distinguished from a polypoid mass that is nonmobile and may exhibit internal vascularity. It differs from nontumefactive sludge, which forms a layering of slowly mobile fluid-fluid level. It can often be difficult to distinguish thick bile from other echogenic nonshadowing material such as hematoma, pus, or tiny calculi.

Ultrasound Appearance

Tumefactive sludge is typically an incidental finding on ultrasound for right upper quadrant pain. The typical sonographic characteristics are of a polypoid, nonshadowing, echogenic mass without internal vascularity. The sludge will typically move with patient's positioning. It may be distinguished from a tumor in which there is lack of mobility and internal vascularity (Figs. S30-1 and S30-2). However, this is more difficult in cases where the sludge is adherent to the gallbladder wall or is too small to rule out vascularity. It can often be found in association with shadowing gallstones, as in this case.

Prognosis/Management

The clinical course of patients with sludge can vary from complete resolution in many patients, to a waxing/waning course, to the development of cholelithiasis. Asymptomatic patients with tumefactive sludge can be treated expectantly. In equivocal cases, follow-up imaging after 1 or 2 weeks may show resolution or decreased size of the mass, which would exclude neoplasm. In symptomatic patients or those with acalculous cholecystitis, cholecystectomy is performed. Complications include biliary colic, ascending cholangitis, acute pancreatitis, and cholecystitis.

References

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 38–39.

Acknowledgment

Special thanks to Wonsuk Kim, MD, for preparation in this case.

CASE 31

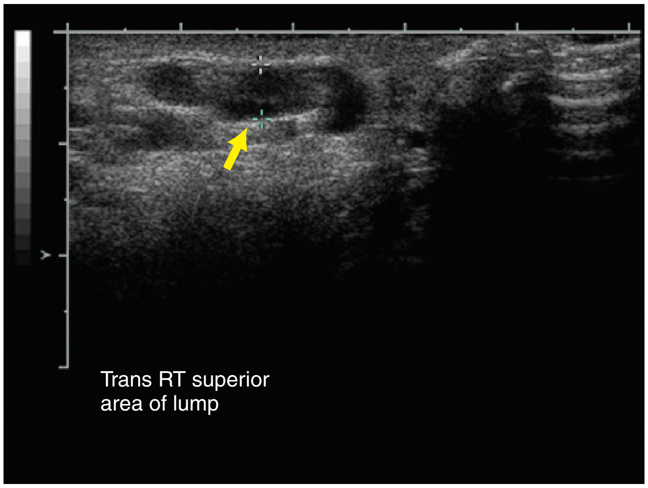

Figure 31-1

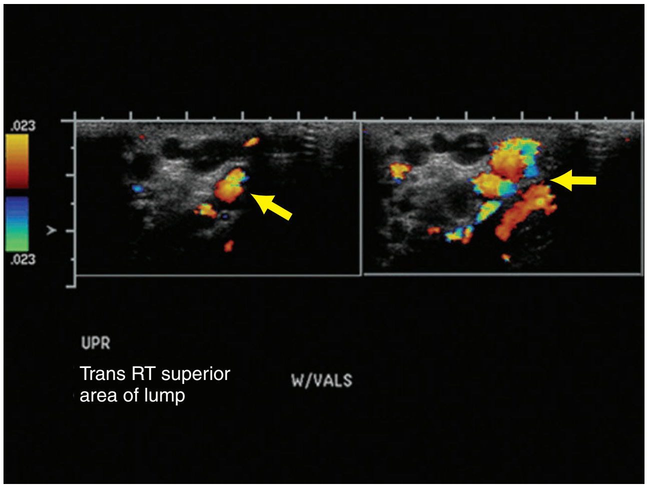

Figure 31-2

HISTORY: A 25-year-old male presents with a 2-week history of intermittent dull, achy pain in his scrotum. He reports that he feels a lump above his right testis.

1. Which of the following could be included in the differential diagnosis as the etiology of the imaging findings presented in Figures 31-1 and 31-2? (Choose all that apply)
   A. Idiopathic, no specific etiology
   B. Renal cell carcinoma
   C. Hypercoagulability
   D. Nephrolithiasis
   E. Epididymitis

2. Which one of the following most accurately describes the correct diagnosis?
   A. It is related to incompetent venous valves and subsequent retrograde flow in the right gonadal vein and is most commonly caused by an obstructive process in the right renal vein or inferior vena cava.
   B. It is most commonly diagnosed in middle-aged men (40 to 60) and is caused by chronic repetitive straining (valsalva).
   C. It is most commonly asymptomatic and a benign incidental finding.
   D. It is caused by dilation and tortuosity of the pampiniform plexus and can lead to testicular atrophy and infertility.

3. Which one of the following most accurately describes the imaging diagnosis of varicocele?
   A. Dilated veins that decrease in size with valsalva
   B. Greater than five to six prominent veins
   C. The gray scale findings include dilated veins greater than 2 to 3 mm
   D. Scrotal scintigraphy is more sensitive but less specific than Doppler sonography

4. What is the LEAST popular method used for treating this condition?
   A. Open varicocele ligation
   B. Microsurgery
   C. Antegrade sclerotherapy
   D. Retrograde embolization

See Supplemental Figures section for additional figures and legends for this case.

CASE 31

Adrenal Masses Varicocele

1. **A, B, and C.** Left-sided varicoceles are most common. They are usually idiopathic. Even the rarer are right-sided varicoceles. Becasuse all are rare, a retroperitoneal etiology should be considered.
2. **D.** Retrograde flow, incompetent valves, and engorgement of the pampiniform plexus are associated with ipsilateral testicular volume loss; it is the most common correctable etiology of infertility in males. Varicocele is most commonly idiopathic, not secondary to obstruction. It is most commonly diagnosed in patients between the ages of 15 and 30. Chronic straining is not associated with varicoceles. While it can be asymptomatic, it is not completely benign as mentioned here.
3. **C.** The imaging features of varicocele include at least two to three prominent veins measuring greater than 2 to 3 mm in diameter, serpiginous dilated veins behind the superior pole of the testis on color Doppler, and an increase in size during valsalva. Scrotal sonography is most often performed with the patient supine; standing before the ultrasound may increase the sensitivity in diagnosis. Scrotal scintigraphy is more specific but less sensitive than Doppler sonography.
4. **A.** While all of the listed treatments are existing procedures that have varying amounts of success, laparoscopic ligation, has replaced open ligation as used by urologists.

Comment

Differential Diagnosis

The differential is fairly straightforward. The real differential is the etiology of the varicocele. An idiopathic varicocele is caused by incompetent venous valves, retrograde flow in the gonadal vein, and subsequent pampiniform venous distention. It is the most common etiology in adolescents and young adults. The incidence of varicocele has been reported as high as 40% in adult males who attend fertility clinics. It is well known that treatment can lead to an increase in ipsilateral testicular growth and function when compared to untreated patients. Varicocele is most commonly found on the left side (90%), but bilaterally (10%) and right-sided varicocele (<1%) can occur. Secondary causes are all related to increased venous pressure and/or some level of obstruction at the renal vein or gonadal vein (Fig. S31-3). The most common cause of secondary varicocele is renal cell carcinoma, but any retroperitoneal tumor such as lymphoma may cause obstruction. Therefore a renal ultrasound should be performed (Fig. S31-3). Other described etiologies include retroperitoneal fibrosis, adhesions, and renal vein thrombosis. In the nutcracker syndrome, the superior mesenteric artery compresses the left renal vein, which may cause a left-sided varicocele. The increased venous pressure, decreased delivery of oxygenated blood and nutrients, and increased temperature of the scrotum are caused by the varicocele. This, in turn, is thought to cause testicular atrophy, Leydig cell dysfunction, and poor spermatogenesis and steroidogenesis. Men with varicoceles have lower mean testosterone levels and lower sperm counts than age-matched controls.

Imaging

While scrotal ultrasonography and color Doppler are the most frequently used modalities to diagnose varicocele, retrograde venography is still considered the gold standard test but is infrequently performed. It is used primarily in uncertain cases or prior to venous embolization. Ultrasound is 98% sensitive and 100% specific when compared to venography. Ultrasonographic features include prominence of two to three veins measuring greater than 2 to 3 mm in diameter (normal veins measure 0.5 to 1.5 mm), serpiginous dilated veins behind the superior pole of the testis on color Doppler, and an increase in size during valsalva (Figs. S31-1 and S31-2). Detection of reverse flow with Doppler improves the diagnostic specificity. In patients with high clinical suspicion of secondary varicocele, computed tomography and magnetic resonance imaging are often used to evaluate for abdominal or retroperitoneal masses.

Treatment

Indications for surgical treatment include a large varicocele in adolescence, childhood testicular atrophy, elevated follicle stimulating hormone levels, low testosterone levels, painful varicocele, and infertility. While many successful procedures have been described, such as the Palomo retroperitoneal technique (open retroperitoneal surgical approach above the internal inguinal ring with high ligation), and the Ivanissevich approach (open surgical approach at the external inguinal ring with ligation), more recently microsurgery, laparoscopic varicocele ligation, retrograde embolization, and antegrade sclerotherapy, are used. Success of the repair is based on varicocele elimination and lack of recurrence, which occurs via missed collaterals. The most common postoperative complication is hydrocele. Embolization techniques have a high success rate with left-sided varicoceles but a lower success rate with right-sided varicoceles.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 68–69.

Acknowledgment

Special thanks to Gary Tse, MD, for preparation of this case.

CASE 32

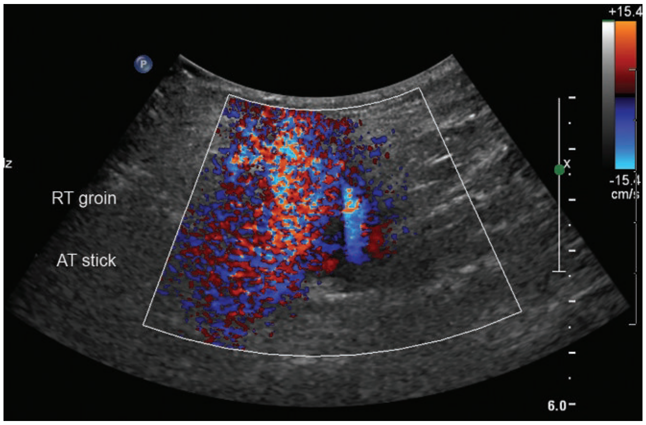

Figure 32-1

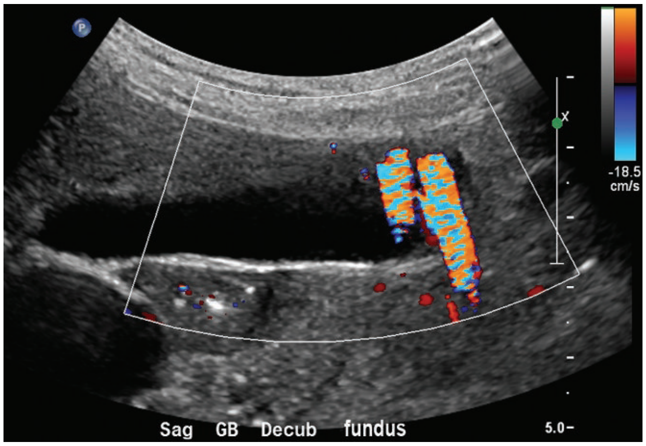

Figure 32-2

HISTORY: Two color images from two different patients are shown. Figure 32-1 is part of a duplex Doppler of the groin in a patient with pain and a bruit following cardiac catheterization. The color was periodic with systole. Figure 32-2 is taken of the right upper quadrant as part of an abdominal examination in a 32-year-old with abdominal pain. The color was constant.

1. What is the most likely diagnosis in Figure 32-1?
   A. Arteriovenous (AV) fistula
   B. Noise
   C. Bleeding
   D. Deep venous thrombosis
2. What is the most likely diagnosis in Figure 32-2?
   A. Gallbladder cancer
   B. Gallbladder varices
   C. Adenomyomatosis
   D. AV fistula
3. What is the cause of the artifact in Figure 32-1?
   A. Inadequate pulse repetition frequency (PRF)
   B. Tissue vibration
   C. An irregular, highly reflective surface
   D. Transducer or patient motion
4. What is the cause of the artifact in Figure 32-2?
   A. Inadequate PRF
   B. Tissue vibration
   C. An irregular, highly reflective surface
   D. Transducer or patient motion

See Supplemental Figures section for additional figures and legends for this case.

CASE 32

Extravascular Color (Perivascular Tissue Vibration [Color Bruit] and Twinkle Artifact)

1. **A.** The most likely diagnosis in Figure S32-1 is an AV fistula. There is excessive color outside of the vascular system. In a patient after cardiac catheterization, the cause is usually an AV fistula, pseudoaneurysm, and rarely, an arterial stenosis. Noise can create extravascular color, but, in this case, the color is localized over a vessel rather than in the entire color box. Bleeding and deep venous thrombosis do not produce extravascular color.
2. **C.** The most likely diagnosis in Figure S32-2 is adenomyomatosis. This has small areas of calcification that can produce a false color signal. There is no flow causing this and the artifact extends outside of the gallbladder, making cancer or varices less likely. There are two areas of artifact and the artifact is elongated, making AV fistula less likely.
3. **B.** The cause of the artifact in Figure S32-1 is tissue vibration. Perivascular tissue vibration or color bruit is an artifact where moving tissue is color encoded because it is vibrating from turbulence. The tissue motion is stronger than normal wall motion and gets encoded. Inadequate PRF causes aliasing, not extravascular color. Motion artifact or flash can cause color in the color box, but it is not related to the cardiac cycle as it was in this case. An irregular surface does not cause periodic color.
4. **C.** The cause of the artifact in Figure S32-2 is an irregular, highly reflective surface. This twinkle artifact is not caused by movement. A false color Doppler signal is created by the interaction of the sound beam in an irregular surface, typically calcification or a stone.

Comment

A Doppler shift is created when there is movement of a reflector as observed by a stationary transducer. Although red blood cells are the typical reflectors in Doppler, anything that is moving, or perceived to be moving, will produce a Doppler shift. Therefore, there are several artifacts that may appear to be flow. For example, in the heart, movement of the myocardium produces its own Doppler shift, which causes an artifact (called "clutter") on the spectral Doppler display that is usually filtered out. Movement by the transducer or the patient may cause a flash artifact filling all or some of the color box during movement. This may be seen from the heart and from respiration or from transducer movement. Power Doppler is sensitive to this artifact.

Some vascular pathologies that create turbulence cause a vibration in the tissue, called a "thrill." When a thrill is audible, it is called a "bruit." These may be seen in color Doppler as extravascular color (Fig. S32-1) and it is typically centered around the vessel causing the turbulence. The artifact is known as perivascular tissue vibration or a "color bruit." Audible bruits may not cause color bruits and vice versa. Tissue vibration is usually caused by high velocity flow or turbulence, such as an AV fistula, pseudoaneurysm (Figs. S32-1 and S32-3), or high-grade stenosis. If this artifact is found, the operator should carefully examine the nearby vessels to look for a cause of the tissue vibration.

Another type of color signal not caused by blood flow is called "twinkle" (Fig. S32-2). Twinkle is a flash of color Doppler behind a rough, bright structure, such as a calculus (Fig. S32-4). The roughness is important and twinkles are rarely seen behind flat reflectors. The twinkle is a mosaic pattern in color, and it is also seen in power Doppler. It is a helpful artifact to search for stones and can confirm a stone even if a shadow behind it is absent (Fig. S32-5). It is found in adenomyomatosis (Fig. S32-2), presumably from small calcifications seen in the thickened wall.

References

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Rubens DJ, Bhatt S, Nedelka S, Cullinan J. Doppler artifacts and pitfalls. *Radiol Clin North Am*. 2006;44(6):805–835.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 296–300, 126.

Acknowledgment

Special thanks to Traci B. Fox, EdD, RT(R), RDMS, RVT, for preparation in this case.

CASE 33

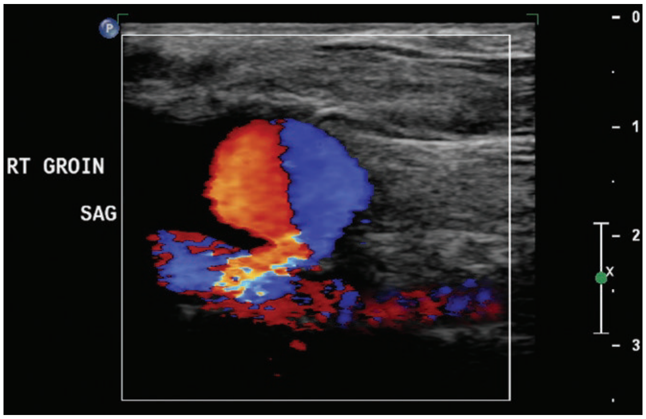

Figure 33-1

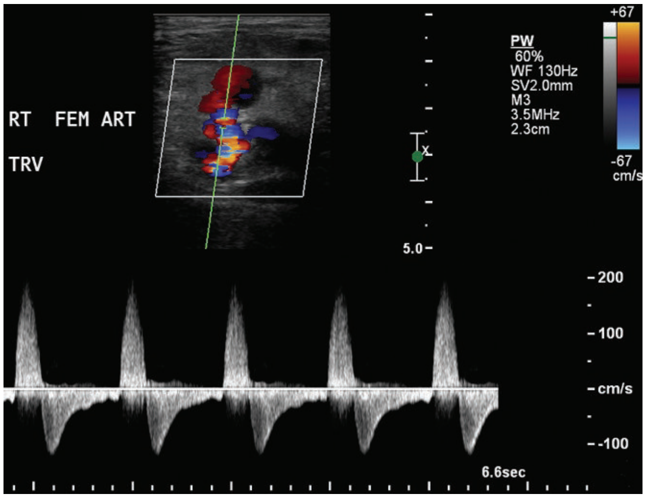

Figure 33-2

HISTORY: Two patients present with right groin swelling after a cardiac catheterization. Color Doppler and spectral Doppler of the right groin were performed.

1. What is the diagnosis?
   A. Superficial femoral artery aneurysm
   B. Superficial femoral artery pseudoaneurysm
   C. Superficial femoral artery pseudoaneurysm and arteriovenous fistula
   D. Postcatheterization vascular track
2. Regarding the to-and-fro waveform, which of the following is true?
   A. It is obtained from the aneurysm.
   B. It is present in aneurysms and pseudoaneurysms.
   C. It is obtained from the neck of a pseudoaneurysm.
   D. It is unique to a pseudoaneurysm.
3. Regarding a pseudoaneurysm, which of the following is true?
   A. Rupture is the most common complication.
   B. Paradoxical embolism may complicate treatment.
   C. Venous thrombosis is the most dangerous complication.
   D. Treatment is warranted to preserve arterial patency.
4. What is the source of the fro wave in the to-and-fro waveform?
   A. Negative pressure in the feeding artery
   B. Suprasystolic pressure in the pseudoaneurysm
   C. Supradiastolic pressure in the pseudoaneurysm
   D. Reflux from a ball valve effect

See Supplemental Figures section for additional figures and legends for this case.

CASE 33

Pseudoaneurysm

1. **B.** There is flow outside the superficial femoral artery (Fig. S33-1) with a typical to-and-fro waveform (Fig. S33-2) in the neck indicating a pseudoaneurysm. The site and appearance are not typical of an aneurysm. The waveform is not consistent with an arteriovenous fistula. The extravascular collection is too large for a track.
2. **C.** To-and-fro waveforms come from the neck of the pseudoaneurysm and are not seen inside of the pseudoaneurysm or aneurysm. The to-and-fro waveform is seen in other processes such as transplant renal vein thrombosis.
3. **A.** The most common complication of pseudoaneurysm is rupture, which can be life threatening. Venous thrombosis caused by compression of normal tissues by the mass or during compression of the artery is rare. Because there is no arteriovenous connection, paradoxical embolism does not occur. Spontaneous thrombosis of small pseudoaneurysms is common, and treatment is tailored to the size of the aneurysm and the patient's clinical condition.
4. **C.** The source of the to-and-fro sign is flow from the native artery to the pseudoaneurysm during systole, pressurization of the pseudoaneurysm, and return of blood to the lower pressure artery from the pseudoaneurysm in diastole. During diastole, the pseudoaneurysm has greater pressure than the native artery, resulting in the "fro" component. There is never negative pressure in the native artery. There is no ball valve effect.

Comment

Differential Diagnosis

Local trauma can damage the local arteries. Frequently this is questioned following catheterization of the groin for cardiac and vascular procedures or from line placement. Pain, swelling, ecchymosis, and occasionally a bruit may be present. A hematoma may form after puncture and a fluid collection is present. Arteriovenous fistulas are created when a connection is created between the artery and vein. It may have no tract between them if the vessels are contiguous (typically the common femoral artery and vein in the femoral sheath), or a tract may connect the two. Pseudoaneurysms occur when a fluid collection is formed and communicates with the artery. A tract connects the artery to the collection. Because the collection is extravascular, it does not have a vessel wall and is a pseudoaneurysm rather than a true aneurysm.

Imaging Findings

Ecchymoses are soft tissue, and these may have a normal ultrasound or there may be altered echogenicity of the subcutaneous fat. Hematomas are fluid collections, vary in size, and show no flow by Doppler. The clot may have varying echogenicity and is typically heterogeneous. A very fresh clot or lysed hematoma may be anechoic or nearly so. Pseudoaneuryms are collections with flowing blood in them. The track connecting them with an artery may or may not be seen on gray scale. They may be partially thrombosed with clot in the wall. Pulsations as it fills and empties are infrequently appreciated. In some, multiple collections can be found.

Doppler Ultrasound of Pseudoaneurysm

Color flow in the pseudoaneurysm is easily seen (Fig. S33-1). Thrombus in the wall may be seen when color does not fill the entire collection. Flow moves around with some flow toward and some away from the transducer, producing the yin and yang sign. The neck can be seen from the feeding artery to the collection (Fig. S33-1). The waveform in the neck should be sought in all cases: blood flows quickly into the pseudoaneurysm during systole and slowly out during diastole (Figs. S33-2 and S33-3). This is the typical to-and-fro sign.

Treatment

Small pseudoaneurysms may close spontaneously. For those with larger pseudoaneurysms and those for whom surveillance is not warranted, closure should be performed. Direct injection of thrombin into the collection is the most widely used treatment. Previously, ultrasound probe compression of the tract was used, but it took longer and was less effective. For selected individuals with adverse anatomy or rupture, surgical or endovascular repair can be performed.

Reference

Tisi PV, Callam MJ. Treatment for femoral pseudoaneurysms. *Cochrane Database Syst Rev.* 2013;11. CD004981.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 282.

CASE 34

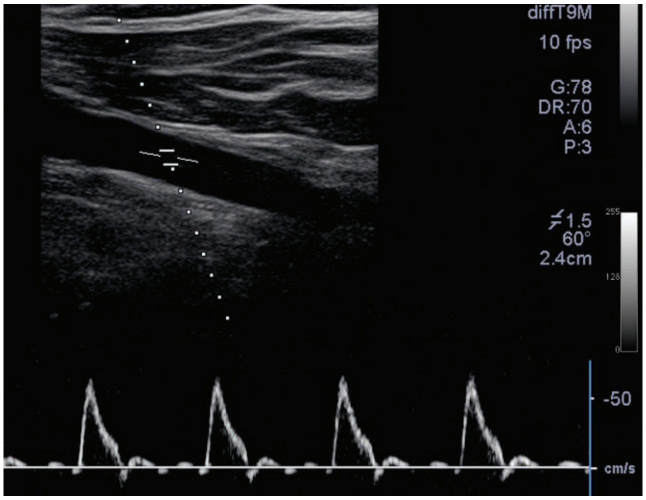

Figure 34-1

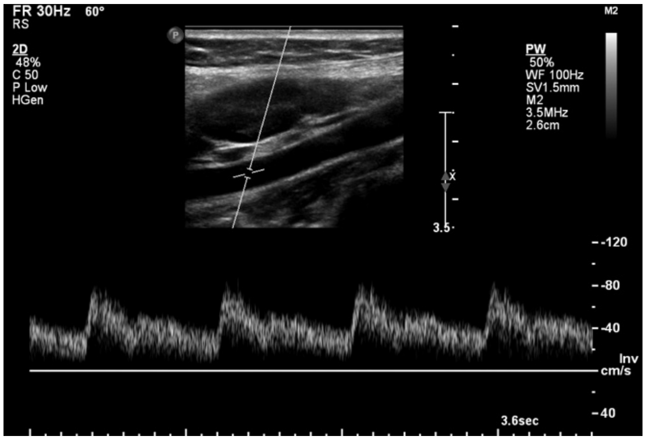

Figure 34-2

HISTORY: Multiple waveforms from a normal subject are shown.

1. What are the likely vessels for Figures 34-1 and 34-2?
   A. Subclavian artery and popliteal artery
   B. Subclavian artery and common carotid artery
   C. Subclavian artery and internal carotid artery
   D. Subclavian artery and external carotid artery
2. What is the main source of the reversed component in a high-resistance waveform?
   A. Compliance
   B. Distal arterioles
   C. Vessel length
   D. Aortic valve closure
3. Regarding antegrade diastolic flow through the cardiac cycle in low-resistance arteries, which of the following is true?
   A. It has spectral broadening.
   B. It is angle dependent.
   C. It is in vessels with low pressure.
   D. It is not affected by cardiac output.
4. Normal high-resistance and low-resistance arteries have which of the following?
   A. Rapid upstroke
   B. Antegrade diastolic flow
   C. No spectral broadening
   D. Velocities above 100 cm/s

See Supplemental Figures section for additional figures and legends for this case.

CASE 34

High-Resistance and Low-Resistance Waveform

1. **C.** The likely vessels for Figures S34-1 and S34-2 are the subclavian artery and internal carotid artery. The artery in Figure S34-1 is high resistance and feeds a peripheral system like the arm or leg. The artery in Figure S34-2 is low resistance with a large amount of diastolic flow. It is typical of a low-resistance bed feeding the brain or kidney. The external and common carotid arteries will not have so much diastolic flow, and they do not have such a gradual downslope after peak systole.
2. **B.** The main source of the reversed component in a high-resistance waveform is distal arterioles. Vessel length and compliance affect resistance, but most of the reversed component is from retrograde waves created at the arterioles. Aortic valve closure does not affect the diastolic component unless regurgitation is present.
3. **D.** Antegrade diastolic flow through the cardiac cycle is generally not affected by cardiac output. Most of the effect is from the arteriole and capillary beds. The flow may or may not have spectral broadening, depending on the size and flow profile of the vessel. Angle does not affect the amount of diastolic flow. The waveform may be seen with high, normal, or low arterial pressures.
4. **A.** Normal high-resistance and low-resistance arteries have rapid upstrokes if there is no stenosis between the heart and the vessel being evaluated. High-resistance waveforms do not have antegrade flow throughout diastole. Spectral broadening may be present in normal vessels. Velocities in normal arteries have a variety of normal velocities.

Comment

The shape of the Doppler waveform is determined by cardiac effects, local effects at the site of the sample, and the downstream circulation. The diastolic component is particularly affected by the resistance that is produced from distal vessels, typically arterioles. High-resistance waveforms (Fig. S34-1) are typical of arteriolar beds, which are constricted at rest, as in the peripheral arteries. Low-resistance waveforms (Fig. S34-2) are typical of circulations that need blood constantly, especially the brain and the kidneys. Other arteries are intermediate (Fig. S34-3), such as the external carotid artery or superior mesenteric artery.

In normal vessels, the flowing blood strikes the arterioles and a reverse wave is created. This is comparable to a water wave striking the edge of a pool and bouncing back to the source. The ultimate shape of any Doppler waveform is, therefore, the sum of the antegrade and retrograde waves. In high-resistance waveforms, the reverse wave is strong and can reverse blood flow during some of diastole. In low-resistance waveforms, the reverse wave is weak and blood flow does not reverse; it stays antegrade.

In high-resistance circulations, systole is forward and flow reverses during part of diastole (Fig. S34-1). This is described as a multiphasic waveform. A multiphasic waveform may have as few as one forward and one reverse component or have more oscillating phases in diastole (Fig. S34-1). An alternative description of the waveform is based on the number of back-and-forth components (e.g., a forward-reverse-forward waveform is described as triphasic). In low-resistance waveforms, the flow is forward throughout the cardiac cycle (Fig. S34-2). This is a monophasic signal.

Waveform shape may change in normal and abnormal conditions. Vasodilatation and vasoconstriction are normal events that the circulation uses to control blood flow. These changes may be identified by showing changes in the Doppler waveform shape. For example, the amount of antegrade diastolic flow in peripheral arteries increases after exercise. The superior mesenteric artery is high resistance when fasting but becomes low resistance after eating due to vasodilatation.

Altered waveform shapes may be present in diseased circulation. The renal circulation is normal low resistance, but diastolic flow may be reduced by renal diseases that destroy the normal circulatory bed. Similarly, the placenta may change from a low-resistance to a higher resistance circulation in cases of placental insufficiency.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 248, 279.

CASE 35

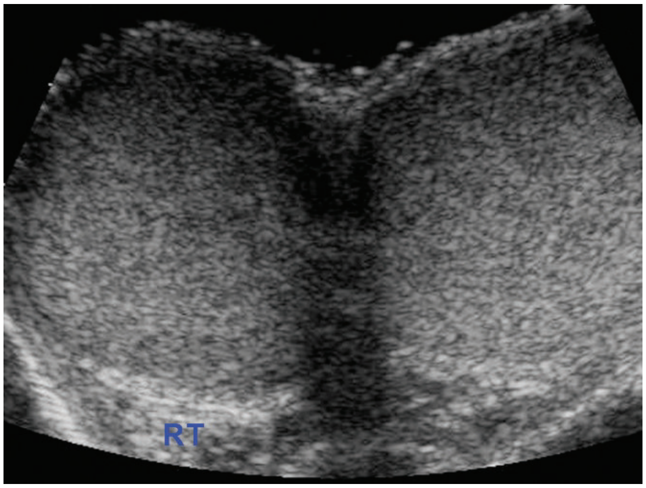

Figure 35-1

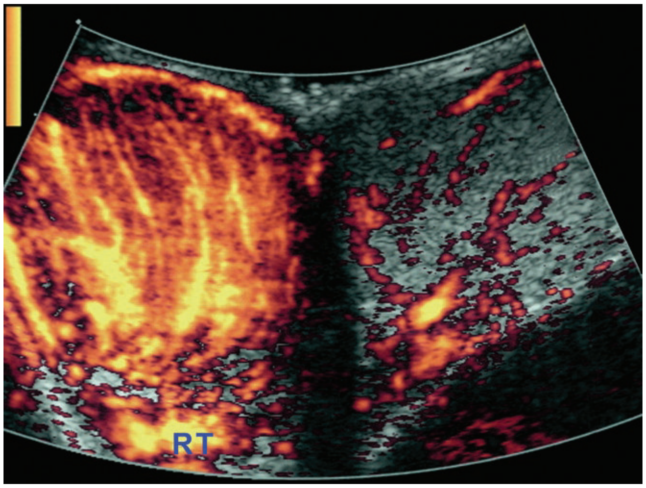

Figure 35-2

HISTORY: A 25-year-old male has this scrotal ultrasound.

1. Which one of the following would be included in the differential diagnosis for the imaging findings in Figures 35-1 and 35-2?
   A. Orchitis
   B. Lymphoma
   C. Normal
   D. Acute torsion
   E. Mixed germ cell tumor
2. Which one of these abnormalities usually has decreased color flow?
   A. Orchitis
   B. Testicular torsion
   C. Lymphoma
   D. Seminoma
3. Which one of the following statements concerning orchitis is FALSE?
   A. Orchitis is often preceded by epididymitis.
   B. Mumps is an etiology of orchitis with accompanying epididymitis.
   C. Tuberculosis is an etiology of orchitis.
   D. Brucellosis may cause orchitis.
4. Which of the following is NOT a sign to help in diagnosing orchitis?
   A. Usually there is involvement of the epididymis.
   B. This is usually a bilateral process.
   C. Mumps orchitis can be bilateral.
   D. Orchitis can lead to a scrotal abscess.

See Supplemental Figures section for additional figures and legends for this case.

CASE 35

Orchitis

1. **A.** With orchitis and acute torsion there may be subtle gray scale abnormalities. It is hard to know without history which testis is abnormal in Figure S35-1. However, power Doppler findings of hyperemia are consistent with orchitis.
2. **B.** This is the best answer. However, if there is detorsion of the testicle, there may be hyperemia of the affected testis.
3. **B.** Mumps is an etiology of orchitis but usually without epididymitis.
4. **B.** With most cases of orchitis of bacterial origin, the orchitis is usually a unilateral process.

Comment

Differential Diagnosis

There are several etiologies of a diffusely enlarged testis, including orchitis and infiltration tumor such as lymphoma or leukemia. Torsion may initially cause no gray scale changes, but within hours the testis may appear hypoechoic. Color Doppler shows hyperemia in the testis with diffuse lymphoma, seminoma, orchitis, and mixed germ cell tumors. However, most germ cell tumors appear as a focal or multiple masses. There is an avascular testis with acute torsion. Color flow is helpful to limit the differential (Fig. S35-2). Off-axis scanning or poor contact with a normal testis could cause one testis to appear slightly hypoechoic as in Figure S35-1.

Ultrasound Findings

The most common finding of orchitis secondary to epididymitis is an enlarged hyperemic testis. The testis may appear slightly hypoechoic. Color or power Doppler will show increased flow in the affected testis (Fig. S35-2). Findings of epididymitis may be present if this is an underlying etiology of orchitis. The findings of epididymitis, including increased size of the epididymis, increase color flow (Figs. S35-3 and S35-4), and a hydrocele may be present. If untreated, orchitis can lead to a testicular abscess or even testicular infarction.

Prognosis/Management

Prognosis is usually excellent if properly treated. Treatment depends on the underlying etiology of orchitis. Mumps orchitis may need only supportive care. However, even mumps orchitis can lead to side effects including some degree of testicular atrophy. Other etiologies of orchitis will require appropriate antimicrobial treatment.

References

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 162–165.

CASE 36

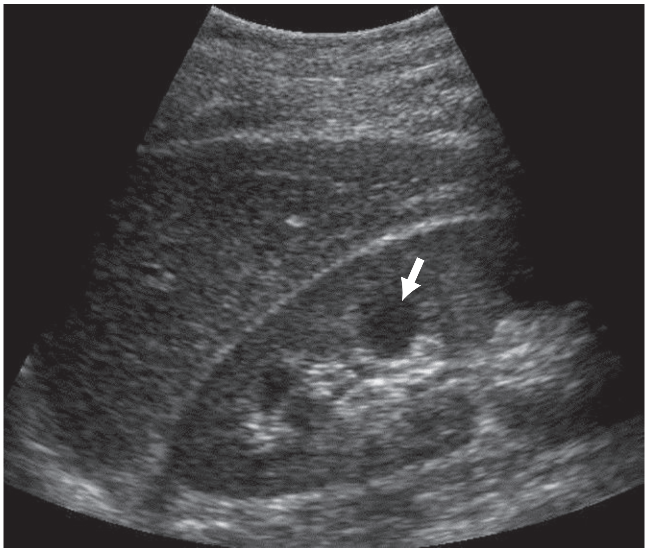

Figure 36-1

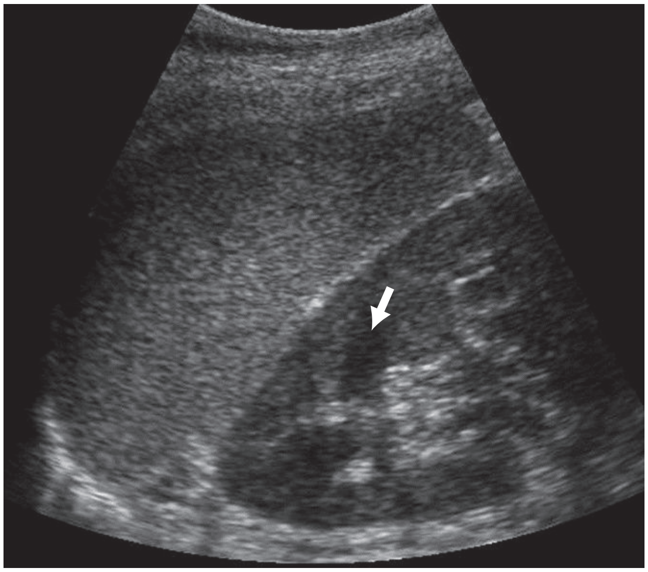

Figure 36-2

HISTORY: A 29-year-old female presents with frequent urinary tract infections.

1. Which one of the following would be included in the differential diagnosis for the imaging findings presented in Figures 36-1 and 36-2? (Choose one.)
   A. Normal kidneys
   B. Acute tubular necrosis
   C. Chronic medial renal disease
   D. Medullary nephrocalcinosis
2. What are the arrows pointing to in the images presented?
   A. Dilated calyx
   B. Renal mass
   C. Medullary pyramid
   D. Hypertrophied columns of Bertin
3. What is the length of normal adult kidneys?
   A. 9 ± 2 cm
   B. 11 ± 2 cm
   C. 13 ± 2 cm
   D. 15 ± 2 cm
4. Select the one correct order of normal echogenicity of the following upper abdomen organs, from most to least echogenic.
   A. Pancreas > liver > spleen > renal parenchyma
   B. Spleen > liver > pancreas > renal parenchyma
   C. Renal parenchyma > spleen > liver > pancreas
   D. Pancreas > spleen > liver > renal parenchyma

See Supplemental Figures section for additional figures and legends for this case.

CASE 36

Normal Kidneys

1. **A.** Both the images represent normal kidneys. Chronic medial renal disease can cause increased cortical echogenicity and small kidneys. Medullary nephrocalcinosis increases echogenicity of the renal pyramids. Acute tubular necrosis may have no imaging abnormalities and could be considered but can sometimes cause increased renal echogenicity.
2. **C.** Arrows are pointing to medullary pyramids, which are the most hypoechoic structures in a normal kidney. Hypertrophied columns of Bertin have the same echogenicity as renal cortex and may simulate a renal mass.
3. **B.** Normal adult kidneys measure 11 ± 2 cm.
4. **D.** In the upper abdomen, the correct order of echogenicity from most to least echogenic structures is: pancreas > spleen > liver > renal parenchyma.

Comment

Normal Imaging Anatomy

Normally, the renal parenchyma is the least echogenic structure in the upper abdomen, followed by the liver and spleen and with the pancreas being the most echogenic organ (Figs. S36-1 and S36-2). Differences in echogenicity within different parts of a kidney lead to a complex sonographic appearance. Renal sinus fat and soft tissues are the most echogenic structures within the kidney. The collecting system and the vessels appear as thin-walled anechoic structures within the renal sinus fat. The medullary pyramids are often less echogenic compared to the parenchyma (Figs. S36-1 and S36-2).

Scanning Technique

Comparing the echogenicity of the kidneys relative to the liver and spleen is crucial to assess for disease condition. Hence, the views obtained should include the liver and the spleen, with the right and left kidneys, respectively, to allow for optimal comparison. The right kidney is easily imaged using the liver as a window (Fig. S36-1). Given the variability in the size of the spleen, it may be difficult to view the spleen along with the left kidney on the same image. Sonography, using a high posterior and lateral approach with the patient supine, will be useful for most patients, except for those with unusually small spleens. Both kidneys may be scanned from a posterior and lateral approach to allow for higher resolution.

Normal Variants

Generally, the external contour of the kidney is smooth. Slight lobulation of the contour may be seen with persistent fetal lobulations (Fig. S36-3). Junctional parenchymal defect (or the internuclear junction) is a common normal variant, producing a wedge-shaped, hyperechoic defect at the anterior aspect of the junction of the upper one-third and lower two-thirds. This is covered in another case. A prominent column of cortical tissue (columns of Bertin) may be present at the middle third of the kidney protruding into the renal sinus. This cervical tissue protruding centrally can be confused with a renal mass.

Reference

Thurston W, Wilson SR. The urinary tract. In: Rumack CM, Wilson SR, Charboneau JW, eds. *Diagnostic Ultrasound*. 3rd ed. St. Louis: Elsevier/Mosby; 2005:322–325.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 103–105.

Acknowledgments

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CASE 37

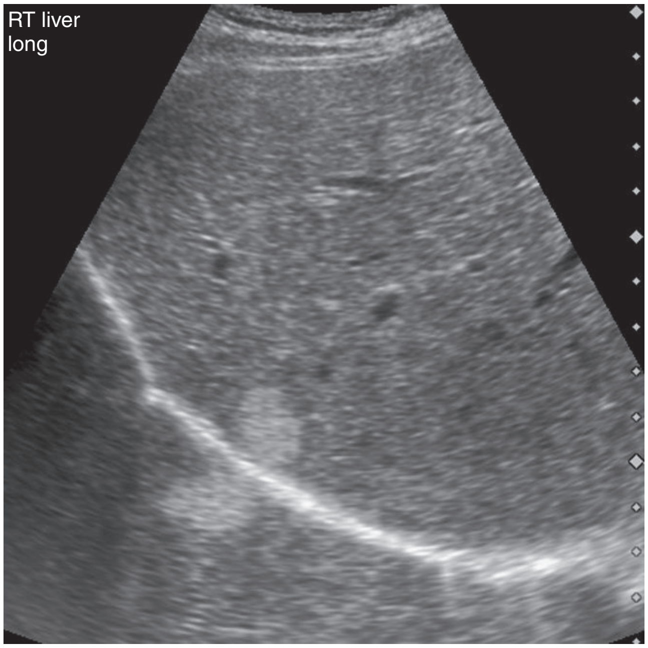

Figure 37-1

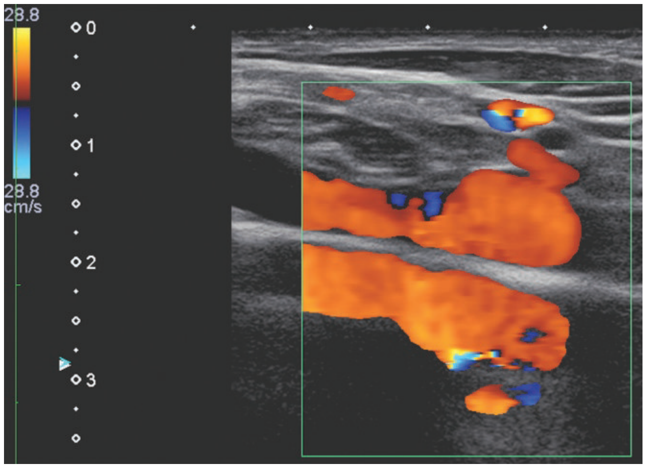

Figure 37-2

HISTORY: Figures 37-1 is an image of the right upper quadrant. Figures 37-2 is a transverse view of the neck in the region of the subclavian artery.

1. What is the artifact in both Figures 37-1 and 37-2?
   A. Noise
   B. Mirror image
   C. Reverberation
   D. Refraction
2. What factor is most important to create a mirror image?
   A. Curved surface
   B. Flat surface
   C. Scatterer
   D. Specular reflector
3. Which does not produce a mirror image?
   A. Lung interface
   B. Diaphragm interface
   C. Bone interface
   D. Blood interface
4. Regarding mirror-image artifact, which of the following is true?
   A. It is seen in color but not spectral Doppler.
   B. It is related to the frequency.
   C. It is related to the acoustic power.
   D. It is an exact duplicate of the original.

See Supplemental Figures section for additional figures and legends for this case.

CASE 37

Mirror-Image Artifact

1. **B.** The artifact is a mirror image. In Figure S37-1, a liver hemangioma is duplicated and appears below and above the diaphragm. In Figure S37-2, the normal subclavian is duplicated below the apex of the lung. The artifact is always deep to the original structure that created it.
2. **D.** Mirror images are typically created by specular reflectors. The surface may be flat or curved. Scatterers do not produce mirror images.
3. **D.** Blood does not produce a mirror-image artifact. The artifact is common in color Doppler, however. Lung, diaphragm, bone, and even the back of some vessels may produce the artifact.
4. **C.** Mirror-image artifact is related to acoustic power and can be decreased by reducing the output of the machine. It is seen in gray scale ultrasound and color and spectral Doppler. It is not related to frequency. If the specular surface is not flat, the mirror image will not be a duplicate of the original.

Comment

Mirror-image artifacts in gray scale imaging (Figs. S37-1 and S37-3) occur when sound is reflected at a specular reflector, a type of reflector whose borders are larger than the incident wavelength. The word "specular" is Latin for "mirror-like," and it is not uncommon to see a duplicated image deep to the original anatomy on the opposite side of the specular reflector. The artifact occurs because sound strikes a strong reflector and bounces back and forth before returning to the transducer. The result is a duplication of the tissue on the other side of the mirror-like interface, deep to the original tissue. If the surface is flat, the mirror image is more true. If the reflector is curved, the mirror image will be distorted (Fig. S37-1).

An interface that frequently causes a mirror-image artifact is air, which reflects approximately 100% of the incident sound (Fig. S37-2). Therefore, mirror-image artifacts are commonly seen at strong interfaces, for example, at the lung in upper extremity venous or arterial examination or at the junction of the abdomen and chest. Bone or even a bright vessel wall may also create a mirror image.

Mirror-image artifacts also occur in color Doppler (Fig. S37-2) and spectral Doppler (Figs. S37-3 and S37-4). The subclavian vein or artery is often duplicated below the pleura (Fig. S37-4). The artifact is always the deeper structure (Figs. S37-2 and S37-4).

Doppler mirror-image artifacts can often be corrected by moving away from a 90-degree angle or reducing the acoustic output (power).

References

Kremkau F. *Sonography Principles and Instruments*. 8th ed. St. Louis: Elsevier; 2011.

Rubens DJ, Bhatt S, Nedelka S, Cullinan J. Doppler artifacts and pitfalls. *Radiol Clin North Am*. 2006;44(6):805–835.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 19–21.

Acknowledgment

Special thanks to Traci B. Fox, EdD, RT(R), RDMS, RVT, for preparation in this case.

CASE 38

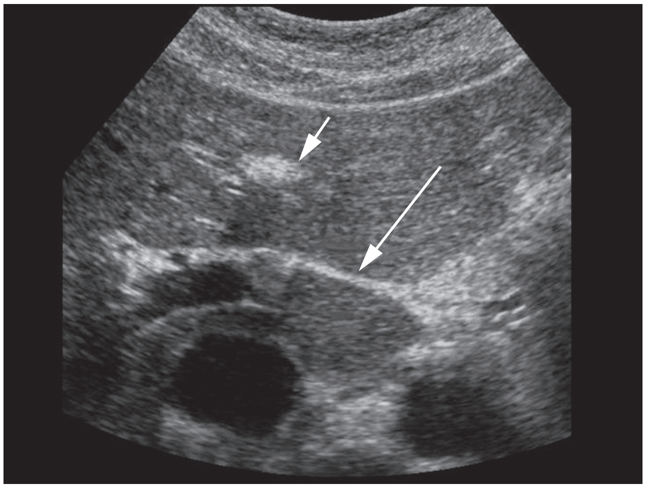

Figure 38-1

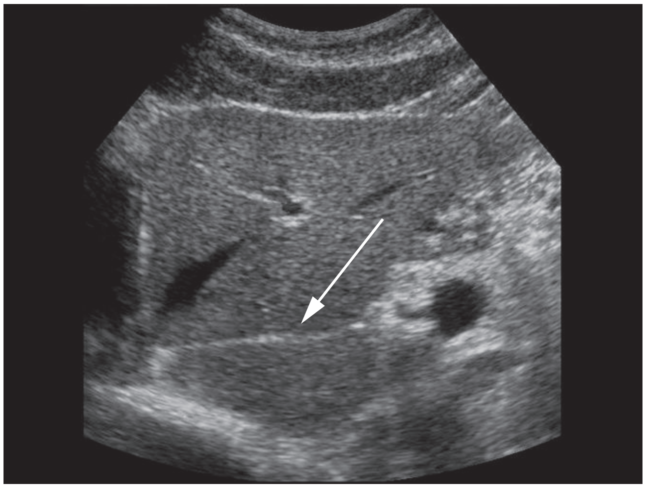

Figure 38-2

HISTORY: A 25-year-old female presented with right upper quadrant pain. These axial (Fig. 38-1) and longitudinal (Fig. 38-1) images of the liver were obtained.

1. The short arrow pointing to an echogenic lesion in the liver in Figure 38-1 most likely correspond to which one of the following?
   A. Focal fatty infiltration of the liver
   B. Hemangioma of the liver
   C. Hepatocellular carcinoma
   D. Ligamentum teres

2. Using Couinaud's segmental anatomy of the liver, which of the following landmarks anatomically separates the right and the left lobe of the liver?
   A. Right hepatic vein
   B. Middle hepatic vein
   C. Left hepatic vein
   D. Right portal vein

3. The caudate lobe is defined as segment 1 and is demarcated by all of the following structures EXCEPT:
   A. Ligamentum venosum.
   B. Portal vein.
   C. Inferior vena cava.
   D. Middle hepatic vein.

4. All of the following statements concerning segment 8 of the liver are true EXCEPT:
   A. The medial margin is defined by the middle hepatic vein.
   B. The right hepatic vein defines the more posterior margin of segment 8.
   C. The left hepatic vein defines the more superior margin of segment 8.
   D. Portions of the anterior segment branch of the right portal vein supplys segment 8.

See Supplemental Figures section for additional figures and legends for this case.

CASE 38

Normal Anatomy of the Liver

1. **D.** There is fat surrounding the ligamentum teres in this typical location that should not be confused with a pathologic finding. Certainly, other considerations including cavernous hemangioma of the liver, liver metastasis (MET), or hepatocellular carcinoma could be considered, but not in this typical location.
2. **B.** This is the correct answer as the middle hepatic vein divides the right and left lobes of the liver. This plane runs through the inferior vena cava to the gallbladder fossa.
3. **D.** This is an incorrect answer. The middle hepatic vein divides the liver into a right and a left lobe. This does not define the border of the caudate lobe.
4. **C.** This is a false statement as the left hepatic vein divides the left lobe of the liver to the more lateral segment (2 and 3) from the medial segment (4A and 4B) (Fig. S38-3).

Comment

Differential Diagnosis

The differential diagnosis in this case is fairly straightforward. All the choices in Question 1 may appear as echogenic masses. Hemangiomas of the liver appear echogenic as does focal fatty infiltration of the liver. Also, some hepatomas appear echogenic, especially those hepatomas that contain fat. However, given this precise anatomical location, this echogenic region represents fat surrounding ligamentum teres, which divides segment 2/3 from segment 4A/B, in the left lobe of the liver.

Ultrasound Findings

Couinard developed an anatomical classification of the segmental anatomy of the liver. Segment 1 is the caudate lobe, which is located posteriorly. It is bounded by the portal vein anteriorly and the inferior vena cava posteriorly. The medial boundary is ligamentum venosum (long arrow) (Figs. S38-1 and S38-2). The right lobe of the liver is separated from the left lobe of the liver by an anatomical plane that extends from the middle hepatic vein to the gallbladder fossa. Within the left lobe of the liver, the ligamentum teres divides segment 2/3 from segment 4 A/B. The left hepatic vein defines the more medial (segment 4A/B) from its lateral segment 2/3 of the left lobe. The right hepatic vein divides the more anterior segment 5/8 from the more posterior segment 6/7 (Fig. S38-3).

Prognosis/Management

Liver anatomy is important for surgical resection. Precise anatomical planes can be utilized by the surgeon for resection of liver tumors or for potential living donor liver transplantation. With liver transplantation, precise liver volumes are needed to ensure both the donor and the recipient have enough liver volume to maintain good hepatic function.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 51–54.

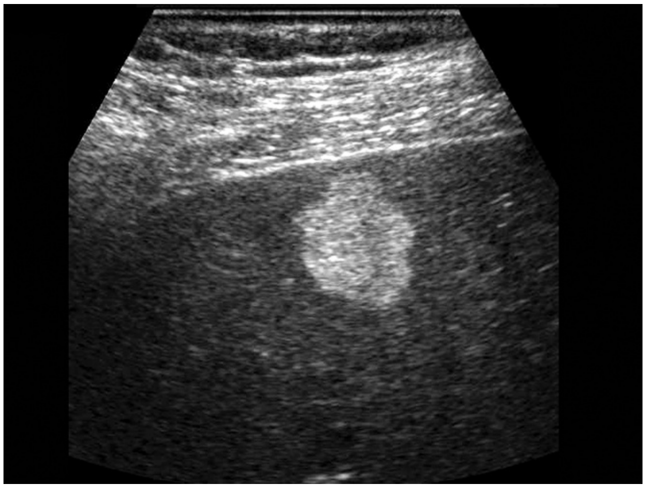

Figure 39-1

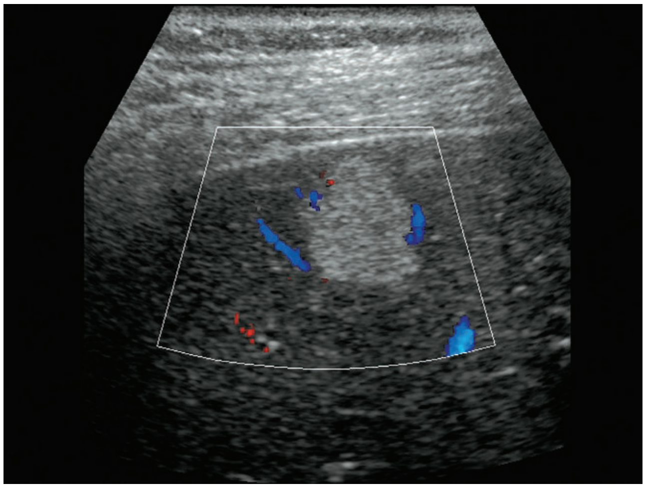

Figure 39-2

HISTORY: A 55-year-old male presents with upper abdominal pain and this ultrasound.

1. Which of the following would be most likely in the differential diagnosis for the imaging findings presented in Figures 39-1 and 39-2? (Choose one.)
   A. Hepatocellular carcinoma (HCC)
   B. Liver metastases
   C. Biliary cystadenoma
   D. Cavernous hemangioma
   E. Focal fatty infiltration
2. Which of the following ultrasound features of a cavernous hemangioma is NOT commonly encountered?
   A. Echogenic mass
   B. Usually less than 3 cm
   C. Usually sharp and smooth margins
   D. Common calcifications
3. Concerning ultrasound features of cavernous hemangiomas, all of the following statements are true EXCEPT:
   A. Doppler flow is readily detectable.
   B. With contrast-enhanced ultrasound (CEUS), there is peripheral puddling of contrast.
   C. Hemangiomas are relatively stable with time.
   D. Rarely a hemangioma will change its appearance at a single exam.
4. All of the following statements regarding cavernous hemangiomas are true EXCEPT:
   A. Hemangiomas have a fairly typical appearance of peripheral nodular filling in of contrast with delayed computed tomography (CT).
   B. Hemangiomas have a fairly typical appearance of peripheral nodular filling in of contrast with delayed magnetic resonance imaging (MRI).
   C. Technetium 99m-tagged red blood cell (RBC) scintigraphy can be used to confirm the diagnosis of a cavernous hemangioma.
   D. An ancillary exam (CT, MRI, or tagged RBC scintigraphy) should always be performed in a patient with an echogenic mass suspected of being a hepatic hemangioma.

See Supplemental Figures section for additional figures and legends for this case.

CASE 39

Hepatic Hemangioma

1. **D.** This would be a typical appearance of a cavernous hemangioma and is the most correct answer. However, focal fatty infiltration, HCC, and metastasis could be considered in Figure S39-1. Lack of color flow in the mass is more consistent with cavernous hemangioma (Fig. S39-2).
2. **D.** Calcification is rare. These tumors are well marginated, echogenic, and usually, but not always, small.
3. **A.** Increased Doppler flow is rare as the flow in hemangiomas is slow. Other findings are true. While rare, it has been reported that during the ultrasound exam the hemangioma may become less echogenic.
4. **D.** In a young patient without other malignancy or risk factors, the ultrasound features may be typical and no further work-up is needed. Hemangioma has a peripheral nodular appearance on delayed contrast-enhanced CT or MRI.

Comment

Differential Diagnosis

The differential diagnosis of a well-circumscribed echogenic mass in a young patient is fairly short and most likely a cavernous hemangioma. However, other masses, including fatty infiltration of the liver, may have a similar appearance. Rarely, lesions including HCC or liver metastases should be included in the differential in high-risk patients.

Ultrasound Findings

Typical ultrasound features are of a small (<3 cm), well-demarcated echogenic mass with smooth margins. Borders are usually sharply marginated (Fig. S39-1). Posterior enhancement may occur, but this feature can be seen with other lesions. There is little flow in these masses with color Doppler ultrasound, as they are a tangle of vessels with slow moving blood (Fig. S39-2). However, CEUS may show a typical appearance of peripheral nodular enhancement. This is a similar pattern to that seen with contrast-enhanced CT or MRI (Fig. S39-3). On T2-weighted MRI, these tumors have a characteristic "lighbulb" appearance (Fig. S39-4).

Prognosis/Management

Prognosis is excellent. These are slow growing lesions with no malignant potential. However, some lesions may enlarge and become symptomatic. In patients with massive hemangiomas, surgery or radiofrequency ablation may be considered. Biopsy is rarely needed, and noninvasive imaging usually establishes the diagnosis. Biopsy of suspected cavernous hemangioma is somewhat controversial.

References

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 54–57.

CASE 40

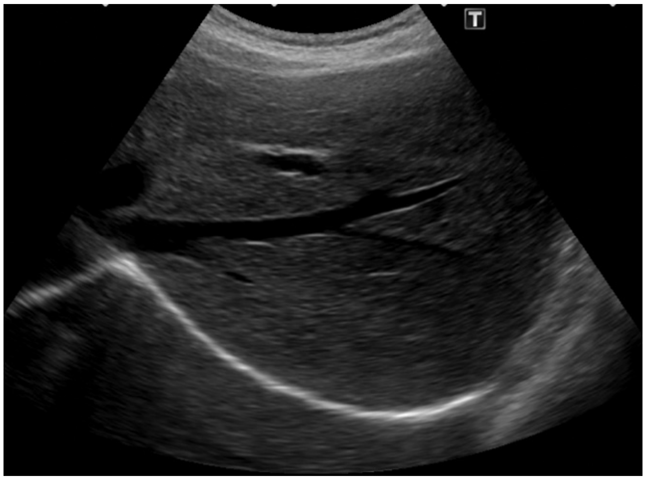

Figure 40-1

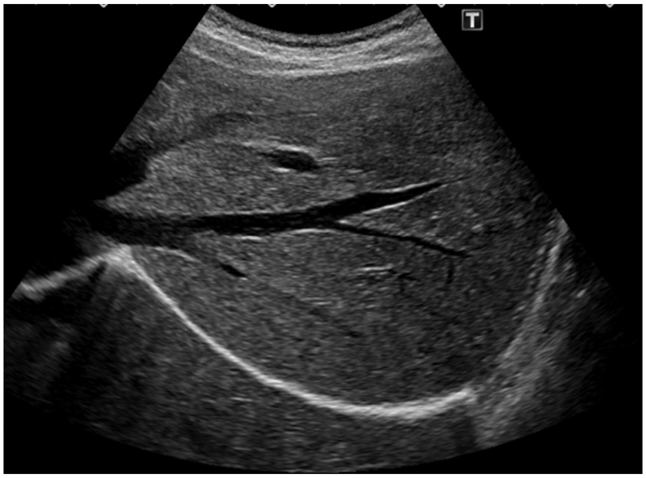

Figure 40-2

HISTORY: A liver survey was done for a hepatitis B carrier. Two gray scale images as part of the abdominal ultrasound were taken seconds apart.

1. What is the difference between the two images?
   A. The time gain compensation was optimized in Figure 40-2.
   B. The frequency was reduced in Figure 40-2.
   C. Tissue harmonic imaging (THI) was used in Figure 40-2
   D. The gain was increased in Figure 40-2.

2. Regarding THI, which of the following is true?
   A. The harmonic signal is produced in the body.
   B. Tissue contrast is decreased.
   C. The beam width is unchanged.
   D. Harmonic frequencies are higher amplitude than fundamental frequency.

3. Regarding the body wall effects, which of the following is true?
   A. They include reverberation, which creates a haze in the near field.
   B. They are not affected by patient size.
   C. They are not reduced by tissue harmonics.
   D. They are eliminated by probe pressure.

4. THI improves all of the following artifacts EXCEPT:
   A. Side lobe artifact.
   B. Shadowing.
   C. Reverberation.
   D. Scatter from the body wall.

See Supplemental Figures section for additional figures and legends for this case.

CASE 40

Tissue Harmonic Imaging

1. **C.** The images look different. Figure S40-2 includes more contrast and fewer near field artifacts, typical of a tissue harmonic image.
2. **A.** The harmonic signal is created in the body from the interaction of tissue with the incoming ultrasound beam. Tissue contrast is increased and the beam width narrower. The harmonic signal has lower amplitude than the fundamental frequency.
3. **A.** The body wall effects include reverberation, which creates a haze in the near field. They are reduced by tissue harmonics and there are more artifacts in a larger patient. Probe pressure will not eliminate the artifacts.
4. **B.** THI improves all of the artifacts except shadowing. Because shadowing is useful to diagnose stones, it is considered a positive artifact. Side lobe artifacts, reverberation, and scatter from the body wall diminish image quality, and they are reduced by THI.

Comment

A traditional ultrasound image is created by the same fundamental frequency that goes into the patient (Fig. S40-1). But, as the sound travels in tissue, the sound beam is altered and additional harmonic frequencies are created. These new frequencies are also reflected back to the transducer, and the ultrasound machine can also create an image based on harmonic frequencies (Fig. S40-2). The harmonic frequencies are half, twice, three times, four times, etc. the fundamental frequency. In practice, the image is created by double the frequency, the second harmonic. The harmonic frequency can be used to create an ultrasound image, which offers several advantages over fundamental images. Harmonic signals are created in the body, and the harmonic image is made from signals traveling from inside the body to the transducer. Some artifacts that are increased by the round trip travel of sound into the body and back to the transducer are reduced using harmonics. This is particularly true of artifacts from scattering and reverberation, especially from the body wall (Figs. S40-2, S40-3, and S40-4).

The harmonic signal is narrower than the fundamental beam and slice thickness, and lateral resolution is improved. Images produced with THI tend to be sharper and have less noise. Cysts are cleaner and shadows more pronounced. Many artifacts are created outside of the main beam, such as side lobes and grating lobes. These are largely eliminated because these weak artifacts have little or no harmonics.

The amplitudes of harmonic signals are weaker than a fundamental signal, and the resultant image has a lower dynamic range. The image is more contrast but has less noise (Fig. S40-2).

References

Choudhry S, Gorman B, Charboneau JW, et al. Comparison of tissue harmonic imaging with conventional US in abdominal disease. *Radiol Soc North Am.* 2000;20(4):1127–1135.

Shapiro RS, Wagreich J, Parsons RB, Stancato-Pasik A, Yeh HC, Lao R. Tissue harmonic imaging sonography: evaluation of image quality compared with conventional sonography. *AJR Am J Roentgenol.* 1998;171(5):1203–1206.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 7–8.

Acknowledgment

Special thanks to Traci B. Fox, EdD, RT(R), RDMS, RVT, for preparation in this case.

CASE 41

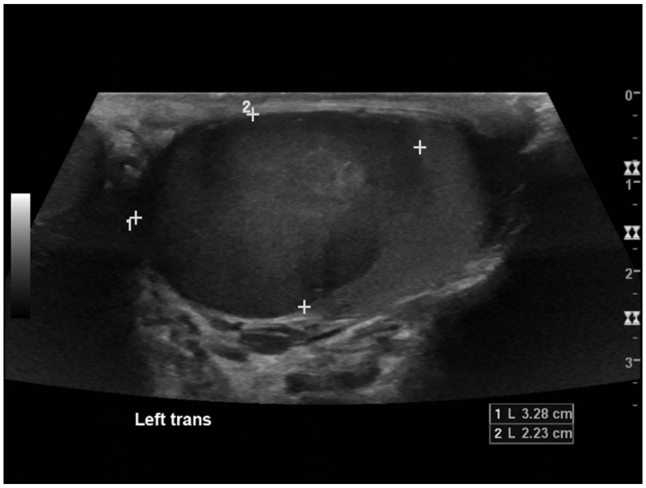

Figure 41-1

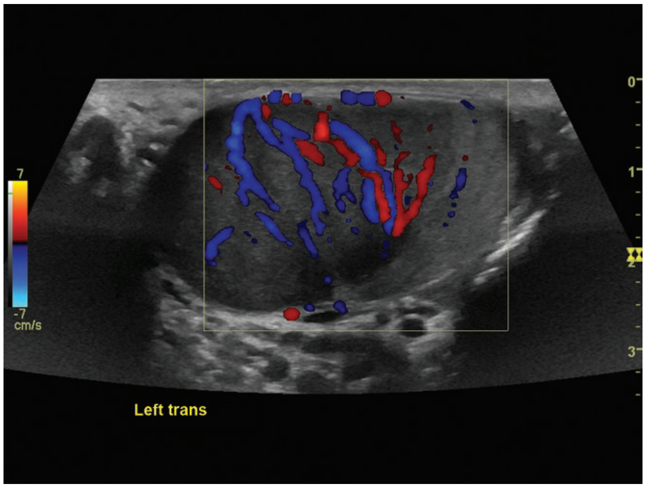

Figure 41-2

HISTORY: A 31-year-old male presents with a palpable testicular mass.

1. Which one of the following would be included in the differential diagnosis for the imaging findings presented? (Choose one.)
   A. Seminoma
   B. Lymphoma
   C. Teratoma
   D. Embryonal cell carcinoma
   E. Nonlymphoma metastasis to the testes
2. What percentage of patients with seminoma has metastases at the time of presentation?
   A. 0%
   B. 25%
   C. 50%
   D. 75%
3. Factors associated with seminoma include all of the following EXCEPT:
   A. Cryptorchidism.
   B. Testicular microlithiasis.
   C. Seminoma in the contralateral testes.
   D. History of recurrent trauma.
4. Concerning the sonographic findings of seminoma, all of the following commonly occur EXCEPT:
   A. Hypoechoic mass.
   B. Increased vascularity.
   C. A homogeneous echo texture.
   D. Calcifications.

See Supplemental Figures section for additional figures and legends for this case.

CASE 41

Testicular Seminoma

1. **A.** Seminomas usually appear as hypoechoic, vascular masses within the testes. While lymphoma of the testis appears as a large testicular mass, it may appear as a small hypoechoic mass replacing part or all of the testes. Nonlymphomatous testicular metastasis may have a variety of appearances and could be considered within the differential. Other germ cell tumors are more heterogeneous in appearance with cystic areas and regions of calcification.
2. **B.** Twenty-five percent of patients with pure seminoma have metastases at the time of presentation.
3. **D.** This is not considered to be a risk factor or associated with the development of seminoma.
4. **D.** The presence of calcifications would be an unusual feature of a pure seminoma. A seminoma occurring with mixed germ cell tumors may have calcifications, but calcification is rare with pure seminomas. A seminoma is usually a hypoechoic mass with increased color flow.

Comment

Differential Diagnosis

Differential for a focal hypoechoic vascular testicular mass is fairly broad. In the right age group of male patients from 25 to 50 years of age, seminoma would be the most likely consideration. Other germ cell tumors seem less likely as often these tumors are inhomogeneous with focal cystic or calcific areas. However, some of the stromal tumors such as Leydig's cell tumors may be small, solid or hypoechoic, and have a similar appearance as a seminoma. A lymphoma can appear as a focal hypoechoic mass within the testes. Often, lymphoma of the testis is much larger and can involve the entire scrotum. There may be other nonmalignant lesions that could have a similar appearance, such as focal orchitis, focal infarct, or a hematoma. An infarct or hematoma would not have increased color flow.

Ultrasound Findings

Typical ultrasound features of a pure seminoma include a fairly uniform mass within the testes. The mass is hypoechoic compared to the rest of the testes. Usually, the echo texture is fairly uniform unless higher resolution transducers are used (Fig. S41-1). Seminomas are solid masses with increased color flow (Fig. S41-2). The contralateral testes should always be examined as there is increased risk of developing a germ cell tumor in the other testis especially when there is underlying etiology such as cryptorchidism.

Prognosis/Management

Orchiectomy is the treatment of choice. A computed tomography scan of the abdomen is helpful to demonstrate if there is para-aortic adenopathy. Of these patients, 25% do have metastases at the time of diagnosis. This tumor is both radiosensitive and chemosensitive. Radiation therapy was previously the standard treatment for patients with clinical Stage I seminoma. Radiation is now known to be associated with increased risks of late side effects including secondary nongerm cell malignancies and vascular disease. Therefore, for Stage I seminomas, close surveillance after orchiectomy is recommended, with treatment reserved for relapse. The overall 5-year disease-specific survival for Stage I seminoma is as high as 99%. In higher grade seminomas, both chemotherapy and/or radiation therapy have been shown to be successful with the long-term side effects of radiation therapy well known but the long-term side effects of chemotherapy not being completely known. The 5-year survival rate at Stage II seminoma with retroperitoneal adenopathy is also very high. As contralateral seminoma may develop, continued surveillance with ultrasound of the remaining testis is warranted.

References

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Resnick MJ, Canter D, Brucker BM, Kutikov A, Guzzo TJ, Wein AJ. A case of synchronous bilateral testicular seminoma. *Nat Clin Pract Urol*. 2008;5(7):397–401.

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Shin YS, Kim HJ. Current management of testicular cancer. *Korean J Urol*. 2013;54(1):2–10.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 154–155.

CASE 42

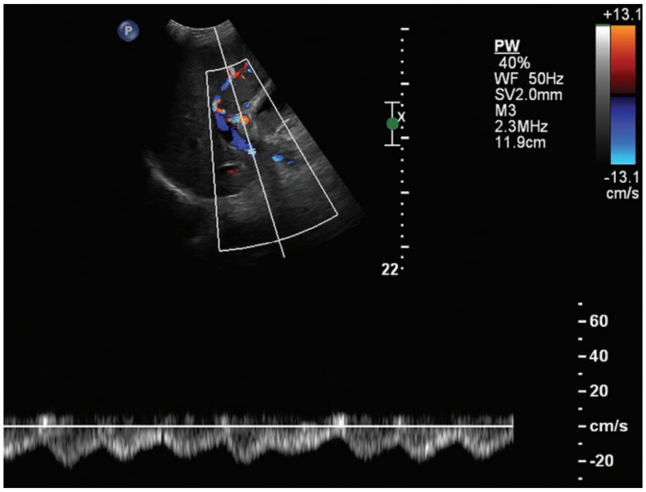

Figure 42-1

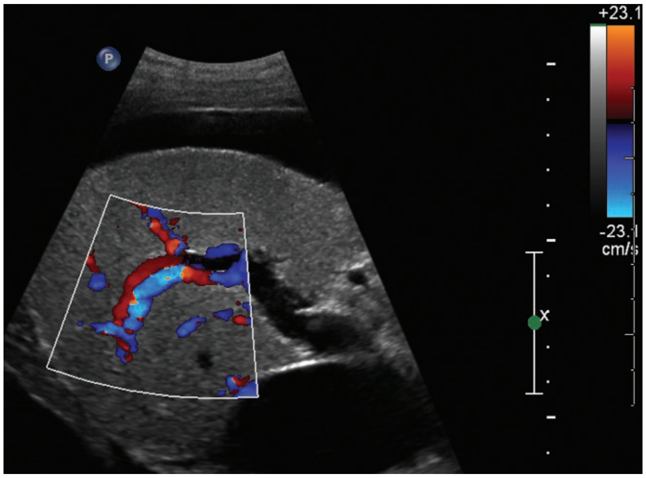

Figure 42-2

HISTORY: A 49-year-old man with known cirrhosis is admitted with decompensated liver disease. Abdominal ultrasound and duplex evaluation of the liver vasculature was performed.

1. What is the most significant finding in Figure 42-1?
   A. Patent portal vein
   B. Hepatofugal portal vein
   C. Hepatic artery stenosis
   D. Blunted hepatic vein
2. In Figure 42-2 of the right lobe, what is the blue vessel in the center of the box?
   A. Right hepatic artery
   B. Right portal vein
   C. Right hepatic vein
   D. Middle hepatic vein
3. Portal venous findings in portal hypertension include all EXCEPT:
   A. Enlarged portal vein.
   B. Low velocity portal vein.
   C. Reversed portal vein.
   D. Pulsatile portal vein.
4. Regarding portal vein flow in cases of portal hypertension, which of the following is true?
   A. Main portal flow may change direction during respiration prior to reversing completely.
   B. Hepatofugal right portal veins usually have reversed main portal veins.
   C. Hepatofugal flow is not seen with Budd-Chiari syndrome.
   D. Proper portal vein flow direction is rare if there is portal hypertension.

See Supplemental Figures section for additional figures and legends for this case.

CASE 42

Hepatofugal Portal Vein

1. **B.** The portal vein is flowing in the wrong direction, hepatofugal flow (Fig. S42-1). The color is away from the transducer and the liver. The spectral Doppler waveform is venous but also flowing away from the liver. Some of the hepatic artery is seen in color, but it is not adequately characterized on this image. The hepatic vein is not seen in this image because the scan is of the porta hepatis.
2. **A.** There are two adjacent vessels so they must be the right hepatic artery and portal vein. The hepatic artery always flows into the liver so it is the blue vessel. The right portal vein is hepatofugal and is red. Hepatic veins do not have a companion vessel.
3. **D.** A pulsatile portal vein is not typical of portal hypertension; it is seen with tricuspid regurgitation and some normals. Portal hypertension findings include a portal vein that may be enlarged due to the increased pressure. As flow through the portals decreases, the velocity in the portal vein decreases. As pressure in the liver increases further, flow in the portal vein may reverse.
4. **A.** As the pressure in portal hypertension increases, the blood flow becomes sluggish or reverses. Prior to reversing there may be flow that goes back and forth with respiration. The most common reason for a hepatofugal right portal vein is a patent paraumbilical vein with hepatopetal, normal direction, main portal flow. In Budd-Chiari syndrome, the main portal vein may become reversed and serve as the liver's venous exit due to the hepatic outflow obstruction. The most common finding in portal hypertension is flow in the proper direction in all of the portal veins.

Comment

Portal hypertension diminishes portal vein flow, leading to lower portal vein velocities. In most cases, the portal flow in the main and segmental portal veins continues to flow into the liver. In extreme cases, the pressure in the liver exceeds the extrahepatic portal vein, and the main portal vein can reverse (hepatofugal flow) (Fig. S42-1). Spectral Doppler demonstrates reversed main portal flow from inside to outside the liver (Fig. S42-1). With a wide sample volume, the portal vein and hepatic artery are on opposite sides of the spectrum (in normal the two both flow into the liver and are superimposed) (Fig. S42-3). Color demonstrates the abnormal color as well (Figs. S42-1 and S42-2).

Before reversal, the portal vein slows down, and it may change direction with normal breathing (bidirectional flow). As the volume flow diminishes, the fewer numbers of red cells and low velocities make detection of flow, particularly by color, difficult (Fig. S42-4). No color flow may be detected despite sluggish flow, which may be detected if contrast-enhanced magnetic resonance or computed tomography is used. Therefore, absence of color should be confirmed as no flow using spectral Doppler and by identifying echoes inside the vein by gray scale.

In some cases, portal hypertension may not affect all parts of the liver equally. One portal vein may reverse while others remain in the correct direction (hepatopetal). This may be lobar (one lobe in the correct direction, the other reversed) or segmental (one or more segments may be reversed with correct direction preserved in others). The main portal vein usually shows correct direction.

A common cause of lobar hepatofugal flow is a recanalized paraumbilical vein. The left portal vein is in the correct direction into the paraumbilical collateral. The main portal vein flow is into the liver, and the right portal vein flow is reversed, all leading to the left portal vein and out of the liver through the paraumbilical collateral.

References

McNaughton DA, Abu-Yousef MM. Doppler US of the liver made simple. *Radiographics*. 2011;31(1):161–188.

Wood MM, Romine LE, Lee YK, et al. Spectral Doppler signature waveforms in ultrasonography. *Ultrasound Q*. 2010;26(2):83–99.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 72–82.

CASE 43

Figure 43-1

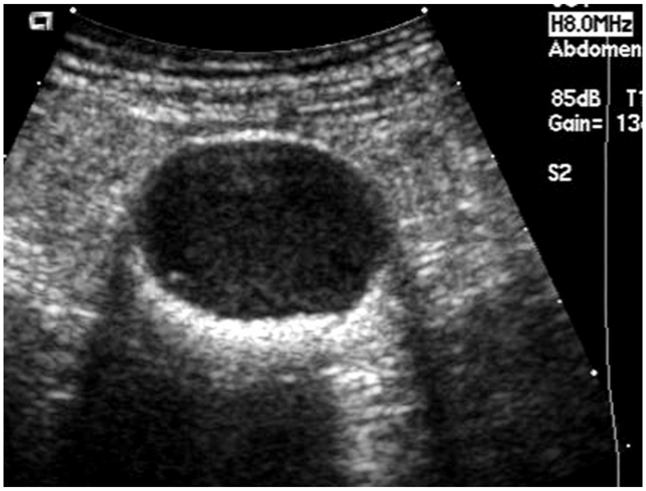

Figure 43-2

HISTORY: Two views of the gallbladder in a 43-year-old with right upper quadrant pain are shown. The scans are taken seconds apart.

1. What is the diagnosis when considering Figure 43-1 as well as Figure 43-2?
   A. Gallbladder sludge
   B. Gallbladder sludge and adjacent bowel
   C. Gallbladder sludge and stones
   D. Normal gallbladder
2. What is the difference between the two images?
   A. Harmonics were in Figure 43-2 but not in Figure 43-1.
   B. Focal zone is correct in Figure 43-2 but not in Figure 43-1.
   C. Frequency was increased in Figure 43-2 but not in Figure 43-1.
   D. Gain was reduced in Figure 43-2.
3. What are the three causes of attenuation?
   A. Absorption, scattering, and reflection
   B. Shadowing, refraction, and tissue composition
   C. Absorption, reflection, and reverberation
   D. Shadowing, inadequate gain, and inadequate power
4. Shadowing can be accentuated by which of the following?
   A. Raising the gain
   B. Lowering the frequency
   C. Using compound imaging
   D. Using harmonic imaging

See Supplemental Figures section for additional figures and legends for this case.

CASE 43

Technical Factors Favoring Shadowing

1. **C.** There are low level echoes in the gallbladder in both images. However, the echogenic material in Figure S43-1 does not shadow and it is not definitive for stone. After adjusting the controls (Fig. S43-2), the echogenic material now shadows, confirming there are stones in the dependent gallbladder as well.
2. **C.** Both images use harmonics. Figure S43-2 doubled the frequency from 4 to 8 MHz (upper right-hand corner). The focal zone and gain were not changed.
3. **A.** The three causes of attenuation are absorption, scattering, and reflection. The others are effects of attenuation or causes of shadowing.
4. **D.** Shadowing can be accentuated by using harmonic imaging. Changing the other controls as described will eliminate or reduce shadowing.

Comment

Shadowing is an artifact that occurs as a result of sound passing through a tissue that has increased attenuation. Attenuation is caused by three processes: absorption, scattering, and reflection. When sound passes through an attenuating structure, like bone, calcified plaque, or a calculus, absorption occurs. With absorption, the resulting sound energy is insufficient to pass through the structure and return to the transducer. The result is a shadow deep to the attenuating structure. A shadow may also result from sound reflecting off of air, in which nearly 100% of the sound is reflected back to the transducer. The strong reflection leaves little to no sound left for transmission into the tissue, and a shadow is produced.

Shadowing is considered a potentially helpful artifact because shadowing can help characterize tissue makeup and identify small calculi that might otherwise be missed (Fig. S43-1). In order to optimally scan for small calculi, the highest frequency transducer should be used, which will allow for adequate penetration. Higher frequency transducers cause more shadowing because they have narrower beams (Fig. S43-2). In addition, the focal zone should be placed in the region of clinical suspicion (Figs. S43-3 and S43-4). Focal zone placement is important because the beam is narrowest at the focal zone. Compound imaging may reduce the conspicuousness of shadows and should be off when shadows are sought (e.g., looking for stones). Tissue harmonic imaging (THI) is another setting that can be used to accentuate shadows. THI produces a narrow beam that enhances useful artifacts such as shadowing while reducing artifacts that degrade the image, such as reverberation and grating lobes.

A nonattenuation cause of shadowing is edge-shadowing, which is a refraction artifact that occurs when sound impinges on a curved surface and is refracted. The sound does not return to the transducer, so no echoes are produced along the original path, causing a shadow.

Reference

Feldman MK, Katyal SK, Blackwood MS. US artifacts. *Radiographics*. 2009;29:1179–1189.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 19–20.

Acknowledgment

Special thanks to Traci B. Fox, EdD, RT(R), RDMS, RVT, for preparation in this case.

CASE 44

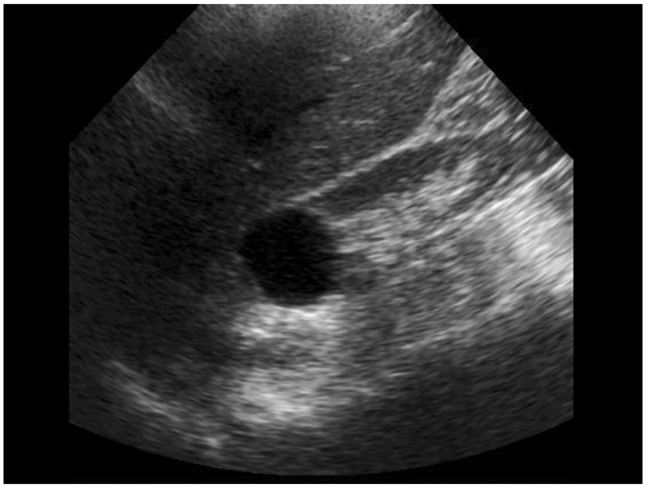

Figure 44-1

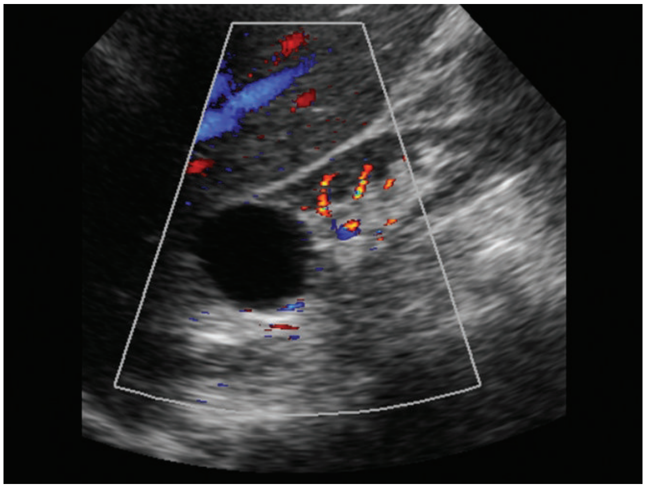

Figure 44-2

HISTORY: A 74-year-old patient presents with generalized abdominal pain. Images of the right kidney are obtained.

1. Differential diagnosis for the ultrasound findings identified in the renal ultrasounds in Figures 44-1 and 44-2 includes which of the following?
   A. Autosomal dominant polycystic kidney disease
   B. Simple renal cyst
   C. Complex renal cyst
   D. Hydronephrosis
2. Which one of the following is most closely associated with increased incidence of simple renal cysts?
   A. Hypertension
   B. Age
   C. Race
   D. Smoking
3. What is the recommended management of simple renal cysts?
   A. Repeat ultrasound in 6 months
   B. Computed tomography (CT)
   C. Magnetic resonance imaging (MRI)
   D. No further management is needed
4. What is the recommended management of complex renal cysts?
   A. No further management is needed
   B. Renal biopsy
   C. Surgical resection
   D. Cross-sectional imaging

See Supplemental Figures section for additional figures and legends for this case.

CASE 44

Simple Renal Cyst

1. **B.** Ultrasound findings of a normal sized kidney with a unilocular, anechoic, round lesion with no internal echogenicity and increased through transmission is consistent with a simple renal cyst. There is no communication with the collecting system to suggest hydronephrosis.
2. **B.** Simple renal cysts have been shown to have a higher incidence in older patients. No strong correlation has been proven to hypertension, race, or smoking.
3. **D.** No further follow-up is required for simple renal cysts.
4. **D.** The differential for complex renal cysts is wide and includes malignant processes. Bosniak II cysts may require ultrasound follow-up. Cross-sectional imaging with CT or MRI is recommended for complex cysts (Bosniak III or Bosniak IV) to direct further management.

Comment

Differential Diagnosis

The differential diagnosis is limited. Simple renal cysts have characteristic features that help distinguish them from other pathologies. The main role of ultrasound in this scenario is to distinguish simple from complex cysts or masses. Differential for a complex cyst includes hemorrhage or infection of a simple cyst, lymphoma, abscess, and a cystic tumor. Another important consideration is hydronephrosis.

Ultrasound Findings

Ultrasound findings characteristic of simple renal cysts are (Figs. S44-1 and S44-2): (1) anechoic, (2) well-defined posterior wall, (3) increased acoustic enhancement/through transmission, and (4) thin walls. Simple renal cysts are relatively common, and their incidence increases with age. The main role of ultrasound is to distinguish simple from complicated cysts. Complicated cysts are characterized by internal debris, thick septations, thick walls, increased vascularity, and thick calcifications. Peripelvic cysts can often resemble hydronephrosis, which can be differentiated by communication with the collecting system. In the case of multiple simple renal cysts, it is important to exclude renal cystic disease; these cysts are classified as category 1 cysts by the Bosniak classification.

Simple renal cysts increase in size by approximately 4% to 6% annually and appear to grow more rapidly in younger patients. Complications are rare but include hemorrhage, infection, and rupture.

Prognosis/Management

Simple renal cysts are benign entities with no further recommended follow-up. However, symptomatic renal cysts may be treated with percutaneous aspiration with or without sclerosis or with open or laparoscopic surgical unroofing.

References

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Israel GM, Bosniak MA. An update of the Bosniak renal cyst classification system. *Urology*. 2005;66(3):484–488 [PubMed].
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Acknowledgment

Special thanks to Behrad Golshani, MD, for preparation of this case.

CASE 45

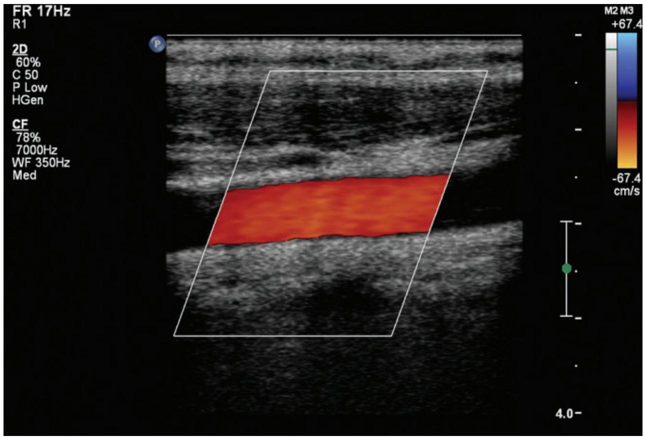

Figure 45-1

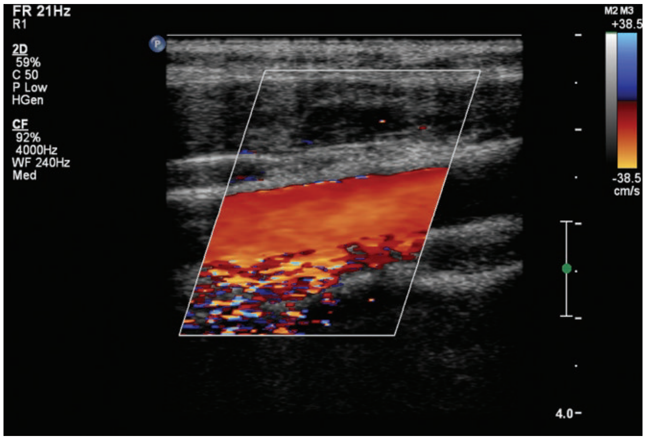

Figure 45-2

HISTORY: Two sagittal images of the common carotid artery in the neck were taken seconds apart.

1. What accounts for the extravascular color in Figure 45-2?
   A. Arterial puncture and bleeding
   B. Pseudoaneurysm filling in systole
   C. Noise
   D. Color recruitment
2. What could be done to improve color filling?
   A. Decrease power.
   B. Decrease gain.
   C. Decrease wall filter.
   D. Change Doppler angle to 60 degrees.
3. What could be done to improve color filling?
   A. Steer color box to the right or left.
   B. Increase power first.
   C. Increase wall filter.
   D. Decrease pulse repetition frequency.
4. With regard to noise, which of the following is true?
   A. It is proportionate to turbulence.
   B. It is first removed by the wall filter.
   C. It fills the entire color box.
   D. It has random colors.

See Supplemental Figures section for additional figures and legends for this case.

CASE 45

Optimizing Color Filling

1. **C.** The color outside the vessel in Figure S45-2 is noise. Tissue vibration would be possible as would a pseudoaneurysm, but the vessel is normal in Figure S45-1. Bleeding does not appear as a color signal. There is no Doppler entity called color recruitment.
2. **C.** Decreasing the wall filter increases color filling by allowing lower velocities to be colorized, but it may lead to excessive color from vessel wall and transducer motion. Filling increases with increased power, increased gain, and a lower Doppler angle.
3. **D.** Decreasing the pulse repetition frequency (typically decreasing the scale) improves sensitivity to low flow. A color box straight down from the transducer may or may not have an adequate Doppler angle. Steering the box toward one side may improve the Doppler angle, but it may actually decrease the signal. Gain is increased before power to try to minimize patient exposure. Increasing the wall filter removes low velocity information from the image.
4. **D.** Noise produces random colors. It first fills the black and darker gray areas in the color box and only fills the entire box when the Doppler settings are excessively sensitive. Noise is not caused by turbulence. Gain is usually the first control adjusted when noise is present. The wall filter may be used if gain and power adjustments are not adequate, but it may or may not remove all noise.

Comment

Several factors control the amount of color filling in vessels (Figs. S45-1 and S45-2). Gain is the most common control. Gain gives an overall change to the amount of color and should be optimized to have as much color information without noise (Figs. S45-3 and S45-4). Too little gain (Fig. S45-3) will not fill vessels adequately. Occlusion or narrowed vessels may be misdiagnosed if there is too little color in the vessel.

If gain is too high, artifacts will be introduced (Fig. S45-2). Excessive gain will cause color to bloom beyond the vessel walls and can overwrite conditions such as plaque or thrombus. Some describe the color outside of the vessel lumen as color "bleeding." Too much gain can also introduce noise or random colors in the image in the soft tissue.

Color filling is optimized by evaluating the image as the gain is progressively increased. After noise appears, the gain is lowered to just below that threshold.

Other Doppler settings also control the amount of color seen. A scale that is set too high will not colorize low velocities. Other things being equal, a color box that is perpendicular to the transducer face has more color filling than one that is steered if the Doppler angles of both are acceptable. The direction of the color box may be perpendicular to the skin as long as there is an acceptable Doppler angle with the vessel. The wall filter eliminates noise and motion from the vessel wall; it must be set low enough to eliminate these artifacts but not so high as to obscure slow moving flow. Color write priority is a control that sets the gray scale level below which color gets written. Black and grays below the level are dark enough to be interpreted as vessels and can have color pixels placed on them. The white and lighter levels will not be colorized because the machine will interpret those grays as soft tissue. If this is set too low (toward darker shades), color information may be lost. Color noise therefore overwrites darker areas of the image before whiter pixels.

Reference

Rubens DJ, Bhatt S, Nedelka S, Cullinan J. Doppler artifacts and pitfalls. *Radiol Clin North Am*. 2006;44(6):805–835.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 17–19.

Fair Game

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CASE 46

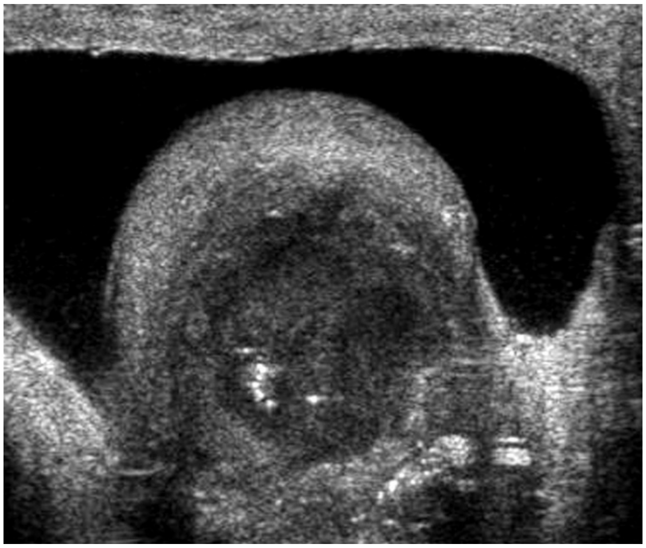

Figure 46-1

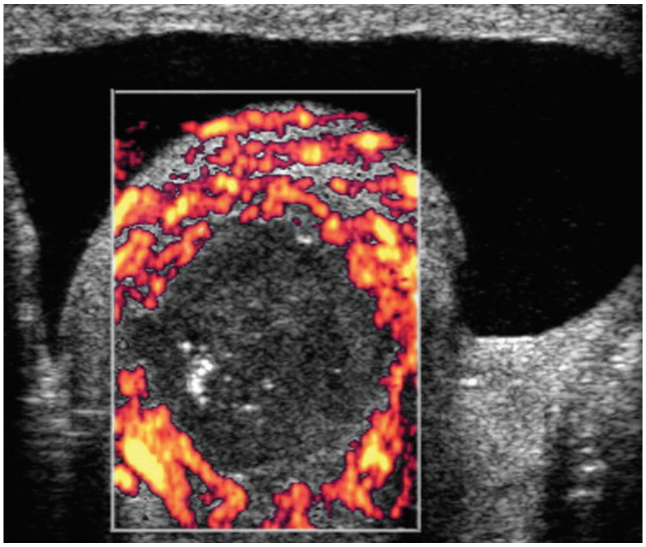

Figure 46-2

HISTORY: A male in his 30s presents with acute scrotal pain.

1. Which one of the following would be included in the differential diagnosis for the gray scale and Power Doppler images in Figures 46-1 and 46-2? (Choose all that apply)
   A. Testicular infarction
   B. Germ cell testicular tumor
   C. Bacterial testicular abscess
   D. Intratesticular hematoma
   E. Tuberculous testicular abscess
2. What is the least common ultrasound appearance of an intratesticular and/or epididymal abscess?
   A. Isoechoic
   B. Hypoechoic
   C. Heterogeneous or mixed echogenicity
   D. Hyperechoic
3. Scrotal abscesses are most commonly secondary to epididymitis. Other common complications of epididymitis include all the following EXCEPT:
   A. Testicular infarction
   B. Intratesticular and/or scrotal abscess
   C. Testicular hematoma
   D. Pyocele/hydrocele
4. What is the most unlikely feature of a testicular abscesses secondary to epididymitis have?
   A. Rim enhancement
   B. Smooth borders
   C. They are often avascular centrally
   D. They have vascular projections into the central portion of the lesion

See Supplemental Figures section for additional figures and legends for this case.

CASE 46

Testicular Abscess

1. **C and E.** Certainly, this is a typical appearance of a testicular abscess of a heterogeneous or hypoechoic, fairly avascular mass with a hyperemic rim and associated hydrocele. Although a tuberculous epididymal abscess would seem rare in the United States, it would have a similar appearance to a bacterial testicular abscess. It is very difficult to discriminate a testicular infarction occurring with epididymitis from a testicular abscess. They often have similar features. A hematoma could be considered.
2. **D.** Hyperechoic lesions would be an uncommon feature of either an intratesticular or an epididymal abscess. Most are either hypoechoic or heterogeneous.
3. **C.** Testicular hematomas would not be a common complication of epididymitis. While most testicular infarction occurs secondary to testicular torsion, in the adult patient, testicular infarction can occur because of complications of epididymitis.
4. **B.** In most testicular abscesses, smooth borders would be uncommon. Irregular borders would be more common. Viable portions of the testis, which are still reactive, may have increased color flow in an otherwise central avascular mass.

Differential Diagnosis

The differential diagnosis is fairly broad in this case. A testicular abscess seems the most common diagnostic consideration. However, testicular infarction secondary to severe epididymo-orchitis should also be considered. These lesions may have a very similar appearance. A hematoma could have a similar feature with a disorganized testis, but there would be a history of trauma. There would be a hypoechoic center corresponding to the hematoma; the rim is usually not as hyperemic, as in this case. Certainly, intratesticular neoplasm must always be excluded. Most germ cell tumors will, in fact, appear solid with hyperemia detected within the mass on either color flow or contrast-enhanced ultrasound.

Ultrasound Findings

Ultrasound findings of an intratesticular abscess are usually that of a hypoechoic or mixed echogenic lesion noted within the testis and/or epididymis. There is often a hyperemic rim. Borders are usually fairly irregular (Figs. S46-1 and S46-2). There is usually associated epididymitis. In addition, hydroceles are very common and pyloceles may occur (Figs. S46-3 and S46-4). Color Doppler sonography may be useful to identify the hyperemic rim in these abscesses. Contrast-enhanced ultrasound has also been advocated to identify and differentiate these abscesses from other masses. Complications of epididymitis include not only abscesses, but also hydroceles or pyloceles, which may be identified with the testicular abscess (Figs. S46-3 and S46-4).

In the United States, most commonly epididymal abscesses and other scrotal abscesses are secondary to *Neisseria gonorrhoeae*, *Chlamydia trachomatis*, *Escherichia coli*, and *Proteus mirabilis*. In other countries, tuberculous epididymitis with its complications from *Mycobacterium tuberculosis* occur. Brucellocis may also be an etiology of epididymitis.

Prognosis/Management

If early in the process, appropriate antibiotic therapy may be curative. However, in severe cases, there may not only be an abscess but also infarction of the testis, and orchiectomy may be required.

References

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Yang DM, Yoon MH, Kim HS, et al. Comparison of tuberculous and pyogenic epididymal abscesses: clinical, gray-scale sonographic, and color Doppler sonographic features. *AJR Am J Roentgenol*. 2001;177(5):1131–1135.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 166.

CASE 47

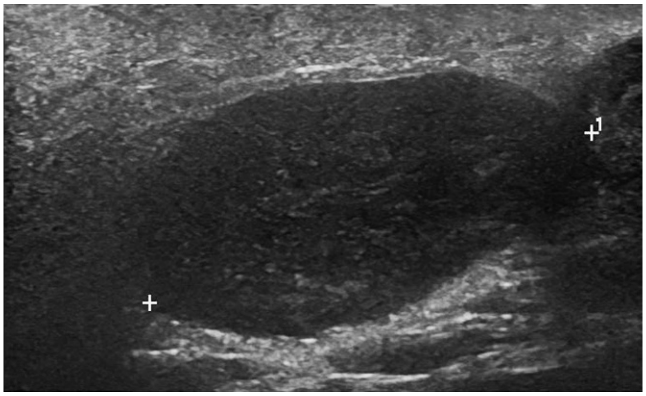

Figure 47-1

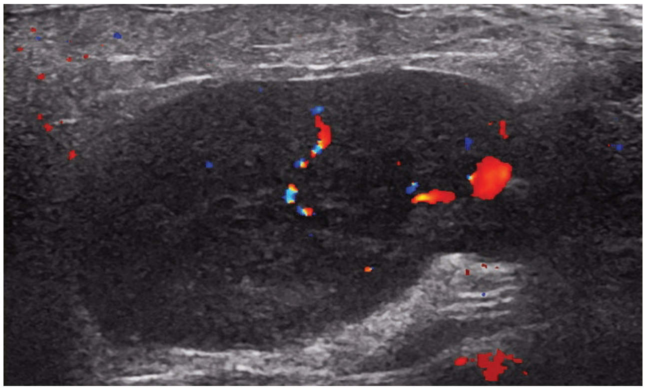

Figure 47-2

HISTORY: A 45-year-old woman presents with a mass in the parotid gland.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply)
   A. Acute parotitis
   B. Parotid duct stone
   C. Pleomorphic adenoma
   D. Warthin's tumor

2. Which of the following is true regarding salivary gland tumors?
   A. The most common benign salivary gland tumor is a Warthin's tumor.
   B. Of all submandibular gland tumors, 60% to 80% are benign, but 50% of parotid gland tumors are malignant.
   C. Lobulated margins have been considered a differential sonographic feature for pleomorphic adenomas.
   D. Pleomorphic adenomas are unilateral, slow-growing, painless masses, and do not undergo malignant transformation.

3. Which of the following is true regarding salivary gland tumors?
   A. Warthin's tumors are benign, solitary, unilateral lesions.
   B. On ultrasound, pleomorphic adenomas are solid, well defined, and hypoechoic.
   C. Warthin's tumors are slow-growing and are more common in women.
   D. Pleomorphic adenomas have a strong association with smoking.

4. Which of the following is true regarding malignant salivary gland tumors?
   A. Adenoid cystic carcinoma is the most common malignant tumor of the salivary glands.
   B. Malignant salivary gland tumors can be differentiated from benign tumors based on gray scale sonographic features.
   C. Malignant salivary gland tumors can be differentiated from benign tumors based on color Doppler; malignant tumors are highly vascular compared to benign tumors.
   D. The prognosis of mucoepidermoid and adenoid cystic tumors is dependent on several factors including tumor histology, age (older), tumor stage, tumor grade, gender (worse in males), presence of pain (nerve involvement), skin and soft tissue infiltration, resection status, and comorbidities.

See Supplemental Figures section for additional figures and legends for this case.

CASE 47

Salivary Gland Tumors

1. **D.** Figure S47-1 shows a homogeneous, hypoechoic lesion in the parotid gland with internal color Doppler flow (Fig. S47-2) consistent with a parotid gland tumor, in this case, a Warthin's tumor. On gray scale ultrasound, Warthin's tumors tend to be well defined and hypoechoic with cystic spaces. However, their sonographic appearance overlaps with other tumors (C).
2. **C.** Lobulation may occur because of tumor growth through defects in the tumor's fibrous capsule; alternatively, lobulations may be due to satellite nodules that merge with the main tumor. However, other salivary gland tumors may have a lobulated shape including malignant tumors. Pleomorphic adenomas are slow-growing, painless, and more common in women. Ten to fifteen percent recur, and if incompletely resected may undergo malignant transformation.
3. **B.** However, there is overlap with the sonographic features of Warthin's tumors. Cystic changes have been reported in pleomorphic adenomas, making differentiation between the two difficult. Cystic areas have also been reported in malignant parotid tumors. Warthin's tumors are slow-growing and more common in men, and are strongly associated with smoking. They can be multifocal and bilateral in 10% to 15% of cases, may recur, and undergo malignant degeneration.
4. **D.** Poorly differentiated tumors have a poor prognosis with 5-year survival rates of 20% to 50%. Mucoepidermoid tumor survival rates depend on the grade of the tumor; low-grade tumors have a 5-year survival rate of 90%, but high-grade tumors, only 50%. Adenoid cystic carcinomas have been reported to have a 5-year survival rate of 60%.

Comment

Introduction

Sixty to eighty percent of parotid gland tumors are benign. Pleomorphic adenomas are the most common and are derived from ductal and myoepithelial cells. Warthin's tumors are composed of epithelial and lymphoid tissue and arise from heterotopic parotid tissue entrapped within parotid lymph nodes. Malignant tumors are uncommon in the parotid gland but account for 50% of tumors in the submandibular gland. The most common is a mucoepidermoid tumor, composed of squamous, mucus-secreting, and undifferentiated small cells. Adenoid cystic carcinoma is composed of ductal and myoepithelial elements and is the second most common malignant tumor. It is slow-growing and tends to invade nerves causing pain and tends to recur and metastasize to liver, lungs, and bone.

Sonographic Findings

Pleomorphic adenomas tend to be hypoechoic, homogeneous, and lobulated; lobulation has been described as a differential feature but can be seen in other tumors. Warthin's tumors tend to be hypoechoic and well defined with cystic spaces. Both have variable degrees of internal vascularity on color Doppler. However, there are overlapping features between the two and between benign and malignant tumors. On ultrasound, malignant salivary gland tumors are often solid or solid-cystic, inhomogeneous, and have ill-defined borders and an irregular shape. However, malignant tumors less than 2 cm may simulate the appearance of a benign tumor. It is also not possible to reliably distinguish benign from malignant tumors on color Doppler. Because of an inability to make a definitive diagnosis based on ultrasound findings, ultrasound-guided fine needle aspiration should be performed.

Treatment

Surgery is the primary treatment for salivary gland tumors. If benign, a superficial parotidectomy is performed, especially if the tumor is small and in the parotid tail, as most pleomorphic adenomas are. This approach spares potential injury to the facial nerve. Complete excision is the treatment for malignant salivary gland tumors. Malignant parotid gland tumors are treated with a conservative total or subtotal parotidectomy, sparing the facial nerve, and level I to V lymph node dissection if clinical or radiologically detected nodes are present or the tumor is high-grade. Adjuvant radiotherapy is indicated for poorly differentiated tumors. Chemotherapy is indicated for palliative treatment.

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Ettl T, Schwarz-Furlan S, Gosau M, Reichert TE. Salivary gland carcinomas. *Oral Maxillofac Surg*. 2012;16:267–283.

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Zengel P, Schrotzlmair F, Reichel C, Paprottka P, Clevert DA. Sonography: the leading diagnostic tool for diseases of the salivary glands. *Semin Ultrasound CT MR*. 2013;34:196–203.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 246–247.

CASE 48

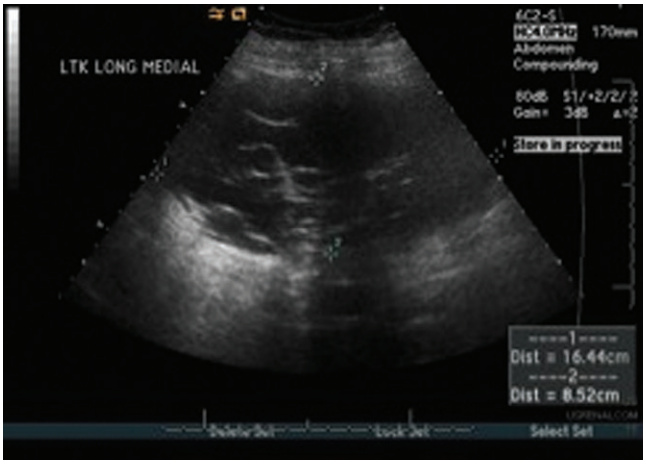

Figure 48-1

Figure 48-2

HISTORY: A 69-year-old female is found to have a 15 cm left renal mass identified on computed tomography (CT) abdomen and ultrasound during work-up and staging for known endometrial cancer.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented in Figure 48-1? (Choose all that apply)
   A. Metastasis
   B. Multilocular cystic nephroma (MCN)
   C. Renal cell carcinoma (RCC)
   D. Abscess
2. What is the next step in management of this patient?
   A. Conservative management
   B. Chemotherapy and/or radiation
   C. Referral for surgical excision
   D. Antibiotics
3. This lesion is more commonly found in which of the following?
   A. Adult men
   B. Adult women
   C. Elderly women
   D. Young girls
4. MCNs typically present as which of the following?
   A. Solitary and unilateral
   B. Multifocal and bilateral
   C. Multifocal and unilateral
   D. Solitary and bilateral

See Supplemental Figures section for additional figures and legends for this case.

CASE 48

Multilocular Cystic Nephroma

1. **A, B, and C.** The differential diagnosis includes cystic metastasis, MCN, and cystic RCC. MCN and cystic RCC are often indistinguishable based on clinical and imaging findings.
2. **C.** Referral for surgical excision is the next step in management, as cystic RCC and MCN are often indistinguishable by imaging. Chemotherapy and/or radiation, as well as antibiotic treatment or other conservative measures, are not part of the treatment strategy for either cystic RCC or MCN.
3. **B.** There is a biphasic age distribution for MCN, typically affecting young males between the ages of 3 months and 4 years, and women between the ages of 40 and 60 years.
4. **A.** MCNs are typically unilateral and solitary. Size ranges from a few centimeters to over 30 cm, and can occasionally replace the entire kidney.

Comment

Differential Diagnosis

Differential considerations for a multicystic renal mass in an adult include a complex cyst, MCN, and cystic RCC. MCN and multicystic dysplastic kidney are in the differential. In children, solid tumors such as Wilms' tumor would be less likely.

Ultrasound/Imaging

MCN is a rare, nonhereditary, benign neoplasm of the kidney. This entity is typically unilateral and solitary. There is a biphasic age distribution, most commonly seen in young males aged 3 months to 4 years, and women aged 40 to 60 years. Depending on the clinical context, ultrasound is often the first imaging test of choice in patients presenting with abdominal masses, especially children. On ultrasound, MCN appears as a multicystic mass without solid or nodular components (Fig. S48-1). On CT, MCN appears as a well-circumscribed, encapsulated cystic mass with enhancing septations (Fig. S48-2). On magnetic resonance imaging, a multicystic, well-encapsulated mass is commonly seen, with low signal intensity of the internal septa on all pulse sequences.

Management

As it is clinically and radiographically difficult to distinguish between MCN and cystic RCC, it is imperative to refer patients for surgical resection for definitive diagnosis. Other treatment options include percutaneous, laparoscopic, or open surgical ablation with cryotherapy or radiofrequency therapy. Although MCN is considered a benign entity, there have been few cases of coexistent RCC. Local recurrences are extremely rare but have been reported in the literature. These are most often seen following partial nephrectomy.

References

Agrons GA, Wagner BJ, Davidson AJ, Suarez ES. From the archives of the AFIP: multilocular cystic renal tumor in children: fadiologic-pathologic correlation. *Radiographics*. 1995;15:653–669.

Silver IAF, Boag AH, Soboleski DA. Multilocular cystic renal tumor: cystic nephroma. *Radiographics*. 2008;28(4):1221–1225.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 122–124.

Acknowledgment

Special thanks to Pavan Khanna, MD, for preparation in this case.

CASE 49

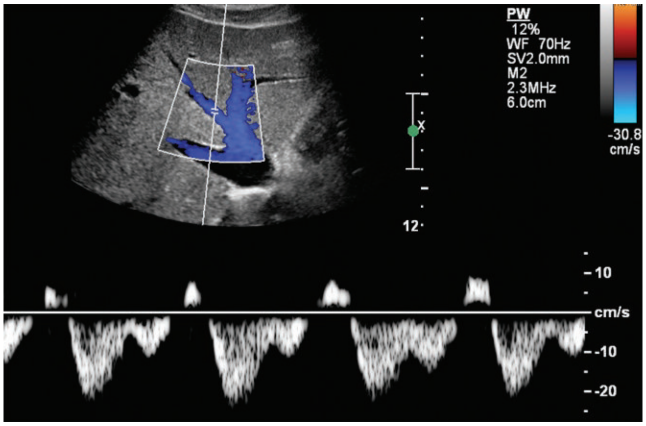

Figure 49-1

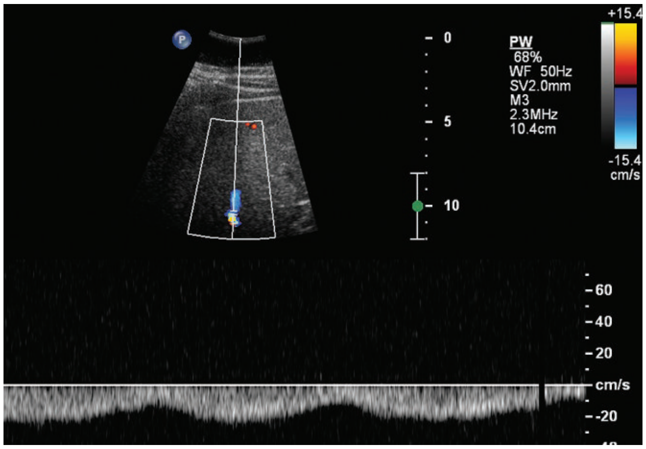

Figure 49-2

HISTORY: Presented are hepatic vein waveforms from two patients.

1. What does the waveform from the hepatic vein in Figure 49-1 indicate?
   A. Tricuspid regurgitation
   B. Cirrhosis
   C. Normal waveform
   D. Technically inadequate waveform
2. What does the waveform from the hepatic vein in Figure 49-2 indicate?
   A. Tricuspid regurgitation
   B. Cirrhosis
   C. Hepatic artery to hepatic vein fistula
   D. Technically inadequate waveform
3. What does an enlarged A wave indicate?
   A. Tricuspid regurgitation
   B. Cirrhosis
   C. Portal vein to hepatic vein fistula
   D. Budd-Chiari syndrome
4. What does a reversal in a single hepatic vein branch indicate?
   A. Tricuspid regurgitation
   B. Cirrhosis
   C. Portal vein to hepatic vein fistula
   D. Budd-Chiari syndrome

See Supplemental Figures section for additional figures and legends for this case.

CASE 49

Normal and Abnormal Hepatic Vein

1. **C.** The waveform from the hepatic vein in Figure S49-1 is within normal limits. There are well defined A, S, and D waves. The A wave is not excessive, which would indicate tricuspid regurgitation. The waveform is not blunted, which would indicate cirrhosis or hepatic venous obstruction. The waveform is technically adequate.
2. **B.** The waveform from the hepatic vein in Figure S49-2 is blunted and is compatible with cirrhosis. The A wave is not enlarged, which would indicate tricuspid regurgitation. There is no arterialization, which would suggest an arteriovenous fistula. The waveform is technically adequate.
3. **A.** An enlarged A wave indicates tricuspid regurgitation. Cirrhosis, portal-hepatic vein fistula, and Budd-Chiari will cause no change or loss of the A wave.
4. **D.** Reversal in a hepatic vein branch indicates Budd-Chiari syndrome. The obstruction in the vein is bypassed via intrahepatic collaterals. Blood flow may be reversed to allow blood to get to these collaterals. Tricuspid regurgitation causes increased reversal during the A wave, but the majority of flow is still to the heart. Cirrhosis has blunted hepatic vein flow, but it still flows out of the liver. Portal-hepatic fistula maintains normal flow direction in the hepatic vein.

Comment

Normal Hepatic Vein Waveforms

The normal hepatic vein spectral waveform has three phases (triphasic pattern): two toward the heart and one away (Fig. S49-1). During ventricular systole, the right atrium has some filling which accounts for the systolic phase (S wave). As the atrium fills, the velocity shows. When the atrioventricular valve opens, the atrium fills during ventricular diastole (D wave). During atrial contraction, the pressure in the right atrium exceeds that in the hepatic vein, which creates the reversed component (A wave).

Abnormal Hepatic Vein Waveforms

The stiffness of the liver in cirrhosis affects the hepatic vein, leading to progressive blunting of the waveform (Fig. S49-2). In milder cases, normal or loss of the A wave is seen. As blunting progresses, the cardiac changes get less pronounced and eventually may become flat. The waveform shape can resemble the portal vein. Processes which obstruct one or more hepatic veins also cause blunted waveforms distally, so the differential includes hepatic vein thrombosis, Budd-Chiari, and inferior vena cava thrombus, which should be distinguished by additional scanning or computed tomography or magnetic resonance angiography.

Doppler Technical Considerations

The normal hepatic vein waveform should be obtained in patients with quiet breathing. A deep inspiration should be avoided because it may blunt normal pulsatility.

Color Doppler in the hepatic vein should show filling of the vein. Inadequate gain may make filling incomplete. Alternatively, too much gain or too little filtering of the cardiac motion may create color outside of the vein (Figs. S49-3 and S49-4).

Duplex Doppler Examination

The liver duplex Doppler evaluation of the hepatic veins should demonstrate the left, middle, and right hepatic veins in one or more color Doppler image. Variants, which are common, should be documented if hepatic surgery is contemplated.

Spectral Doppler waveforms should be obtained in the three hepatic veins also. Waveforms should be compared with one another. If asymmetry in one or more vein is observed, techniques should be optimized so the veins are evaluated with similar breathing and position. Occasionally, a change from supine to decubitus may create a difference in waveform shape as well.

Reference

McNaughton DA, Abu-Yousef MM. Doppler US of the liver made simple. *Radiographics.* 2011;31(1):161–188.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 72–84.

CASE 50

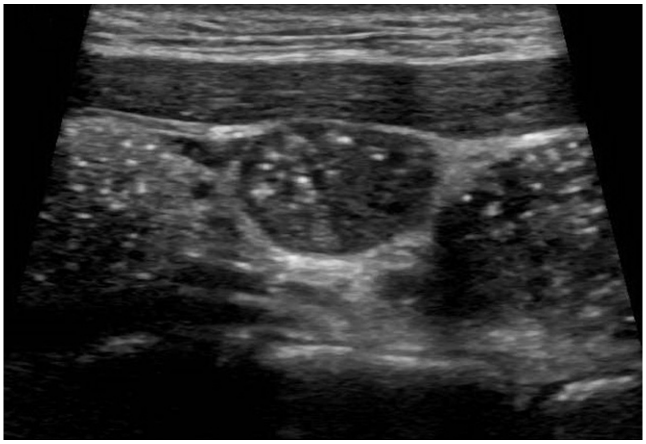

Figure 50-1

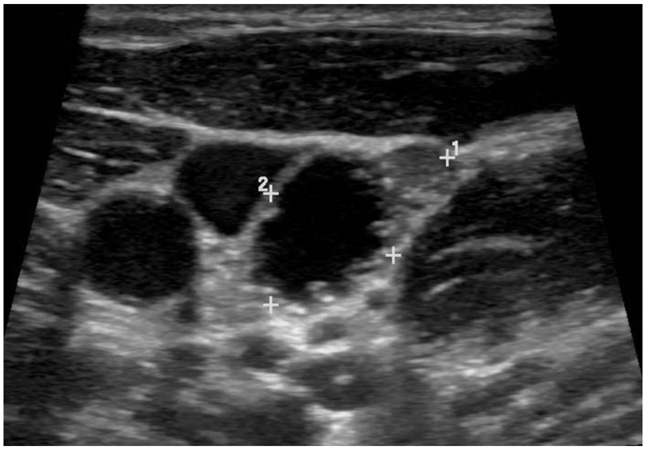

Figure 50-2

HISTORY: A 40-year-old female post thyroidectomy presents with an elevated thyroglobulin.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply)
   A. Normal lymph node
   B. Branchial cleft cyst
   C. Metastatic lymph node from papillary serous carcinoma of the ovary
   D. Metastatic lymph node from papillary thyroid carcinoma
2. What is a sonographic finding of a normal lymph node in the neck?
   A. Presence of a fatty hilum
   B. Peripheral blood flow on color Doppler
   C. Round shape
   D. Cystic areas within the lymph node
3. What is a sonographic finding of an abnormal lymph node in the neck?
   A. A lymph node short axis of less than or equal to 5 mm
   B. Presence of hilar blood flow on color Doppler
   C. Presence of peripheral blood flow on color Doppler
   D. Presence of a fatty hilum
4. Concerning lymph nodes, which statement is true?
   A. Lymph node size is a predictor of metastatic involvement with papillary thyroid carcinoma.
   B. The presence of nonreflecting echogenic foci (microcalcifications) is indicative of metastatic spread of papillary thyroid carcinoma to a lymph node.
   C. Cystic areas are a normal finding in lymph nodes in the neck.
   D. Normal lymph nodes in the neck can be heterogeneous or homogeneous.

See Supplemental Figures section for additional figures and legends for this case.

CASE 50

Lymph Node Metastases in Papillary Thyroid Carcinoma

1. **D.** Figure S50-1 shows a morphologically abnormal lymph node that is hypoechoic and solid with microcalcifications (arrow), findings of a metastatic lymph node from papillary thyroid carcinoma. However, a metastatic lymph node from papillary serous carcinoma of the ovary (C) can also have microcalcifications and should be considered in the appropriate clinical setting.
2. **A.** A normal lymph node typically has a long to short axis ratio of 0.5 or less and is oval or elongated. Level 2 lymph nodes tend to be slightly larger and can be rounder but be normal. Normal lymph nodes have a fatty hilum of variable size.
3. **C.** Normal lymph nodes have hilar blood flow; the artery and vein enter the node through the hilus. Vascular branches then arborize into the lymph node. Blood flow in a metastatic lymph node is peripheral. This occurs because malignant cells enter the node through afferent lymphatic channels on the cortex, grow in the subcapsular sinus, and stimulate angiogenesis and neovascularization.
4. **B.** Microcalcifications are present in approximately 40% to 70% of papillary thyroid carcinomas and have a high specificity but lower sensitivity. One theory states that microcalcifications are caused by expression of a bone matrix protein in papillary thyroid carcinoma.

Comment

Introduction

Papillary thyroid carcinoma is increasing in incidence worldwide, partly due to increasing imaging. The greatest increase is in microcarcinomas in patients greater than 45 years of age. Palpable nodal metastases occur in approximately 30% of patients at presentation. The disease is confined to the neck in 93% to 99% of patients. Preoperative ultrasound is the standard of care for detecting cervical nodal metastases prior to surgery. However, ultrasound is less sensitive for detecting central compartment lymph nodes due to their often small size and location in the tracheoesophageal groove.

Sonographic Findings

At ultrasound, a normal neck lymph node is oval or elongated, is hypoechoic and homogeneous, and has a fatty hilus (which may not be seen in small nodes) and hilar blood flow on color Doppler. A metastatic lymph node from papillary thyroid carcinoma is often round and has a varied appearance (heterogeneous, hypoechoic, or hyperechoic areas). The hilus is absent, and microcalcifications (arrow, Fig. S50-1), cystic areas (arrow, Fig. S50-2), and peripheral flow on color Doppler are often observed. Microcalcifications, cystic change, and hyperechoic areas are the most specific features of metastatic lymph nodes from papillary thyroid carcinoma.

Treatment

Standard treatment for papillary thyroid carcinoma is bilobar resection because of the high incidence of multifocal and bilateral disease, both of which increase the risk of nodal recurrence. It is also well established that abnormal cervical lymph nodes detected on physical examination or suspicious lymph nodes detected with preoperative ultrasound are an indication for therapeutic central or lateral lymph node dissection, or both. It is very controversial as to whether a central lymph node dissection should be performed in the absence of clinically or sonographically detected lymph nodes.

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Cross-reference

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CASE 51

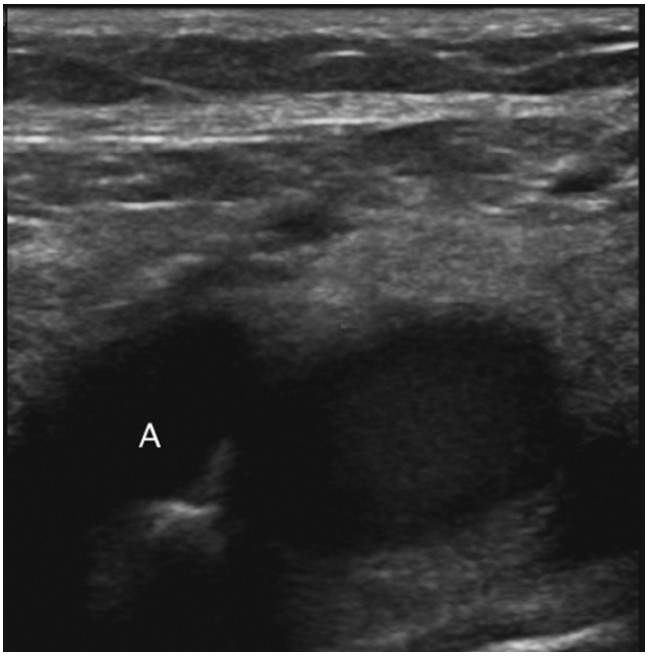

Figure 51-1

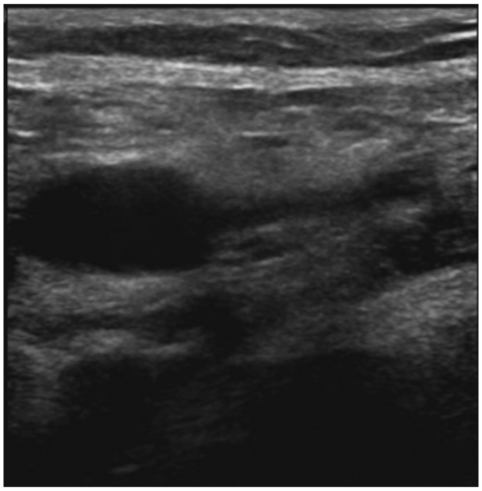

Figure 51-2

HISTORY: A 45-year-old is having a venous ultrasound for varicose veins. Views of the common femoral artery (A) and vein without and with compression during venous duplex examination are obtained.

1. The echoes in the common femoral vein are due to which of the following?
   A. Acute venous thrombosis
   B. Acute venous thrombosis with pulmonary embolism during compression
   C. Residual venous thrombosis
   D. Artifact
2. The artifact in the vein is likely which of the following?
   A. Noise
   B. Reverberation
   C. Rouleaux
   D. Side lobe artifact
3. Regarding noise, which of the following is true?
   A. Noise can be reduced by lowering the depth.
   B. Noise can be reduced by lowering the gain.
   C. Noise can be reduced by turning off compound imaging.
   D. Noise can be reduced by turning off harmonic imaging.
4. Regarding echoes inside vessels, which of the following is true?
   A. Rouleaux have echoes which change over seconds; thrombi have immobile echoes.
   B. Rouleaux and thrombi have echoes which do not change over time.
   C. Reverberation favors the portion of the vein at the side of the vein.
   D. Reverberation is more likely in veins than arteries.

See Supplemental Figures section for additional figures and legends for this case.

CASE 51

Rouleaux

1. **D.** The vein contains mid-level echoes filling the side of the vein (Fig. S51-1). The vein is normally compressible (Fig. S51-2), ruling out acute or residual thrombosis. While a clot which embolized from the compression is possible, it is uncommon compared with artifactual echoes in the vein.
2. **C.** The echoes in the vein are a rouleaux. The echoes are not throughout the artery and vein and noise is not likely. Reverberation favors the anterior aspect of the vessels and is present in the artery in Figure S51-2. Side lobe artifacts do appear in anechoic structures but do not have the shape of this artifact.
3. **B.** Noise can be reduced by lowering the gain. It is unaffected by the image depth. Methods to increase signal to noise include compound imaging and harmonic imaging.
4. **A.** Rouleaux have echoes which move in real time. The echoes change shape and move in the direction of blood flow. The echoes in thrombi do not change in real time. Reverberation is most apparent at the anterior aspect of anechoic structures such as arteries and veins equally.

Comment

Echoes Inside of Vessels Are Common Artifacts

Rouleaux are created by red cell aggregation. Slow-moving or stagnant blood favors aggregation, so the artifact is most apparent in veins and not seen in most arteries. Rouleaux are inconstant, so the echoes move in the image and change shape (Figs. S51-1, S51-2, S51-3). Because this is not a thrombosis, the veins are normally compressible. Augmentation will make the rouleaux disappear during the faster movement of the blood. Rouleaux are not a risk factor for thrombosis although it is seen in slower flow, for example, in a pregnant woman's lower extremity veins.

If rouleaux are found, spectral Doppler should be confirmed to rule out venous obstruction as the cause of the aggregation. The overwhelming number of patients with rouleaux are not obstructed.

Noise, which changes over time, produces random echoes in the image. It is present in anechoic structures such as vessels as well as in soft tissues, but it is most apparent in structures that should have no echoes within them. Random noise can be reduced by lowering the gain. Reduction of gain should not be excessive in order to preserve the diagnostic information in the scan.

Reverberation is an artifact throughout the entire image, but it is frequently apparent in vessels. Ultrasound imaging uses echolocation. The machine sends the sound along a line, and an object in the path produces an echo which returns to the transducer; the echo is placed on the line based on the time it takes to reach the transducer. The reverberation artifact is caused when sound bounces back and forth between echogenic structures in the ultrasound line and these artifactual echoes are also placed in the image. Because it adds time go back and forth, reverberation occurs deeper in the image. The echogenic walls of vessels and cysts are sites that commonly create a strong enough interface to produce reverberation, and the artifact is common in these structures. Reverberation is most marked along their anterior aspects (Figs. S51-4 and S51-5).

Some artifacts, such as side lobe artifacts, can be created if echoes return to the transducer from tissue outside of the line and are incorrectly assigned.

References

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Cross-reference

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CASE 52

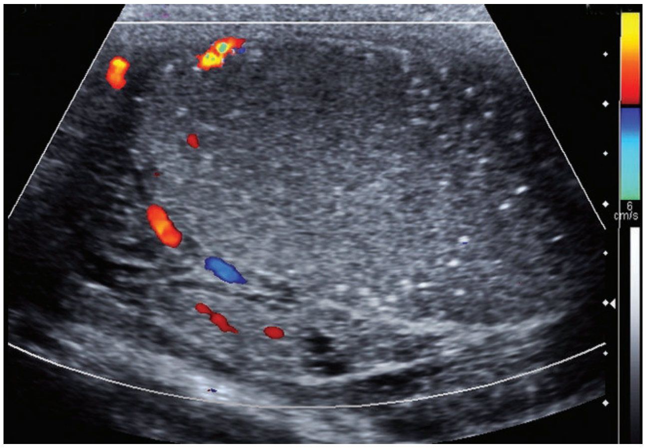

Figure 52-1

Figure 52-2

HISTORY: An 18-year-old male presents with acute onset of left testicular pain.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply)
   A. Orchitis
   B. Epididymo-orchitis
   C. Testicular torsion
   D. Testicular torsion with minimal color Doppler flow
2. Which of the following is true regarding testicular torsion?
   A. A torsion knot is not a very sensitive or specific sign of torsion.
   B. Global absence of testicular flow on color Doppler may be due to epididymo-orchitis.
   C. Torsion occurs in neonates and teenagers but not adults.
   D. The bell clapper deformity is a unilateral deformity.
3. Which of the following is true regarding testicular torsion?
   A. Testicular torsion presents with acute pain and urinary tract symptoms.
   B. The twisted testis has a normal lie in the scrotum.
   C. Viability of the twisted testis can be predicted based on the echogenicity of the testis.
   D. Viability of the testis is independent of the number of cord twists.
4. Which of the following is true regarding testicular torsion?
   A. Patients with intermittent testicular torsion present with recurrent acute scrotal pain that spontaneously resolves.
   B. In the setting of a missed torsion (delayed diagnosis), there will be absence of color Doppler flow in the testis and peritesticular tissues.
   C. The presence of some testicular flow on color Doppler is the most common appearance for testicular torsion.
   D. The acutely twisted testis is small and hyperechoic.

See Supplemental Figures section for additional figures and legends for this case.

CASE 52

Partial Testicular Torsion

1. **D.** Figure S52-1 shows minimal color Doppler flow in the testis (arrow). Figure S52-2 shows a twisted spermatic cord (torsion knot) (arrow). These findings indicate testicular torsion. The arterial waveform in the partially twisted testis can be variable; it may have an increased, decreased, or normal amplitude. Diastolic flow reversal indicates high resistance to flow. C is also true, but D is more correct.
2. **B.** Though rare, testicular infarction can occur from epididymo-orchitis due to venous outflow obstruction from cord edema and inflammation. It is important to obtain a history to determine the cause of the infarction. Sixty-five to eighty percent of cases of torsion occur between 12 and 18 years, but torsion can occur in men less than or greater than 50 years old. Torsion is due to a bell clapper deformity (lack of attachment of the testis to the posterior scrotal wall) and is bilateral in approximately 43% of cases.
3. **C.** A normal homogeneous echogenicity of a twisted testis is a strong predictor of viability at surgery. Testicular viability is dependent on the number of twists and duration of torsion. The salvage rate is 97% to 100% if the testis is untwisted in less than 6 hours, and decreases over time. At 13 to 24 hours, the salvage rate is only 35%.
4. **A.** Intermittent testicular torsion can have multiple appearances on ultrasound depending on the duration and degree of torsion. The testis may appear normal, there may be reactive hyperemia simulating epididymo-orchitis, or the testis may be hypoechoic with areas of infarction.

Comment

Introduction

The differential diagnosis of acute scrotal pain is broad and includes epididymo-orchitis, torsion, testicular fracture, strangulated inguinal hernia, and tumoral hemorrhage. While signs and symptoms overlap, there are distinguishing features. In epididymo-orchitis, pain has a more gradual onset and urinary tract symptoms are present, whereas in torsion, pain is abrupt and nausea/vomiting may occur. On physical exam, the testis has a horizontal lie. A history of recurrent episodes of acute scrotal pain with rapid resolution further supports a diagnosis of torsion.

Sonographic Findings

The epididymis and testis appear normal on gray scale ultrasound when torsion has been present less than 6 hours. After 6 hours, both enlarge and become more hypoechoic/heterogeneous. A torsion knot (arrow, Fig. S52-2) is a very specific/sensitive finding for torsion. If the diagnosis of torsion is missed, the testis becomes small and heterogeneous/hypoechoic due to fibrosis. Color Doppler is very accurate for diagnosing testicular torsion. The most common finding is absence of testicular color Doppler flow. If the diagnosis is delayed, reactive peritesticular hyperemia develops. If torsion is partial, diminished venous and/or arterial flow may be present. The diagnosis of torsion is problematic when torsion is intermittent. Ultrasound can be falsely negative depending on the duration/degree of torsion and the time between the torsion and the ultrasound. The sonogram may appear normal, or reactive hyperemia may simulate epididymo-orchitis. Clinical history, physical exam, and laboratory findings become very important in differentiating between the two.

Treatment

Testicular torsion is an emergency and is treated surgically with detorsion and orchiopexy if the testis is viable. If the testis is not viable, orchiectomy is performed and a prosthesis can be placed into the scrotal sac. Orchiopexy is performed on the contralateral testis due to the high percent of patients with bilateral bell clapper deformities. If the patient can tolerate manual detorsion, an attempt should be made; however, severe pain may preclude manual detorsion. If manual detorsion is successful, orchiopexy should nevertheless be performed.

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Cross-reference

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CASE 53

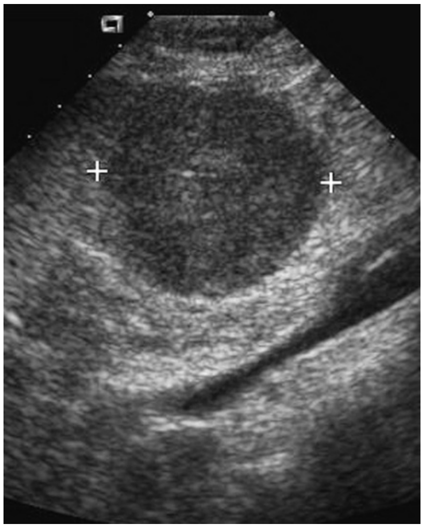

Figure 53-1

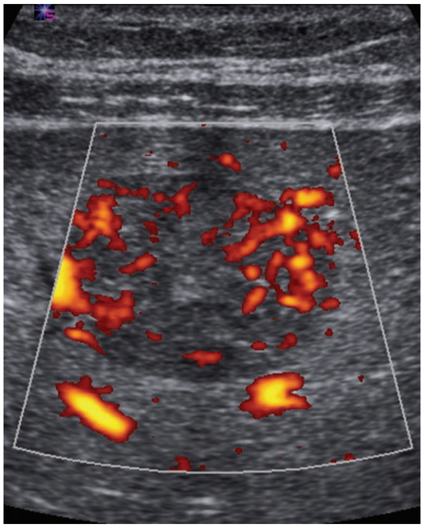

Figure 53-2

HISTORY: A 56-year-old male with hepatitis C presents with a screening ultrasound of the liver.

1. Which one of the following would be included in the differential diagnosis for the imaging findings presented in Figures 53-1 and 53-2? (Choose one)
   A. Hepatic abscess
   B. Focal nodular hyperplasia (FNH)
   C. Cavernous hemangioma
   D. Hepatocellular carcinoma (HCC)
2. Which one of the following is an uncommon finding with HCC?
   A. Focal mass
   B. Dominant mass with satellite mass
   C. Infiltrative mass
   D. Mass with calcifications
3. Hepatomas occur less frequently in patients with which of the following liver diseases?
   A. Hepatitis C
   B. Hepatitis B
   C. Autoimmune hepatitis
   D. Alcoholic cirrhosis
4. Which one of the following is least likely to be a treatment for a 3 cm focal HCC?
   A. Percutaneous radiofrequency ablation (RFA)
   B. Systemic chemotherapy
   C. Surgical resection
   D. Percutaneous microwave ablation

See Supplemental Figures section for additional figures and legends for this case.

CASE 53

Hepatocellular Carcinoma

1. **D.** A hepatic abscess and HCC may appear hypoechoic or echogenic. HCC will have increased vascularity. A bacterial hepatic abscess can have detectable color flow. FNH is often isoechoic with increased color flow. It is usually well encapsulated. Cavernous hemangiomas are most commonly echogenic, but have a variety of appearances, with little detectable color flow.
2. **D.** Of these findings, calcification is the most uncommon feature of an HCC.
3. **C.** While HCC can occur in any of these entities, it is least frequent with autoimmune hepatitis.
4. **C.** Surgery is considered the "gold standard" for treatment of a 3 cm HCC. However, percutaneous focal ablation has shown promising results, while chemotherapy is reserved for advanced disease.

Comment

Differential Diagnosis

The differential diagnosis for a hypoechoic hepatic mass with increased color flow is very broad. In the setting of hepatitis B or hepatitis C with cirrhosis, HCC is a primary consideration. A hepatic adenoma in an otherwise healthy patient, with or without use of steroids, could present with this pattern. A hepatic abscess may be echogenic to hypoechoic and may have increased color flow. A focal hepatic metastasis could be considered. Other tumors such as FNH would seem less likely. A cavernous hemangioma would seem unlikely.

Ultrasound Findings

Sonographic features of HCC vary. They may be hypoechoic (Figs. S53-1 and S53-2) to hyperechoic (Fig. S53-3). Some tumors have mixed echogenicity (Fig. S53-4). Smaller tumors are usually discreet, but larger tumors may have satellite lesions or have diffuse infiltration. This pattern of diffuse infiltration of HCC may be difficult to detect. HCCs usually have increased color flow and eventually invade the portal vein. HCC in the portal vein will expand the vein, and the tumor will have increased color flow. Various ultrasound contrast agents have shown increased detection of HCCs. Focal HCCs have increased uptake and rapid washout of contrast with enhanced ultrasound (CEUS). This is a typical pattern of HCC with CEUS.

Treatment and Prognosis

Treatment depends on the site and location of the tumor, the overall health of the patient, and the severity of cirrhosis. Surgery is the gold standard, but there is a high mortality in resection of HCCs in patients with severe cirrhosis or other comorbidities. In these patients, focal ablation using alcohol, RFA, cryoablation, and microwave ablation have been used with good success. Transarterial chemoembolization (TACE) is another accepted treatment of focal or multifocal HCC. TACE can be combined with focal ablation in the treatment of larger HCCs. Diffuse HCC may be treated by systemic chemotherapy including sorafenib.

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Cross-reference

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CASE 54

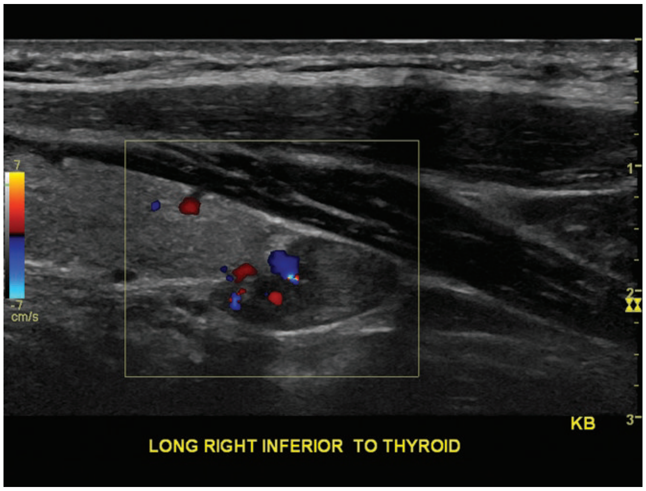

Figure 54-1

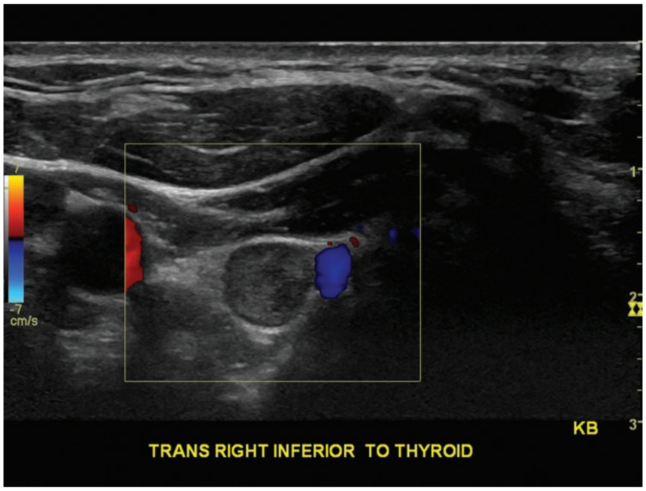

Figure 54-2

HISTORY: A 50-year-old female presents with this ultrasound of the neck.

1. Which one of the following would be the most likely diagnosis for the imaging findings presented in Figures 54-1 and 54-2? (Choose one)
   A. Thyroid adenoma
   B. An abnormally enlarged lymph node
   C. A normal esophagus
   D. Parathyroid adenoma
   E. Carotid sheath tumor
2. Concerning the ultrasound findings of parathyroid adenoma, all of the following statements are true EXCEPT:
   A. They are hypoechoic.
   B. They are most commonly round.
   C. They are often hypervascular on color Doppler.
   D. They are most commonly posterior to the thyroid.
3. Concerning parathyroid adenomas, all of the following statements are true EXCEPT:
   A. There are usually four glands.
   B. Superior glands are located superior to the superior pole of the thyroid.
   C. Most inferior glands are located posterior to the lower pole of the thyroid.
   D. Approximately 10% of the population has five glands.
4. Concerning patients with parathyroid adenomas, all of the following statements are true EXCEPT:
   A. These patients often have elevated calcium levels.
   B. These patients often have elevated parathyroid hormone (PTH) levels.
   C. Advanced cases have excess calcification of the bony cortex.
   D. Advanced cases may be associated with renal stones.

See Supplemental Figures section for additional figures and legends for this case.

CASE 54

Parathyroid Adenoma

1. **D.** A parathyroid adenoma is the most correct answer. However, a posteriorly located thyroid adenoma on a lymph node could be considered.
2. **B.** Most adenomas are not round. Most are oval and elongated in the cranial caudal direction. They are hypoechoic and vascular masses typically located posteriorly to the thyroid.
3. **B.** Most superior glands are posterior to the mid pole of the thyroid. There are usually four glands.
4. **C.** There is subperiosteal bony reabsorption with parathyroid adenomas. They are associated with elevated calcium and PTH levels.

Comment

Differential Diagnosis

A hypoechoic mass located posterior to the thyroid is a typical appearance and location for a parathyroid adenoma in the correct clinical setting. Patients with renal failure may develop secondary hyperparathyroidism with hyperplasia of the glands. A posterior thyroid adenoma may cause confusion and could be considered in the differential. Thyroid adenomas usually can be recognized to be within the thyroid, and may have cystic components. The esophagus lies posterior to the left lobe. By having the patient swallow, air and fluid can be identified in the esophagus. Enlarged nodes are usually lateral to the thyroid and often have an echogenic fatty hilum.

Ultrasound Findings

Parathyroid adenomas are not always where we think they should be. Superior glands are most commonly posterior to the mid portion of the gland. While the majority of the inferior glands lie posterior to the lower pole of the thyroid, they may lie lower in the neck or in a retrosternal location. Rarely, adenomas have been located in the carotid sheath, in the thyroid, and in the thymus. Most adenomas are homogeneously hypoechoic and elongated in appearance (Figs. S54-1 and S54-2). They are often vascular on power or color Doppler (Fig. S54-3). Most adenomas are singular.

Prognosis/Management

The prognosis is usually good when the adenoma is detected. Surgical cure is excellent and associated with low morbidity. Only 1% of adenomas are cancerous. If not detected early or at all, the patient can have bony reabsorption and may develop renal stones. He or she may also develop bubbly bone lesions, "brown" tumors. Secondary hyperparathyroidism results from chronic renal disease.

If ultrasound cannot detect the adenoma, the nuclear medicine sestamibi scan may be useful. In cases where there is difficulty in diagnosing an adenoma, magnetic resonance imaging and computed tomography may also be used, especially when searching for ectopic glands. Some have advocated use of ultrasound-guided aspiration and PTH washout in equivocal cases (Fig. S54-4).

Recently, contrast-enhanced ultrasound has been advocated as helpful in localization of parathyroid glands. Parathyroid adenomas can be associated with multiple endocrine neoplasia Type I with associated pituitary adenomas and pancreatic adenomas.

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Cross-reference

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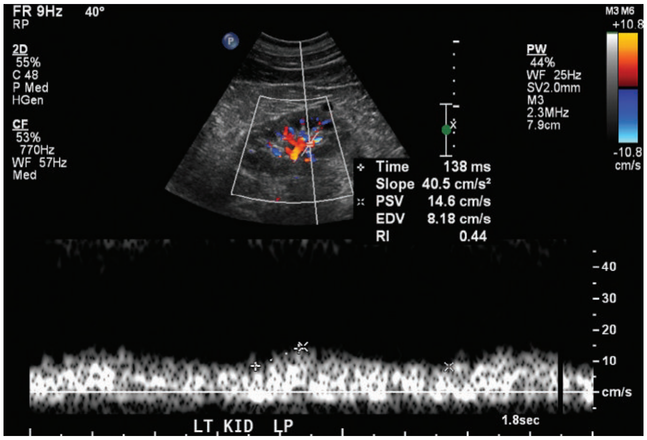

Figure 55-1

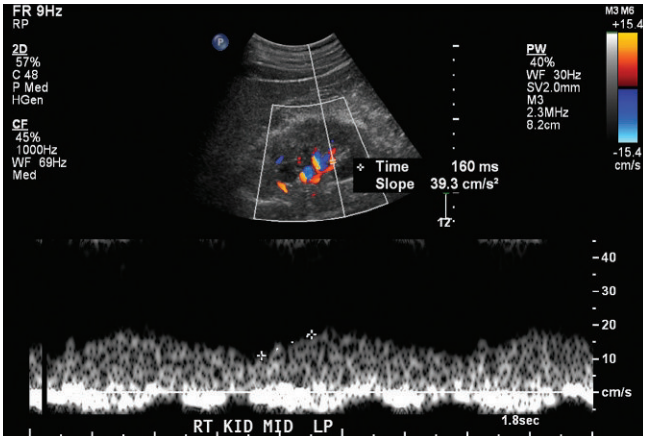

Figure 55-2

HISTORY: The patient is a 24-year-old with newly diagnosed hypertension. Figures 55-1 and 55-2 are part of a duplex Doppler scan of the kidney and renal arteries.

1. What is the most likely diagnosis?
   A. Right renal artery stenosis (RAS) greater than 60%
   B. No RAS
   C. Bilateral renal artery atherosclerosis
   D. Aortic coarctation
2. Regarding the renal acceleration time, which of the following is true?
   A. It is the slope of the waveform from the onset of systole to peak velocity.
   B. It is the time of the notch after peak systole.
   C. It is the time from the onset of systole to peak systole.
   D. It is peak systolic velocity (PSV) minus end diastolic velocity divided by PSV.
3. Renal aortic ratio is calculated by which of the following?
   A. Proximal renal artery PSV divided by aortic PSV
   B. Maximum renal artery PSV divided by aortic PSV
   C. Aortic PSV divided by proximal renal artery PSV
   D. Renal maximal PSV minus aortic PSV divided by renal maximal PSV
4. Regarding renal Doppler criteria for RAS, all of the following are true EXCEPT:
   A. The main renal artery sensitivity depends on the quality of the scan.
   B. Intrarenal waveforms are more specific but less sensitive than main renal criteria.
   C. Main renal artery end diastolic velocities are related to the degree of stenosis.
   D. Intrarenal resistive indices are elevated in RAS.

See Supplemental Figures section for additional figures and legends for this case.

CASE 55

Aortic Coarctation Causing Renal Artery Tardus Parvus Waveforms

1. **D.** There is bilateral, abnormal blunting of the intrarenal waveforms. In a young person, the most likely diagnosis to affect both kidneys is coarctation or fibromuscular dysplasia (FMD). There are right and left changes, so a diagnosis affecting just the right kidney is not correct. Atherosclerosis is unusual in this age group.
2. **C.** Renal acceleration time is the time from onset of systole to PSV. Acceleration is the slope of the waveform. The notch is a sign of a normal waveform; it is not measured. Answer D is the resistive index.
3. **B.** Renal aortic ratio is the highest velocity in the renal artery (typically at a stenosis) divided by the aortic PSV at the level of the renal artery.
4. **D.** Resistive indices are not widely used to diagnose RAS, but they should decrease, not increase, beyond a flow-reducing lesion. Elevated resistive indices may indicate parenchymal renal disease. The quality of the scan affects the reliability of the study. Intrarenal waveforms are more specific but less sensitive than direct scanning of the renal arteries. In RAS, systolic velocity increases first, but diastolic velocity does increase in more severe stenoses.

Comment

Renal Artery Stenosis

RAS is the most common reason for renovascular hypertension. There are two common etiologies: atherosclerosis, which is generally found at the origin of the renal artery, and FMD, which occurs in the mid or distal renal artery or proximal branches. In children, other etiologies should be considered, particularly when both kidneys are affected (Figs. S55-1 and S55-2). Aortic coarctation lowers the pressure beyond the thoracic narrowing and may restrict flow to the kidneys (Fig. S55-3). Midaortic syndrome narrows the aorta in the abdomen and can restrict flow to the kidneys, bowel, and lower extremities. Other causes of renovascular disease in the pediatric population include FMD, neurofibromatosis, and extrinsic renal or renal vascular compression.

There are two ways to diagnose RAS: identifying the stenosis and detecting the high velocity jet in the artery and detecting the tardus parvus waveform in the intrarenal vessels (Figs. S55-1 and S55-2).

Intrarenal Evaluation

Normal arterial waveforms demonstrate an extremely rapid upstroke related to the fast acceleration of blood at the initiation of systole. A number of indices have been described for quantitating if an abnormal tardus parvus, blunted, waveform is present. The two most common are (1) delay to peak: the acceleration time, and (2) delayed acceleration, a slow slope at the early part of systole. The acceleration time is abnormal when it is above 70 to 120 ms. When very delayed—beyond 120 ms—the finding is quite specific.

A third measure, diastole compared to systole, is less widely used. Stenosis is diagnosed by too much diastolic flow producing a lower than normal renal resistive index.

Intrarenal evaluation is less sensitive but more specific than main renal artery evaluation.

Main Renal Artery Duplex Findings

The direct evaluation is most accurate if visualization of the renal artery is adequate by color Doppler. Most groups use a spectral Doppler renal: aortic ratio determined by dividing the peak velocity in the renal artery by the aortic velocity at the level of the renal arteries to determine if the elevated velocity is significant. A ratio of greater than 3.5 is significant. Elevated systolic and diastolic velocities are also used.

Treatment

The value of angioplasty and stenting for atherosclerotic disease has been called into question in some recent large trials. Percutaneous renal angioplasty is generally the treatment for FMD. Correcting a coarctation will reestablish renal blood flow.

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Acknowledgment

Special thanks to Sandeep P. Deshmukh, MD, for preparation in this case.

CASE 56

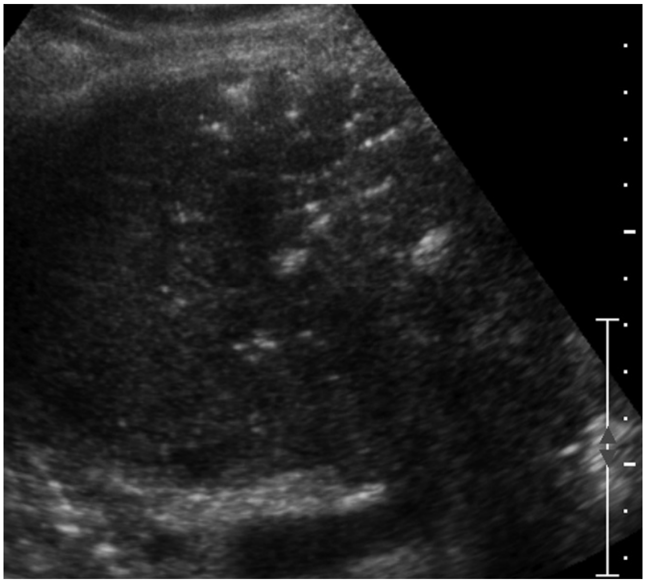

Figure 56-1

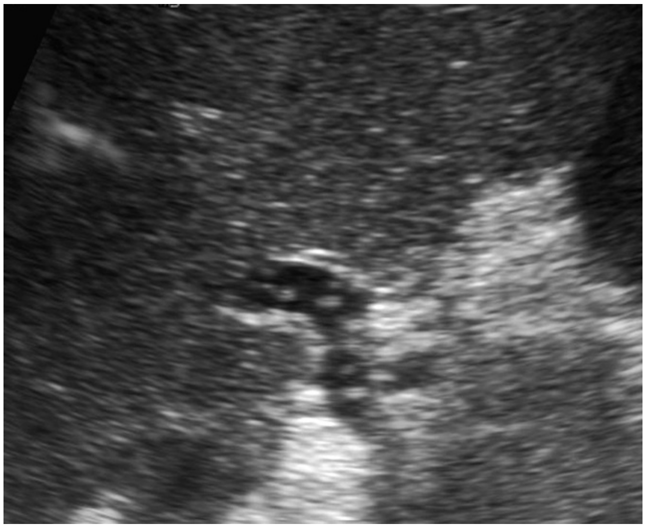

Figure 56-2

HISTORY: The images shown are of two patients with the same ultrasound diagnosis.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented?
   A. Pneumobilia
   B. Multicentric hepatocellular carcinoma
   C. Portal vein thrombosis
   D. Portal venous gas
2. Differentiating pneumobilia from portal venous gas by ultrasound includes which of the following?
   A. Pneumobilia is usually identified in the peripheral liver.
   B. Pneumobilia has mobile echoes.
   C. Portal venous gas has a characteristic spectral Doppler appearance.
   D. Portal venous gas generally has identifiable thick bowel.
3. What is the management of portal venous gas found by ultrasound?
   A. Urgent surgical exploration
   B. Plain radiograph for confirmation
   C. Computed tomography (CT) for detection of the source of gas
   D. No further imaging is warranted
4. Clinical conditions associated with portal venous gas include all of the following EXCEPT:
   A. Ischemic bowel
   B. Inflammatory bowel disease
   C. Childbirth
   D. Enema

See Supplemental Figures section for additional figures and legends for this case.

CASE 56

Portal Venous Gas

1. **D.** There is punctate and rounder areas of hyperechoic areas in the liver (Fig. S56-1) and echoes inside the portal vein (Fig. S56-2) indicating portal venous gas. No liver mass is seen. The gas is peripheral, favoring portal vein gas rather than pneumobilia.
2. **C.** Portal vein gas has a characteristic spike in spectral Doppler (Fig. S56-3). The echoes in pneumobilia are generally central and immobile. Thick bowel may be identified in some, but not all, patients with portal vein gas.
3. **C.** CT is usually performed to help characterize the etiology of portal vein gas. Not all patients will have identifiable gas in the portal vein because ultrasound is extremely sensitive. Surgical exploration is warranted for some, but not all, patients. Surgery, instead of further imaging, may be performed if there is ischemic bowel and for sicker patients. But many patients have a benign etiology and expectant management is warranted. The plain radiograph is less accurate than ultrasound.
4. **C.** Childbirth is not associated with portal vein gas. The others are associated.

Comment

Clinical Overview

Originally considered a uniformly ominous sign, portal venous gas is now identified in a wide variety of patients, from critically ill to asymptomatic. The management depends on the etiology of the gas. Bowel ischemia remains the most common single cause, and aggressive surgery for this is the standard. Ischemia has mortality rates greater than 50%. Benign portal venous gas can be handled with conservative management with virtually no morbidity. A third group consists of those with a variety of conditions including infections, bowel distension, and gastric ulcers who are at intermediate risk. Aggressive monitoring and early surgical intervention are recommended in this group if the clinical condition deteriorates or at any time ischemia is suspected.

Other causes of pneumatosis include diverticulitis, inflammatory bowel disease, enemas, colonoscopy, chemotherapy, steroids, and liver transplantation. Both ulcerative colitis and Crohn's disease are associated with portal venous gas.

Because of the heterogeneity of patients, imaging findings alone should not determine the clinical management. Management requires proper identification of the etiology, and, particularly if bowel ischemia can be excluded, more conservative management may be warranted.

Ultrasound Findings

Gas is one of the strongest reflectors of ultrasound, and even a small amount creates a bright echo. Gas in the portal vein and its branches are identified in gray scale as punctate echogenic foci that move in the blood (Fig. S56-2). The gas can accumulate and a dot, more linear or fluffy echogenic areas are seen in the nondependent peripheral liver (Fig. S56-1).

Gas on spectral Doppler may be seen as bright areas inside the portal venous waveform. A characteristic spectral Doppler appearance is seen when the gas produces a narrow bright spike that appears on both sides of the waveform (Fig. S56-3).

Gas in the biliary system is also echogenic, but it tends to be in the central portion of the liver and common duct. The gas is typically immobile and can usually be differentiated from portal vein gas.

Other Tests

The determination of the etiology of portal venous gas should be sought if immediate surgery is not indicated. Ultrasound may detect bowel thickening and suggest an etiology, but CT is frequently necessary and it is a good tool to evaluate for a variety of benign and more ominous causes. Ultrasound is more sensitive to gas than plain films and at least equal to CT. Not seeing portal venous gas on these tests after identification on ultrasound should not alter this diagnosis.

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Cross-reference

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CASE 57

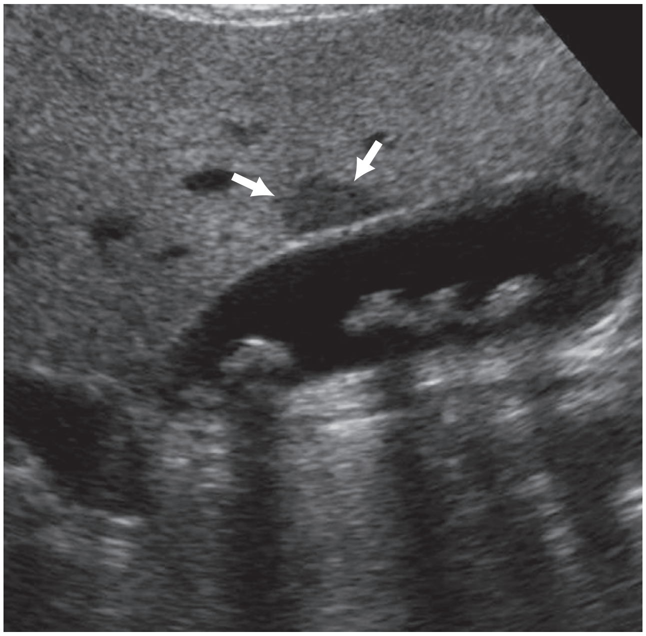

Figure 57-1

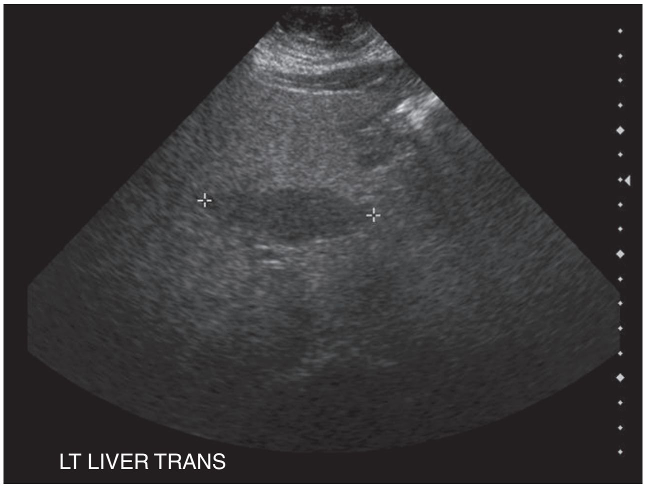

Figure 57-2

HISTORY: Two patients present for routine abdominal ultrasound with these findings. The patient in Figure 57-1 presents with right upper quadrant pain and with a hypoechoic area adjacent to the gallbladder. The patient in Figure 57-2 also presents with abdominal pain and a region identified in the left lobe of the liver.

1. Which one of the following would be included in the differential diagnosis for the imaging findings presented in Figures 57-1 and 57-2? (Choose one)
   A. Metastatic liver disease
   B. Hepatocellular carcinoma
   C. Diffuse fatty infiltration of the liver with focal fatty sparing (FFS)
   D. Hepatic abscess
   E. FFS
2. A typical location for focal sparing of the liver in a liver with diffuse fatty infiltration is:
   A. Segment 1 of the liver
   B. Segment 4 of the liver
   C. Segment 2 of the liver
   D. Segment 8 of the liver
3. Typical findings of focal sparing in a liver with diffuse fatty infiltration include all the following EXCEPT:
   A. Usually has no mass effect
   B. Is usually not spherical
   C. May change dramatically on short-term follow-up
   D. Is surrounded by a rim of hyperemia on color flow
4. What would be the one most definitive test to help diagnose focal sparing of the liver?
   A. Ultrasound
   B. Radionuclides of liver/spleen sonography
   C. Single phase contrast-enhanced computed tomography (CT) scan
   D. Magnetic resonance imaging (MRI) with chemical shift imaging

See Supplemental Figures section for additional figures and legends for this case.

CASE 57

Fatty Infiltration of the Liver with Focal Sparing

1. **C.** Certainly, in Figure S57-1, diffuse fatty infiltration with an area of focal sparing would be the most likely consideration. For Figure S57-2, this could be considered, but with less certainty. A hepatic abscess or an unusual metastasis could be considered for Figure S57-2.

2. **B.** It is common to have FFS in segment 4 of the liver immediately anterior to the portal bifurcation.

3. **D.** This is not a true statement. In fact, vessels may be noted to course through a large area of FFS of the liver, which itself has no mass effect.

4. **D.** MRI with chemical shift imaging (in-and-out-of-phase) would be very helpful in establishing the diagnosis. There would be a drop off of the signal in the out-of-phase imaging in the entire liver except for the portion in which there was FFS. Thus, this region would be hyperintense on the out-of-phase image compared to the rest of the liver (see Figs. S57-3 and S57-4). A noncontrast CT would also be helpful.

Comment

Differential Diagnosis

The differential diagnosis is fairly broad. Certainly, a hypoechoic mass within an echogenic liver may be FFS. This would be a fairly easy diagnosis in Figure S57-1, in which there is focal sparing around the gallbladder fossa. This is a typical location of FFS. However, in some instances, the sparing may not occur in this region or in the other typical location—segment 4 of the liver. The differential is much broader for Figure S57-2. It would be appropriate to exclude a liver mass such as metastases to the liver. In patients with known cirrhosis, certainly underlying hepatoma could also be excluded, but it may not have the appearance. Thus, in Figure S57-2, the differential would be much broader, as this is an atypical location for an area of fatty sparing with generalized fatty infiltration of the liver.

Ultrasound Findings

FFS occurs in typical locations. Commonly FFS occurs in the medial segment of the left lobe of the liver (segment 4) and, as seen in Figure S57-1, adjacent to the gallbladder fossa. FFS may occur along the liver margins. Typical features of FFS include hepatic vessels that are not displaced. There is no hyperemia surrounding or within the mass. On occasion, some vessels are noted to traverse through liver metastases; however, this is rare. Geometric margins are present most of the time with FFS and usually the mass is not rounded. There is no mass effect. Also, fatty infiltration or FFS may resolve fairly rapidly. More recent data has also shown that contrast-enhanced ultrasound (CEUS) may be helpful in characterization of specific liver lesions in fatty liver. There is both a high sensitivity and specificity of CEUS in diagnosing FFS in a fatty liver. There has also been preliminary work in trying to characterize or separate FFS from other hepatic lesions using ultrasound elastography.

Prognosis/Management

Certainly, chemical shift MRI may be helpful to distinguish either diffuse fatty infiltration of the liver, focal fatty liver, or FFS with diffuse fatty infiltration of the liver. In these situations, the chemical shift (in-and-out-of-phase) imaging will show drop off of signal in regions in which there is fatty infiltration of the liver, but no drop off of signal in the regions in which there is FFS as seen in Figures S57-3 and S57-4. Noncontrast CT may also be helpful to show a region of slightly increased density (focal sparing) in the liver with otherwise decreased density (diffuse fatty infiltration) of the liver. Biopsy would not be indicated after obtaining the above specific findings on MRI or CT. Also, radionuclide liver and spleen scintigraphy will yield normal results with FFS and may be helpful.

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CASE 58

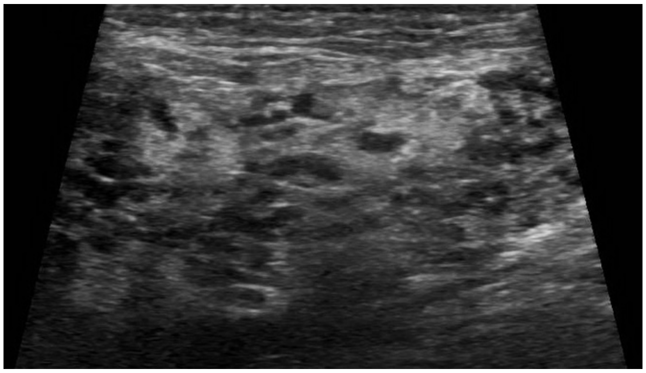

Figure 58-1

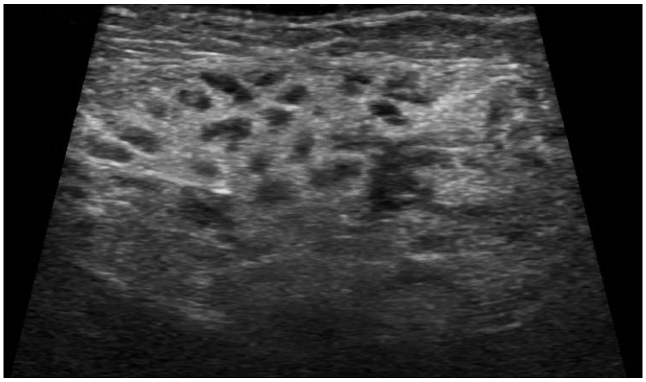

Figure 58-2

HISTORY: A 45-year-old female presents with a history of a dry mouth and dry eyes.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply)
   A. Sialolithiasis
   B. Warthin's tumor
   C. Sjögren's syndrome
   D. Chronic sialadenitis

2. Which of the following is true regarding benign salivary gland diseases?
   A. The echogenicity of the salivary glands is dependent on the amount of fibrous tissue in the gland.
   B. The differential diagnosis of multiple small hypoechoic lesions in the submandibular gland includes Sjögren's syndrome, sarcoidosis, and hematogeneous metastases.
   C. The small, hypoechoic lesions in the submandibular gland in Sjörgen's syndrome represent neutrophilic infiltration of the gland.
   D. The incidence of lymphoma in the salivary glands is increased in patients with sarcoidosis.

3. Which of the following is true regarding benign salivary gland diseases?
   A. Benign lymphoepithelial cysts occur in patients with von Hippel-Landau.
   B. Lymphoepithelial cysts in the parotid gland are septated and cystic, allowing differentiation from a parotid gland tumor.
   C. Granulomatous disease of the salivary glands can cause the glands to become mass-like and diffusely hypoechoic on ultrasound.
   D. Salivary gland involvement is much more common in sarcoidosis than Sjögren's syndrome.

4. Which of the following is true regarding benign salivary gland diseases?
   A. Sialolithiasis (salivary duct stones) occurs more commonly in the parotid gland than in the submandibular gland.
   B. Acute and chronic inflammation of the salivary glands is most commonly due to a bacterial infection.
   C. On ultrasound, the acutely inflamed parotid gland (sialadenitis) is enlarged and heterogeneous, with small hypoechoic areas.
   D. On ultrasound, the chronically inflamed parotid gland is enlarged, with multiple small hyperechoic areas throughout the parenchyma.

See Supplemental Figures section for additional figures and legends for this case.

CASE 58

Benign Salivary Gland Diseases

1. **C.** Figures S58-1 and S58-2 show multiple small hypoechoic nodules throughout both submandibular glands. The patient's history and ultrasound findings are most consistent with Sjögren's syndrome. Chronic sialadenitis (D) can also present as multiple hypoechoic lesions in the salivary gland and is also a differential; however, the patient had Sjögren's syndrome.
2. **B.** Chronic sialadenitis (less frequently, acute sialadenitis) and lymphoma can also present as multiple hypoechoic nodules in the salivary gland. The small hypoechoic nodules represent lymphoplasmacytic infiltration of the gland in Sjörgen's syndrome. The incidence of lymphoma of the salivary glands is increased in patients with Sjögren's syndrome, not sarcoidosis. Patients should be routinely monitored and an ultrasound-guided biopsy should be performed of any rapidly enlarging lesion.
3. **C.** Granulomatous disease (sarcoidosis and mycobacterial disease) can cause the salivary glands to enlarge and become diffusely hypoechoic. Mycobacterial involvement has been reported to simulate the appearance of a tumor. Lymphoepithelial cysts occur in human immunodeficiency virus (HIV) patients.
4. **C.** The acutely inflamed parotid gland is enlarged, heterogeneous, and hypervascular with small hypoechoic areas. The overlying subcutaneous tissue/skin is often edematous and erythematous. The most common cause is the mumps virus. The gland in chronic sialadenitis is normal or decreased in size and often hypovascular with multiple small hypoechoic areas. It is usually due to a chronic bacterial infection (*Streptococcus* or *Staphylococcus* species). The parotid glands are more commonly involved than the submandibular glands.

Comment

Introduction

The differential diagnosis for benign diseases of the salivary gland is broad. Demographics (gender, age, medical history, and signs and symptoms) help to narrow the differential diagnosis. A history of Sjögren's syndrome, sarcoidosis, a primary neoplasm, or HIV is invaluable for making the correct diagnosis. Acute or intermittent pain suggests inflammation; gland swelling during eating suggests sialolithiasis. Salivary duct stones can also be the cause of a bacterial infection.

Sonographic Findings

The differential for a focal hypoechoic mass and multiple small focal hypoechoic lesions overlaps. Sarcoidosis, mycobacterial infection, Sjögren's disease, lymphoma, and acute sialadenitis can all cause multiple small focal hypoechoic lesions and also enlarge the gland. Increased flow on color Doppler is present in most of these diseases. In chronic sialadenitis, the gland is usually small with diminished color Doppler flow. A hypoechoic mass can be due to a primary tumor, lymphoma, metastases, or tuberculosis (TB); fine needle aspiration (FNA) and correlation with clinical history is necessary. A solid-cystic lesion could represent a lymphoepithelial cyst in the HIV patient or a primary tumor such as a Warthin's tumor. Lymphoepithelial cysts are usually solitary but may have a variable sonographic appearance (cystic, septae, debris, or solid-cystic) and can mimic the appearance of a tumor. Clinical history and FNA are required to make the correct diagnosis. Sialolithiasis occurs most commonly in the submandibular gland (80% to 90% of cases). The presence of an echogenic focus with posterior acoustic shadowing within a dilated duct clinches the diagnosis.

Treatment

While many diseases can involve the salivary glands, treatment is based on the primary disease process, which is often systemic in nature (Sjögren's, sarcoidosis, TB, lymphoma, metastases). Acute bacterial sialadenitis is treated with antibiotics, usually fluoroquinolones or cephalosporins administered orally or intravenously. If sialadenitis is chronic, endoscopy of the salivary duct may reveal occult stones that are then removed. Endoscopy is a very effective treatment for sialolithiasis and is minimally invasive. Lithotripsy has also been combined with endoscopy for stone removal. Surgical resection of a salivary gland is now becoming much less common with the advent of minimally invasive techniques.

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Cross-reference

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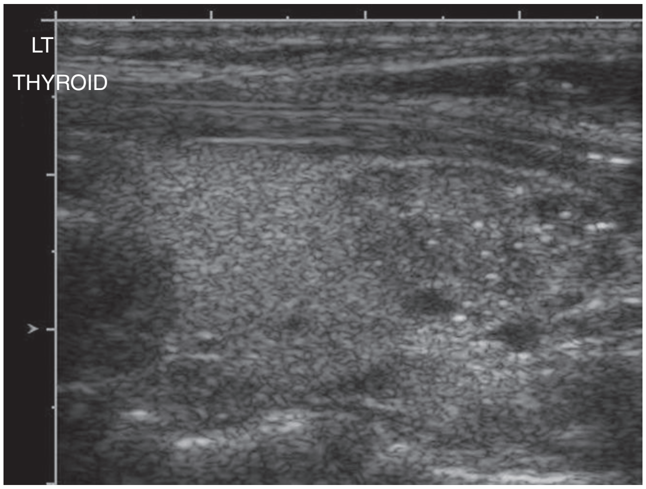

Figure 59-1

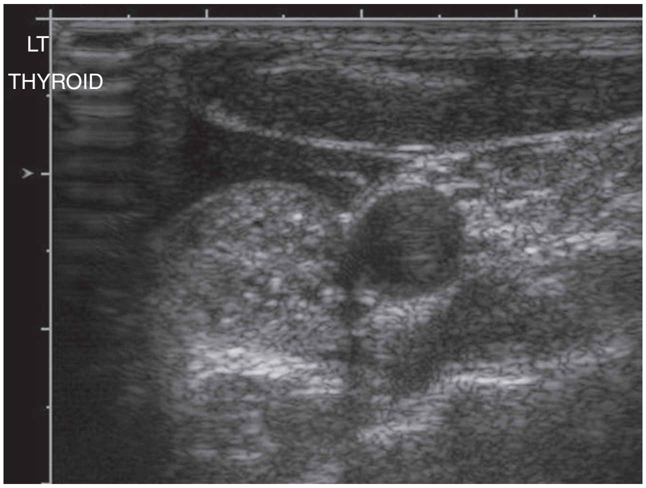

Figure 59-2

HISTORY: This 55-year-old presents with a sub-mandibular mass. An incidental abnormality is detected within the thyroid.

1. Which one of the following would be included in the differential diagnosis for the imaging findings presented in Figures 59-1 and 59-2? (Choose one)
   A. Lymphoma
   B. Parathyroid adenoma
   C. Papillary carcinoma of the thyroid
   D. Colloid cyst of the thyroid
   E. Follicular carcinoma of the thyroid
2. The sonographic features of papillary carcinoma of the thyroid would include all of the following EXCEPT:
   A. Microcalcifications
   B. Hypervascularity
   C. Hypoechoic or markedly hypoechoic
   D. Eggshell calcifications
3. In consensus studies, which of the following ultrasound findings are not helpful in predicting thyroid cancer? (Choose one)
   A. Microcalcifications
   B. Markedly echogenic nodule
   C. Irregular or spiculated margins
   D. Taller rather than wider
4. Once a suspicious nodule is detected on ultrasound, what is the next best study that should be performed?
   A. Thyroid scintigraphy
   B. Fine needle aspiration (FNA) biopsy
   C. Deoxyribonucleic acid (DNA) analysis of the thyroid sample
   D. Core biopsy of the thyroid

See Supplemental Figures section for additional figures and legends for this case.

CASE 59

Papillary Thyroid Cancer

1. **C.** Papillary thyroid carcinoma is the most likely diagnosis as there are microcalcifications in this hypoechoic mass. This is the best answer. Follicular carcinoma could appear similar to this mass, but is usually without the microcalcifications; other choices likewise are without microcalcification or appear cystic.
2. **D.** Peripheral eggshell calcifications are usually benign and not associated with papillary carcinoma. Other choices are more typical for a papillary carcinoma.
3. **B.** In most studies, a hypoechoic or markedly hypoechoic ultrasound finding is more specific for thyroid cancer, rather than an echogenic mass. Other features are typical of thyroid cancer.
4. **B.** In most institutions, FNA is the most commonly utilized next exam of a suspicious nodule. However, thyroid scintigraphy, DNA analysis, and core biopsy have been advocated by some.

Comment

Differential Diagnosis

For a hypoechoic mass with microcalcifications, the most likely diagnosis would be papillary thyroid carcinoma. This is the most common type of thyroid cancer. Colloid cysts would be a potential pitfall as they do appear anechoic and do have microcalcification, but within the colloid cysts, they usually have a “comet tail” artifact. Metastasis from such sites as melanoma and breast would be less likely considered in these cases. Malignant follicular carcinoma has a similar appearance to that of a papillary cancer but without microcalcifications. Medullary carcinomas, while rare, could be included in the differential. They are hypoechoic and may have fine internal calcification. These types of carcinomas are associated with multiple endocrine neoplasia Type II.

Ultrasound Findings

Ultrasound features of papillary carcinoma include a hypoechoic or markedly hypoechoic mass with microcalcifications (Figs. S59-1 and S59-2). The mass may have irregular margins and may be taller rather than wider. These tumors may have increased color flow. Examination of the neck for enlarged, rounded nodes with or without microcalcification is important.

Prognosis/Management

Genetic analysis of the cytological specimen from thyroid biopsy has been found to enhance diagnostic accuracy and to predict poor prognosis in patients with thyroid cancer. Analysis of the BRAF-V600E mutation has been reported exclusively with papillary thyroid carcinoma. Both cytology and tissue analysis can be performed using FNA biopsy (Fig. S59-3). However, inadequate FNA specimens are obtained in approximately 10% of most series. In these cases, core needle biopsy can be performed if there is a suspicious nodule. There have been debates within the literature concerning suspicious feature thyroid nodules and subsequent management. The Society of Radiologists in Ultrasound felt that thyroid nodules less than 1 cm should not be biopsied, although the American Thyroid Association, The American Association of Clinical Endocrinologists, and the Associazione Medici Endocrinologi recommended routine biopsy of thyroid nodules smaller than 1 cm with suspicious ultrasound features. It appears the latter recommendation is shared by multicenter Korean studies. Once the diagnosis is made, the treatment usually consists of thyroidectomy and iodine 131 treatment in the United States. In some countries, thyroidectomy and node dissection are utilized without iodine 131 therapy.

Prognosis is usually good, and ultrasound can be utilized for detection of local node reoccurrences in the neck.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 230–237.

CASE 60

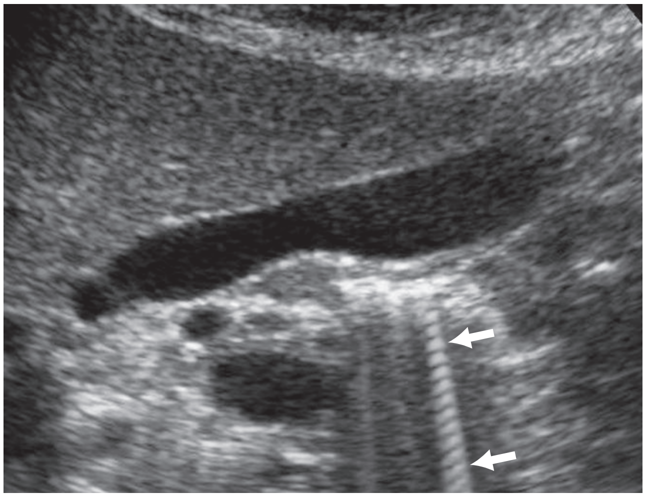

Figure 60-1

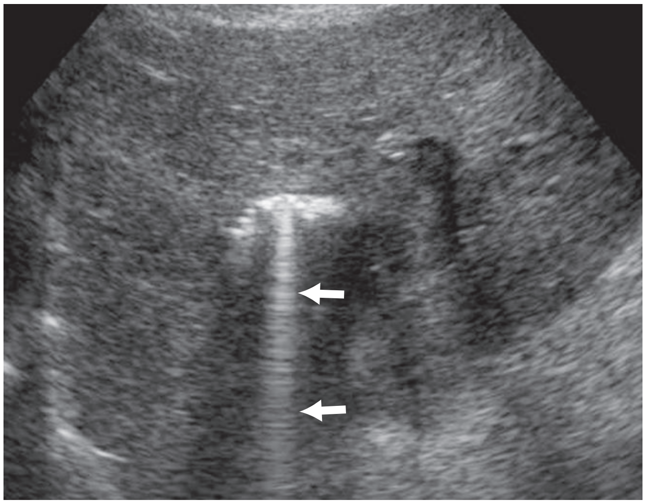

Figure 60-2

HISTORY: Two different patients with gray scale images of the right upper quadrant are shown.

1. What is the artifact in both of these images?
   A. Shadowing
   B. Refractive edge
   C. Ring-down
   D. Noise
2. In Figure 60-2 what is the cause of the artifact?
   A. Calcification in a tumor
   B. Air in an abscess
   C. Ethiodol
   D. Biliary stones
3. Regarding ring-down artifact, which of the following is true?
   A. Only gas causes the artifact.
   B. It is a form of reverberation.
   C. It can be caused by multiple bubbles of gas.
   D. It is eliminated by lowering the gain.
4. Regarding ultrasound artifacts, which of the following is true?
   A. Ring-down is the gray scale analog of twinkle artifact.
   B. Enhancement behind a cyst and the echogenicity in the ring-down have similar causes.
   C. Comet tail artifacts are a form of reverberation artifact.
   D. Ring-down is eliminated by harmonic imaging.

See Supplemental Figures section for additional figures and legends for this case.

CASE 60

Ring-Down Artifact

1. **C.** Both images show a ring-down artifact. The ring-down is a series of bright periodic echoes streaming behind an echogenic focus. There is no shadowing or refractive edge shadowing. The artifact is localized and it is not noise.
2. **B.** Air is the most common cause of a ring-down artifact. There is a curvilinear area of echogenicity with a ring-down in the center, suggesting air rising to the top of a collection. The location and size does not favor portal venous or biliary air. Calcifications do not cause ring-down.
3. **C.** Ring-down artifact is typically created by the sound beam interacting with multiple bubbles of gas. Metal can also cause a ring-down. It is not a form of reverberation. Gain does not eliminate ring-down.
4. **C.** Comet tail artifacts are a form of reverberation artifact in which the sources of the reverberations are close together. Ring-down, enhancement, and twinkle artifacts are not related, and ring-down is not eliminated by harmonic imaging.

Comment

A long band of parallel echoes behind a reflector characterizes the ring-down artifact (Figs. S60-1 and S60-2). Ring-down artifact is commonly caused by the vibration that occurs from sound striking multiple gas bubbles. Gas bubbles expand and contract in the ultrasound beam and give off a train of echoes (Fig. S60-1). Each vibration occurs later in time, which the ultrasound interprets as deeper in the tissue. While ring-down most commonly is associated with air, it may also occur with metal as a result of the vibrations produced when the metal resonates when struck by ultrasound. Ring-down artifact is different from reverberation because ring-down does not occur from echoes repeatedly bouncing back and forth between structures in the beam. Ring-down artifacts may have a similar appearance to comet tail artifacts, but the comet tail is a type of reverberation artifact.

Ring-down can be considered a potentially beneficial artifact because it points to the presence of air, which may indicate an underlying pathological condition. For example, ring-down may be visualized in the soft tissue in the presence of an abscess containing air (Fig. S60-2).

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 23.

Acknowledgment

Special thanks to Traci B. Fox, EdD, RT(R), RDMS, RVT, for preparation in this case.

CASE 61

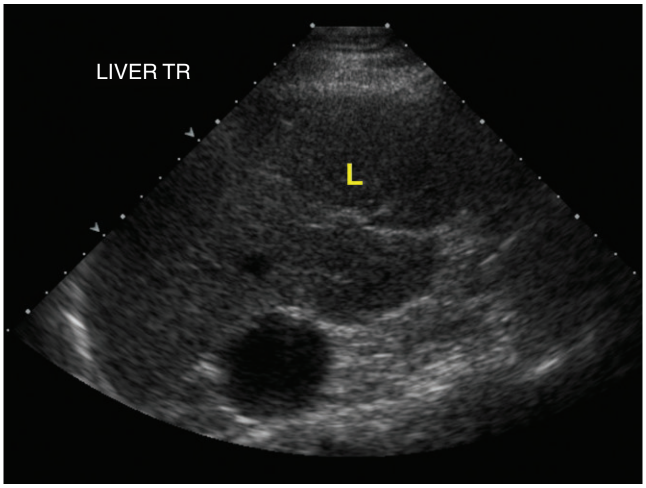

Figure 61-1

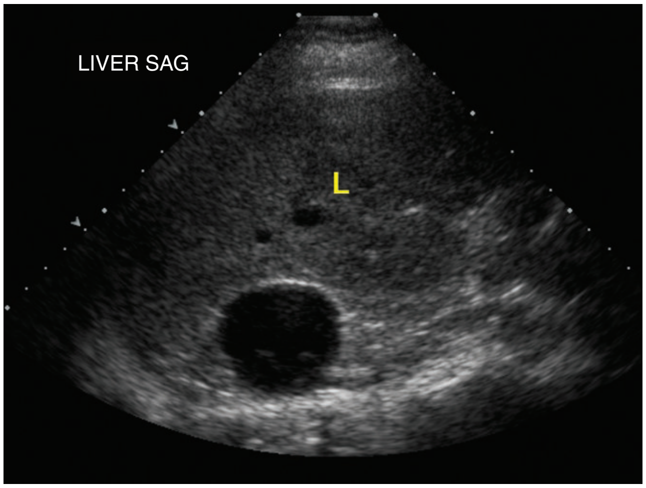

Figure 61-2

HISTORY: A 45-year-old man undergoes an abdominal ultrasound for right upper quadrant pain. An incidental finding was identified during an examination.

1. Which of the following should be included on the differential? (Choose all that apply)
   A. Simple adrenal cyst
   B. Renal cyst
   C. Adrenal metastasis
   D. Adrenal lymphoma
   E. Parasitic cyst

2. Which of the following is true of adrenal cystic lesions?
   A. They are more commonly bilateral.
   B. Thick walls and septations are concerning for malignancy.
   C. Aspiration should not be performed.
   D. Patients typically present with abdominal pain.

3. Which of the following is NOT a feature of a complicated adrenal cyst that is suggestive of malignancy?
   A. Calcifications
   B. Septations
   C. Cyst wall greater than 3 mm
   D. Internal debris

4. What would be the least common etiology of an adrenal cyst?
   A. Hydatid or echinococcus cyst
   B. Endothelial-lined cyst
   C. Epithelial-lined cyst
   D. Pseudocyst

See Supplemental Figures section for additional figures and legends for this case.

CASE 61

Adrenal Cyst

1. **A, B, and E.** A simple epithelial cyst of the adrenal would be considered. An upper pole renal cyst could be confused with an adrenal cyst. Lymphoma would appear as a hypoechoic mass. Echinococcal or hydatid cysts can involve the adrenal glands.
2. **B.** More than 90% of all adrenal cysts are unilateral. Most adrenal cysts are found incidentally. When cysts are symptomatic, aspiration can be performed. Thick septa, thick walls, and internal echoes are concerning for malignancy.
3. **A.** Calcification is seen in 15% of all adrenal cysts and is not necessarily indicative of malignant potential. The other answer choices are all features that describe a complicated adrenal cyst and are concerning for malignancy.
4. **A.** This is a bit of a trick question. Certainly, in the United States, a pseudocyst from prior hemorrhage or even an adrenal mass with hemorrhage would be very common. Endothelial-lined cysts, including lymphangiomas, would also be common. True cysts which are epithelial lined are less common. In the United States, hydatid or echinococcal cysts would be the least frequent of these four choices, but worldwide, depending on the specific country, these parasitic cysts may be more common. Thus this answer depends on the country under consideration.

Comment

Differential Diagnosis

The term "adrenal cyst" is not in itself a diagnosis but merely a term used to describe any cystic lesion within the adrenal gland. Adrenal cysts may be congenital, posttraumatic, infectious, or neoplastic in origin and thus the differential is broad. Superior pole renal cysts may be difficult to distinguish from adrenal cysts. Simple cystic lesions include simple epithelial cysts or lymphangiomas. They are congenital lesions that are often small (<15 mm) and thus may not be routinely detected with ultrasound. They are lined with endothelium, making them true cysts. They are rarely of any consequence. Adrenal pseudocysts are similar to pancreatic pseudocysts in that they do not feature an endothelial lining. They represent organization of prior adrenal injury, most commonly hemorrhage. Echinococcal cysts form due to infection by *Echinococcus granulosus* and are typically widespread in the abdomen, with the adrenal glands being an uncommon location of involvement. The most critical differential diagnosis is that of cystic degeneration of a neoplastic process. Nearly every primary adrenal tumor may undergo cystic necrosis if the tumor outgrows its blood supply.

Ultrasound

Simple cystic lesions include true simple cysts. These have characteristic findings of simple cysts on ultrasound: thin wall, homogenously hypoechoic, with posterior acoustic enhancement (Figs. S61-1 and S61-2). Lymphangiomas may feature thin septations. Adrenal pseudocysts may have the sonographic findings of a simple cyst. However, they may have internal debris or thin septations, thick walls greater than 3 mm, heterogenous internal debris, or areas with increased color flow.

Management

Typical appearing cysts may not need further evaluation unless symptomatic. They can be evaluated with contrast-enhanced computed tomography or magnetic resonance imaging. Correlation with adrenal steroid hormone levels should be performed, especially in patients with refractory hypertensions or cushingoid features.

In some cases, malignant adrenal masses may become necrotic and appear cystic. Cysts may be aspirated if definitive diagnosis is sought. Even true endothelial-lined cysts may contain cholesterol and adrenal steroid hormones, and such findings do not suggest malignancy or even a functional adrenal adenoma. Of note, benign cystic lesions may change in size over time and may reaccumulate after aspiration. For these reasons, an asymptomatic simple adrenal cyst without any of the aforementioned concerning features should be managed conservatively.

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Acknowledgment

Special thanks to Ethan Neufeld, MD, for preparation in this case.

CASE 62

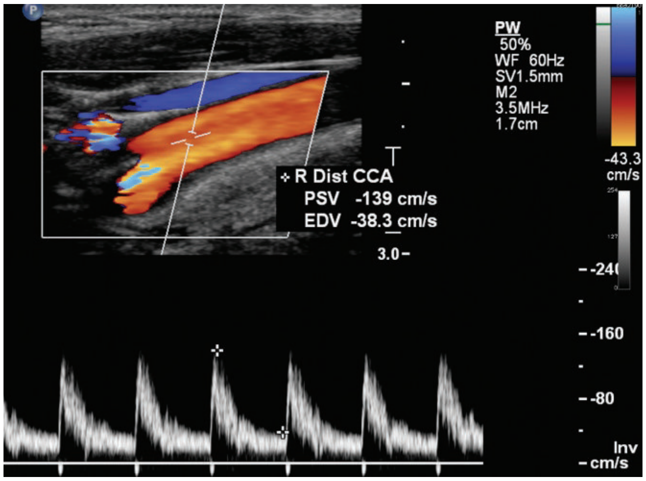

Figure 62-1

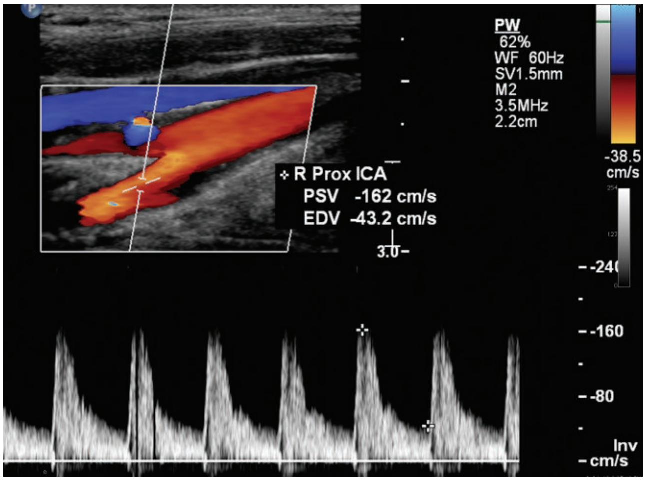

Figure 62-2

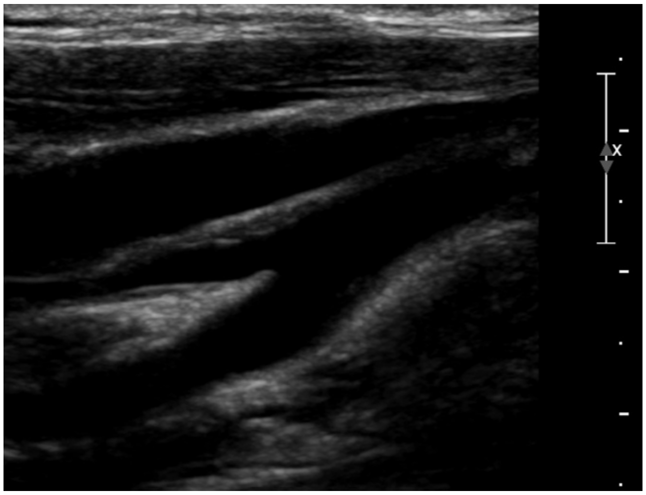

Figure 62-3

HISTORY: A 42-year-old presents with a neck bruit. Spectral and color Doppler of the distal common carotid artery (CCA), proximal internal carotid artery (ICA), and gray scale ultrasound of the bifurcation were obtained as part of an extracranial cerebrovascular duplex Doppler examination.

1. What is the degree of stenosis?
   A. 1% to 49% diameter reduction
   B. 50% to 69% diameter reduction
   C. 70% diameter reduction to near occlusion
   D. 80% diameter reduction
2. Regarding the waveform in the proximal ICA, which of the following is true?
   A. It has noise.
   B. It is excessively pulsatile.
   C. It is indicative of stenosis.
   D. It has spectral broadening.
3. Which is an abnormal internal to common carotid peak systolic velocity (PSV) ratio?
   A. 125 cm/s
   B. 2
   C. 1
   D. 0.5
4. False positive carotid duplex scans may be caused by which of the following? (Choose all that apply)
   A. Improper Doppler angle
   B. Hyperdynamic states
   C. Tortuous vessels
   D. Aortic stenosis

See Supplemental Figures section for additional figures and legends for this case.

CASE 62

Internal Carotid Artery Stenosis (Pitfall)

1. **A.** There is only mild plaque and the vessel is widely patent. Although the velocities are elevated, the internal carotid velocity is not elevated significantly compared with the common velocity. Therefore, there is no stenosis above 50%.
2. **D.** The ICA waveform does demonstrate some spread in velocities (filling in of the spectral window) and very mild reversed flow below the baseline. These indicate spectral broadening, which is a normal finding in the carotid bulb. There are no random signals and, therefore, no significant noise. The amount of diastolic flow is acceptable for the ICA and not decreased, which would suggest excessive pulsatility. The ICA velocity is elevated compared with normal, but this is not, by itself, indicative of stenosis without gray scale, color, and spectral findings.
3. **B.** As stenoses become worse, the internal velocity increases, and when above 50%, the IC:CC ratio rises above 2.
4. **A, B, and C.** An improper Doppler angle may cause the ICA velocity to be falsely high. Hyperdynamic states can cause the velocities in the ICA, CCA, and other arteries to be elevated. A turn in the vessel may cause acceleration of the blood in the turn and create a falsely high velocity. Aortic stenosis does not generally affect ICA velocities.

Comment

ICA stenoses are graded using North American Symptomatic Carotid Endarterectomy Trial grades. After normal and mild plaque, both of which have normal velocities, the first grade of stenosis is 50% to 69%. Elevated velocity is the hallmark of this grade and the next most severe grade, 70% to near occlusion.

A variety of criteria are used to grade 50% to 69% stenoses. The most common is a PSV in the stenosis of over 125 cm/s. The accuracy of the velocity depends on several factors: plaque must be present on gray scale, and color Doppler should show narrowing. To be confident that the PSV is accurate, the velocity in the area of narrowing must be focally elevated. The CCA velocity before the stenosis and the ICA velocity after the narrowing must be lower.

Pitfalls in ICA Stenosis

If the velocities are unusually high in the CCA (Fig. S62-1), internal carotid highest velocity: distal CCA velocity (IC:CC) ratios are used (Figs. S62-1 and S62-2). The most common cutoff for 50% is a ratio of 2 or greater. The ratio is also helpful when ICA velocity may be falsely elevated and the degree of actual stenosis is less than the ICA velocity would usually indicate (Fig. S62-3). The most common situation occurs when there is contralateral high-grade stenosis or occlusion. Collateral flow causes an increase in both the CCA and ICA velocities. A second common example occurs when there is a hyperdynamic state. This can occur with hyperthyroidism, sepsis, or anemia. Another instance in which elevated velocities would be interpreted with caution is in younger patients who often have higher velocities throughout the carotid circulation.

The criteria of 125 cm/s is used for short stenoses and for the first several centimeters of the ICA. Normal patients often have higher velocities without stenosis in the mid to distal ICA beyond 1 to 2 cm from the bifurcation. Tortuousity of the vessel may also cause an elevation without stenosis.

Reference

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 244.

CASE 63

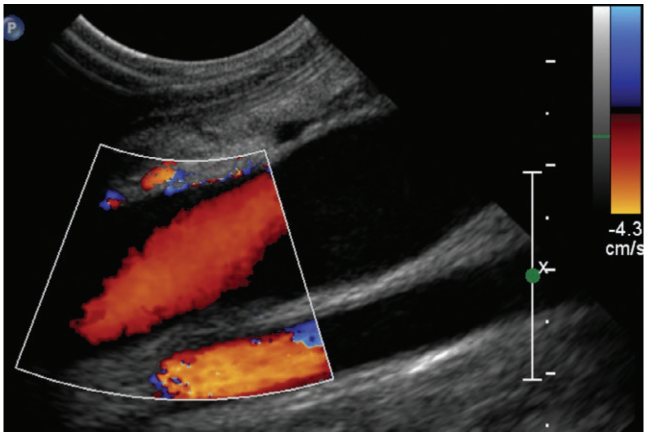

Figure 63-1

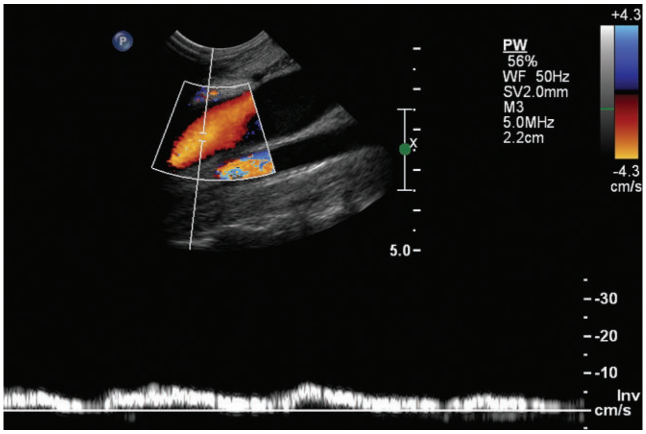

Figure 63-2

HISTORY: A 65-year-old with history of cancer, on treatment, presents with left arm and facial swelling. An upper extremity venous ultrasound was performed including images of the left jugular vein.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply)
   A. Carotid jugular fistula
   B. Left innominate occlusion
   C. Abnormal technique, Doppler probe inverted
   D. Metastatic lymphadenopathy compressing axillary vein
2. What is a spectral Doppler finding of mid subclavian vein obstruction?
   A. Continuous central subclavian vein
   B. Pulsatile innominate vein
   C. Reversed peripheral subclavian vein
   D. Pulsatile axillary vein
3. What may be indicated by continuous waveforms in the left jugular vein and pulsatile waveforms in the left subclavian vein?
   A. Left subclavian obstruction
   B. Left innominate obstruction
   C. Tricuspid regurgitation
   D. Left jugular scarring
4. Regarding pulsatile waveforms in the central subclavian vein and symmetric phasic but not pulsatile waveforms in the peripheral subclavian vein, which of the following is true?
   A. They are within normal limits.
   B. They indicate thoracic outlet syndrome.
   C. They indicate tricuspid regurgitation.
   D. They indicate chronic disease.

See Supplemental Figures section for additional figures and legends for this case.

CASE 63

Obstruction of the Upper Extremity Veins

1. **B.** The jugular vein is reversed, flowing away from the probe, toward the head, in the same direction as the common carotid artery (Fig. S63-1). This is one pattern of collateralization from central venous obstruction. A carotid jugular fistula will produce an arterialized waveform, not the mildly undulating waveform in this case (Fig. S63-2). If the Doppler probe were inverted and the patient was otherwise normal, the common carotid and jugular vein would not be flowing in the same direction. Compression of the axillary vein does not affect jugular waveforms.
2. **C.** Upper extremity veins can reverse to bypass central obstructions. The neck, chest wall, and mediastinum offer collateral pathways. The peripheral subclavian can reverse and collateralize via chest wall veins. The central subclavian is generally not affected by obstruction peripheral to it. A pulsatile innominate vein is normal and not related to subclavian vein obstruction. Because the axillary vein is peripheral to the obstruction, it should be a blunted, not a normal, pulsatile waveform.
3. **D.** The continuous waveform is abnormal and indicates jugular obstruction, which may be due to jugular deep venous thrombosis (DVT), jugular scarring, or compression on the jugular vein. Because the jugular vein is blunted and the subclavian vein is normal (pulsatile), the obstruction is not in the subclavian, innominate, or superior vena cava (SVC). Tricuspid regurgitation causes an accentuated A wave, not a blunted, continuous signal.
4. **A.** The waveforms in the central subclavian vein may be different from the peripheral subclavian vein because the latter lies further from the heart. The peripheral subclavian veins are symmetric, favoring normal variation. Thoracic outlet syndrome is possible but should not be diagnosed unless symptoms are present. Tricuspid regurgitation should affect all veins.

Comment

Upper Extremity Veins

Color Doppler should be recorded at the internal jugular, subclavian, and axillary veins. The innominate should be recorded if it is seen. Long axis images are preferred for color Doppler and mandatory for spectral Doppler.

Color Doppler of Upper Veins

Color should fill the veins. This may be subject to the cardiac cycle because the velocity and direction of blood flow changes with time. The veins are easier to fill with color because the velocities are higher.

Spectral Doppler

Normal central upper extremity veins demonstrate cardiovascular pulsatility and respiratory phasicity. There is frequently flow reversal associated with atrial systole (A wave). As the veins are farther from the heart, pulsatility is attenuated. In the peripheral subclavian and axillary veins (and occasionally the midsubclavian), phasic changes must be present but pulsatile changes may be blunted or even absent. For this reason, symmetry from side to side is necessary to determine if the waveforms have similar degrees of pulsatility and phasicity. Subclavian vein waveforms are obtained bilaterally even if the study is otherwise unilateral.

In central veins, an abnormally blunted spectral Doppler has absent or blunted pulsatility and should be diagnosed even if phasicity is present. Phasicity may also be less than normal or absent, and when phasicity is lost, the signal is continuous. No flow has no signal.

Because collateralization via the chest wall, mediastinum, or across the neck are possible, reversed flow around a central obstruction is a relatively common finding of central obstruction (Figs. S63-1 and S63-2).

An abnormally blunted signal (Fig. S63-2) indicates one of three processes: acute venous obstruction (typically DVT), obstructions from scarring (typically from prior lines and/or DVT), and extrinsic compression. Extrinsic compression in the upper arm can be caused by lung or mediastinal masses, but lymphadenopathy (Fig. S63-3) and masses of neural origin are also possible.

Localization of the Site of Obstruction

If the cause of the obstruction is not visible by color and/or gray scale (Fig. S63-3), the level is established by determining which veins are obstructed. For instance, if all of one side is obstructed and the contralateral side is normal, the level is at the innominate vein. If the subclavian is obstructed but the innominate and jugular are normal, the level is at the subclavian vein. If all veins are blunted, the obstruction is typically from the SVC or both innominates.

Reference

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 254, 282–283.

CASE 64

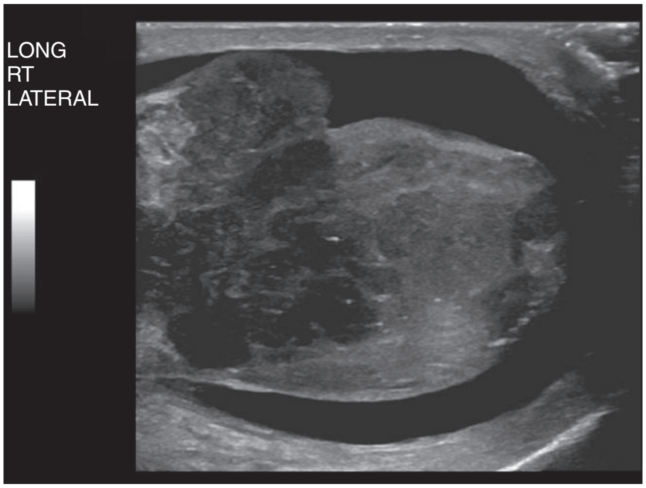

Figure 64-1

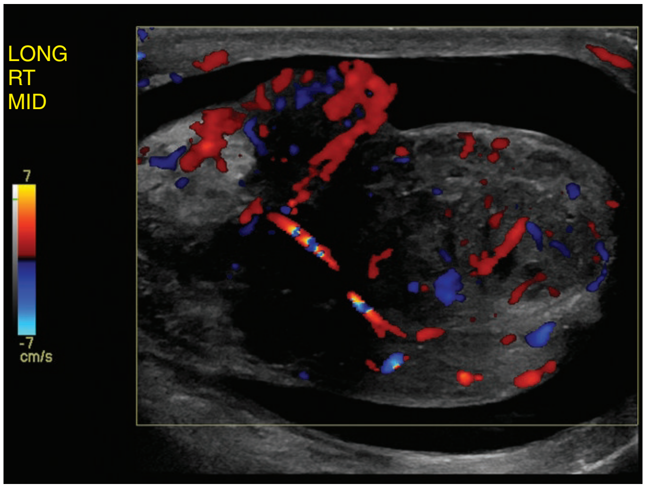

Figure 64-2

HISTORY: A 25-year-old male presents with scrotal enlargement.

1. Which one of the following would be included as the most likely diagnosis for the imaging findings presented in Figures 64-1 and 64-2?
   A. Seminoma
   B. Embryonal cell carcinoma
   C. Leydig's cell tumors
   D. Mixed germ cell tumors
   E. Leukemia
2. Nonseminomatous germ cell tumor types include all of the following EXCEPT:
   A. Embryonal cell carcinoma
   B. Teratomas
   C. Sertoli cell tumors
   D. Mixed germ cell tumors
3. Which one of the following is an Azzopardi tumor of the testes?
   A. A metastatic tumor to the testes from the colon, stomach, or pancreas
   B. A burned-out testicular tumor with metastasis to the retroperitoneum and abdominal lymphadenopathy
   C. Bilateral seminomas of the testis
   D. Gonadal stromal tumors of the testis
4. Which of the following is the correct statement concerning nonseminoma germ cell tumors?
   A. Embryonal cell carcinoma is the most common type of nonseminoma germ cell tumor.
   B. Mixed germ cell tumors are the most common nonseminoma germ cell tumors.
   C. Teratomas are the most common nonseminoma germ cell tumors.
   D. Choriocarcinoma is the most common nonseminomatous germ cell tumor.

See Supplemental Figures section for additional figures and legends for this case.

CASE 64

Mixed Germ Cell Tumor

1. **D.** Mixed germ cell tumors are the most common nonseminoma germ cell tumors and would have both cystic as well as echogenic components. Embryonal cell carcinoma has mixed cystic and echogenic components and would be a good choice. The other tumors are more homogenous in appearance.
2. **C.** Sertoli cell tumors are considered gonadal stromal tumors, which include Sertoli cell, Leydig's cell, and granulosa cell tumors, to name a few. The other tumors are germ cell tumors.
3. **B.** This is a "burn-out" primary tumor of the testis which spontaneously regresses with the presence of retroperitoneum adenopathy.
4. **B.** This is the correct answer as there are various germ cell elements in various combinations and they constitute approximately 40% to 50% of all germ cell tumors. Embryonal cell carcinomas are the most common components of mixed germ cell tumors.

Comment

Differential Diagnosis

Differential diagnosis for this case would include nonseminomatous germ cell tumors including mixed germ cell tumors. These tumors may contain elements of seminoma. Embryonal cell carcinoma is the most common component of a mixed germ cell, followed by teratoma; choriocarcinoma is rare. Additionally, each of these tumors may have a similar appearance to a mixed germ cell tumor, but occur in a pure cell line which is much less frequent. Other malignant neoplasms such as metastasis to the testes, while uncommon, could have this appearance. Seminoma is usually more hypoechoic and well marginated without calcification and should not have this appearance. Leukemia and some lymphomas are more hypoechoic and may cause the diffused enlargement in the testes and should not be confused. More benign entities such as focal orchitis usually can be differentiated on ultrasound or follow-up imaging.

Ultrasound Findings

Ultrasound features of a mixed germ cell tumor are that of a heterogenous mass or masses. This is due to a secondary hemorrhage and necrosis. In addition, they often have cystic areas as well as calcifications as illustrated in Figure S64-3. There may be associated microcalcifications (Fig. S64-1). These tumors are usually vascular on color Doppler ultrasound (Fig. S64-2).

Prognosis/Management

Nonseminoma germ cell tumors are more aggressive than seminomas. It is estimated that 30% of patients with a clinical stage-1 nonseminoma germ cell tumor do, in fact, have metastasis. If imaging is negative for metastasis and there is a stage-1 mixed germ cell tumor, then surveillance after orchiectomy may avoid unnecessary treatment-related morbidity and cost. Surveillance would include follow-up chest, abdominal, and pelvic imaging. In patients with retroperitoneal adenopathy with relapse, both chemotherapy as well as retroperitoneal lymph node dissection has been utilized. As many of these germ cell tumors have elevated levels of alpha-feto protein or human chorionic gonadotropic hormone, these serum values can be followed.

References

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Cross-reference

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CASE 65

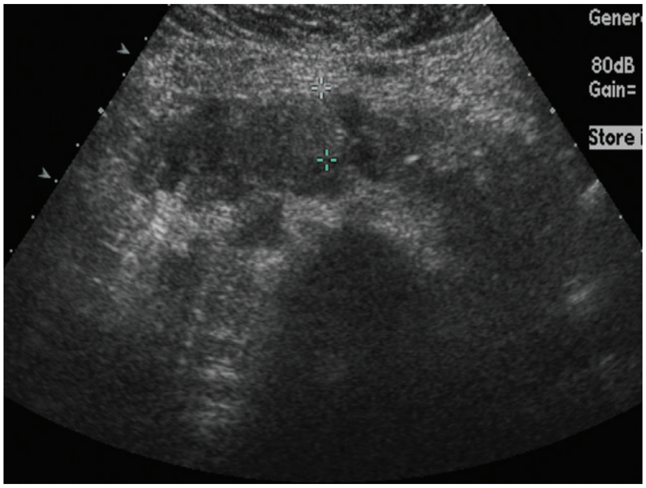

Figure 65-1

Figure 65-2

HISTORY: A 38-year-old male presents with an incidental finding on ultrasound of the mid-abdomen.

1. Which one of the following would be the most likely diagnosis for the imaging findings presented? (In Figure 65-1 of the mid-abdomen and Figure 65-2 of the right side of the abdomen)
   A. Retroperitoneal adenopathy
   B. Primary retroperitoneal neoplasm
   C. Thickened bowel loop
   D. Horseshoe kidney
2. What is the incidence of horseshoe kidney in the general population?
   A. 1 out of 5 births
   B. 1 out of 50 births
   C. 1 out of 500 births
   D. 1 out of 5000 births
3. Which one of the following possible complications is NOT associated with a horseshoe kidney?
   A. Urinary obstruction and reflux
   B. Increased risk of renal trauma
   C. Increased risk of renal cell cancer (RCC)
   D. Increased risk of Wilms' tumor
4. At what level is the ascent of horseshoe kidneys arrested during development?
   A. Aortic bifurcation
   B. Inferior mesenteric artery
   C. Superior mesenteric artery
   D. Celiac artery

See Supplemental Figures section for additional figures and legends for this case.

CASE 65

Horseshoe Kidney

1. **D.** The mass seen anterior to the aorta may represent a primary retroperitoneal mass or adenopathy, or a thickened bowel loop. Connecting the mass to the inferior poles of bilateral kidneys confirms the diagnosis of horseshoe kidney. Absence of peristalsis helps in excluding a decompressed bowel loop.
2. **C.** The incidence of horseshoe kidney is approximately 1 out of 500 births.
3. **C.** Horseshoe kidneys predispose to urinary obstruction and reflux, recurrent urinary tract infections (UTIs), and stone formation and increased risk of trauma. While an increased risk of Wilms' tumor is reported, risk of RCC in horseshoe kidneys is similar to the general population.
4. **B.** Superior renal migration is arrested at the level of the inferior mesenteric artery with horseshoe kidneys.

Comment

Differential Diagnosis, Embryology, and Development

Differential considerations for a mass anterior to the aorta in the mid-to lower abdomen (Fig. S65-1) includes a primary retroperitoneal mass, adenopathy, decompressed bowel loops, and, rarely, a horseshoe kidney. Connecting the mass to inferior poles of the kidneys clinches the diagnosis (Figs. S65-2 and S65-3).

Horseshoe kidneys develop when the metanephric blastema fuses across the midline in the lower pole region. The connecting tissue between the inferior poles may consist of functioning renal parenchyma or nonfunctioning fibrous bands (Figs. S65-2 and S65-3). The superior migration of the kidney is restricted at the level of the inferior mesenteric artery with the connecting parenchymal/fibrous tissue, prohibiting further cranial ascent of the kidneys. Multiple renal arteries can supply these kidneys with branches coming off the aorta, common and internal iliac arteries, and/or the inferior mesenteric artery. Duplicated collecting systems are also commonly seen.

Ultrasound Findings

Presence of a horseshoe kidney should be suspected on ultrasound if there is unusual difficulty in measuring the craniocaudal dimensions of the kidneys. Also, the axis of the renal moieties may be abnormal, with lower poles directed medial to the upper poles and a more anterior orientation of the collecting systems being noted on ultrasound and CT (Fig. S65-3 & Fig. S65-4). If there is any suspicion based on the above findings, a thorough scan should be performed in the periaortic region to look for soft tissue mass bridging the inferior poles of bilateral kidneys.

Management

Horseshoe kidneys are predisposed to urinary obstruction, reflux, recurrent UTIs, and stone formation. Due to the location of the kidney, it is at an increased risk of trauma. Increased incidence of Wilms' tumor has been reported, while the incidence of RCC is similar to normally developed kidneys. Asymptomatic horseshoe kidneys do not require any intervention, and any management is geared toward treating complications, such as stone formation, or pyonephrosis, if present.

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Cross-reference

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Acknowledgment

Special thanks to Priyanka Jha, MD, for preparation in this case.

CASE 66

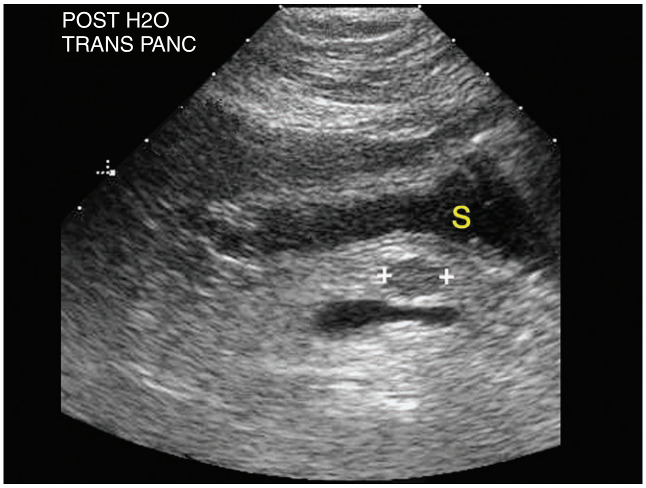

Figure 66-1

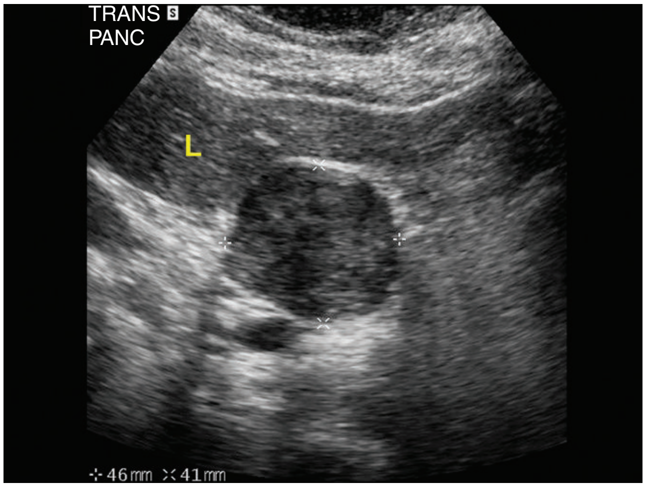

Figure 66-2

HISTORY: A 60-year-old male presents with vague abdominal pain with these images of the pancreas.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented in Figure 66-1? (Choose all that apply)
   A. Insulinoma
   B. Intraductal papillary mucinous neoplasms (IPMN)
   C. Adenocarcinoma of the pancreas
   D. Metastasis

2. The most common type of functioning islet cell tumor is:
   A. Gastrinoma
   B. Glucagonoma
   C. Insulinoma
   D. Vipoma

3. All of the following are true statements concerning gastrinomas EXCEPT:
   A. They occur with multiple endocrine neoplasms (MEN) Type II syndrome.
   B. They occur most commonly in the head of the pancreas.
   C. They may be multiple.
   D. They may be malignant.

4. Concerning imaging findings with the insulinomas, all are true statements EXCEPT:
   A. They are usually small.
   B. They have cystic regions in the tumor.
   C. They are hypoechoic on ultrasound.
   D. They are vascular.

See Supplemental Figures section for additional figures and legends for this case.

CASE 66

Islet Cell Tumor of the Pancreas

1. **A, B, and D.** While insulinoma seems like the most likely diagnosis in the correct clinical setting, all others except IPMN should be considered; IPMN is cystic.
2. **C.** An insulinoma is the most common type of functioning islet cell tumor.
3. **A.** All are true statements except A. Islet cell tumors may occur in MEN Type I syndrome with parathyroid adenomas and pituitary adenomas. MEN Type IIA occurs with pheochromocytomas, parathyroid tumor, and medullary carcinoma of the thyroid. MEN Type IIB occurs with pheochromocytomas, neurofibromatosis, and medullary carcinoma of the thyroid.
4. **B.** Insulinomas usually present with symptoms of hypoglycemia. If these are detected early, when they are small, they are hypoechoic on ultrasound. They enhance on arterial phase contrast computed tomography (CT) and magnetic resonance imaging (MRI). Cystic regions occur with nonfunctioning islet cell tumors which are detected when larger, after undergoing necrosis, but not so with insulinomas.

Comment

Differential Diagnosis

The differential for small hypoechoic pancreatic mass is rather small. Functioning islet cell tumors are usually well demarcated and hypoechoic. A small adenocarcinoma of the pancreas or metastasis could be considered. Small serous cystadenomas of the pancreas or a mucinous cystic neoplasm (MCN) of the pancreas could be considered. However, cystic components are usually seen with MCN but not with serous cystadenoma. Nonfunctioning islet cell tumors are detected later. These tumors are larger, with necrosis, and may have calcifications. The differential for a larger nonfunctioning islet cell tumor is much broader and includes other tumors such as adenocarcinoma or variant pancreatic carcinomas, and a solid pseudopapillary tumor of the pancreas.

Ultrasound Features

Insulinomas are the most common functioning islet cell tumors. Other functioning islet cell tumors include gastrinomas, glucagonomas, and vipomas, to name a few. Some would classify all islet cell tumors as neuroendocrine tumors (NETs). If the tumors are functioning, they may be difficult to detect on transabdominal ultrasound, as they are small and hypoechoic. (Fig. S66-1) Intraoperative ultrasound is very helpful to detect islet cell tumors, especially those such as gastrinomas, which may be multiple and in ectopic locations (Fig. S66-2). Due to necrosis, nonfunctioning islet cell tumors are larger with cystic components. They may have calcifications. These tumors are more commonly malignant.

Evaluation and Treatment

If a functioning islet cell tumor is suspected, often, contrast enhanced CT or MRI is useful. These tumors enhance rapidly and rapidly wash out. They may appear bright on T2 MRI. MRI and CT are useful to detect ectopic or multiple locations of islet cell tumors. Surgical resection is the treatment of choice. Intraoperative ultrasound is very useful in detection of small islet cell tumors.

More recently there have been publications demonstrating the feasibility and potential of contrast-enhanced ultrasound (CEUS) in preoperative detection of insulinomas. Furthermore, some studies have shown that adenocarcinomas appear as a hypoenhancing pattern using CEUS. This is in distinction to neuroendocrine pancreatic tumors that have a hyperenhancing pattern. Thus, CEUS is valuable in differentiating adenocarcinomas from NETs.

More recently, there has been use of radiofrequency ablation (RFA) in treatment of some NETs. It is felt that percutaneous RFA is a safe and effective option for very small NET.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 185–186.

CASE 67

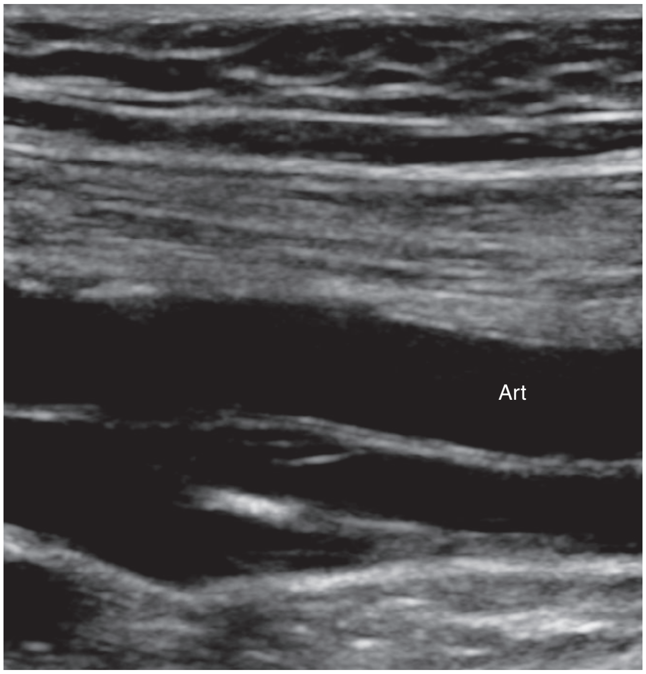

Figure 67-1

Figure 67-2

HISTORY: A female with remote history of deep venous thrombosis (DVT) presents with intermittent right leg pain and swelling. Long axis and short axis images of the femoral vein were taken as part of a venous ultrasound study.

1. What is the diagnosis?
   A. Acute DVT
   B. Residual venous thrombosis
   C. Recurrent DVT
   D. Superficial thrombophlebitis
2. Six months after an acute DVT, gray scale findings include all EXCEPT:
   A. Normal vein
   B. Free-floating intraluminal material
   C. Flat intraluminal material
   D. Wall thickening
3. Regarding Virchow's triad, which of the following is true?
   A. It describes the pretest probability for DVT.
   B. It describes the three indications for an inferior vena cava filter.
   C. It includes vein wall injury.
   D. It includes von Willebrand factor.
4. Scarring in the vein may indicate which of the following?
   A. Anticoagulation has been ineffective.
   B. Anticoagulation must be continued.
   C. The patient is at risk for future DVT.
   D. The patient has had a pulmonary embolism.

See Supplemental Figures section for additional figures and legends for this case.

CASE 67

Residual Venous Thrombosis

1. **B.** Residual venous thrombosis (scarring) is correct. There are thin and thick webs of tissue in the femoral vein which are flat with a long attachment to the posterior vein wall (Fig. S67-1). Residual venous thrombosis is the term used in the internal medicine literature; other descriptions are chronic DVT or scarring. The material inside the vein is not acute; the material is flat, indicating retraction rather than the smooth round material that is typical of acute DVT. Recurrent DVT indicates new acute DVT after a prior episode. The femoral vein is deep, and superficial thrombophlebitis does not apply.
2. **B.** Free-floating intraluminal material is indicative of acute DVT and is not present months after the acute DVT. Flat material may be present after healing but it is typically immobile. As the vessel recanalizes, wall thickening may result. In at least half of cases there is complete resolution of DVT.
3. **C.** Virchow's triad includes vein wall injury. The triad includes the three major risk factors that predispose to DVT; the other two are stasis and hypercoagulability. Wells' criteria describe the pretest probability for DVT.
4. **C.** Scarring in the vein may indicate the patient is at risk for future DVT. Scarring may be a factor to decide to continue anticoagulation, but it is not the only criterion. Scarring and pulmonary embolism are unrelated. Anticoagulation does not eliminate the risk of residual venous thrombosis after an acute episode.

Comment

Pathophysiology

As soon as deep venous thrombosis (DVT) is formed, the body begins to lyse it. In around 50%, there is no residua at 6 months. In the rest there is scarring. After several weeks, the thrombus has evolved to a fibrin scar. This residual material has several terms: the internal medicine literature calls this residual venous thrombosis. Chronic venous thrombosis and scar are other terms. The residual material can be a nidus for future acute DVT (recurrent DVT).

DVT can embolize, or be lysed. If the breakdown is central, there will be wall thickening over all or part of the wall. The residual material becomes firmly attached to the vein wall as it ages. If the edges are lysed, the residual material will be attached to one wall. The material is frequently irregular.

Imaging Findings

Both acute DVT and scar have intraluminal material and therefore have noncompressible veins (Figs. S67-2 and S67-3). The conditions can be differentiated in the vast majority of cases by their appearance. If there has been recanalization, the only finding may be a thickened wall, often circumferentially thick (Fig. S67-4). In retraction, the material in the vein is usually irregular (Fig. S67-1). The residual material is firm during compression, and therefore it is not deformable (most acute DVT is soft, deformable, and smooth). The residual material may be reduced to a thin fibrin line (also called a synechia or web) or a thick band which is immobile (Fig. S67-1). In all cases, the material is firmly attached to the wall.

Treatment and Follow-up

Residual VT is frequently seen because patients with prior DVT may have new symptoms. The symptoms may be due to recurrent DVT but can be from edema, chronic venous insufficiency, or other causes. The identification of scar is important but does not mandate anticoagulation. It does identify a patient for recurrent DVT in the future. If the diagnosis of scarring is uncertain, short-term follow-up may be considered to confirm the appearance is chronic, arguing against acute DVT.

Reference

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 274–276.

CASE 68

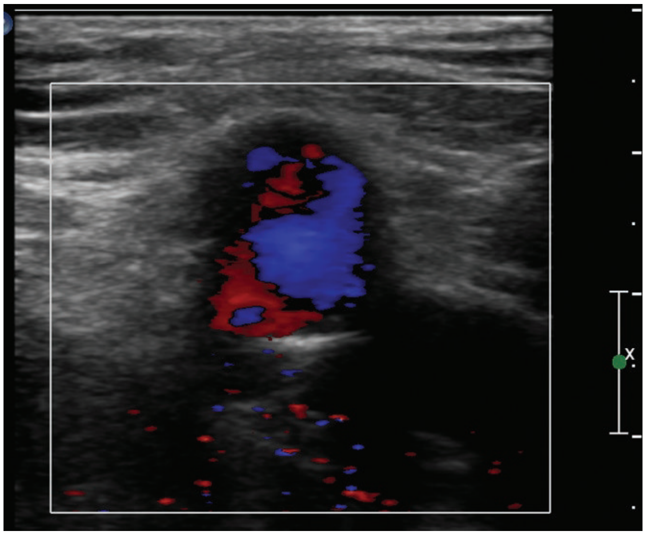

Figure 68-1

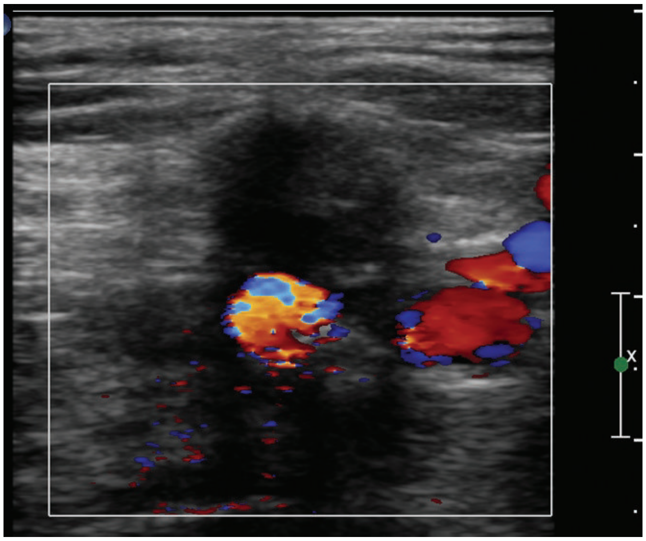

Figure 68-2

HISTORY: A patient presents with a groin abnormality after angiography catheterization. Two color images were taken seconds apart.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply)
   A. Thrombin injection of pseudoaneurysm
   B. Pseudoaneurysm during diastole
   C. Ultrasound-guided compression repair
   D. Arteriovenous fistula
2. Complications of thrombin injection include all of the following EXCEPT:
   A. Arterial embolization
   B. Arterial thrombosis
   C. Arteriovenous fistula
   D. Abscess
3. Failure to treat a pseudoaneurysm with thrombin may indicate which of the following?
   A. Long neck
   B. Arterial laceration
   C. Inactivation of thrombin by the patient
   D. Use of local anesthesia prior to treatment
4. Regarding treatment of pseudoaneurysms, which of the following is true?
   A. Brachial artery pseudoaneurysms should not be treated with thrombin.
   B. A potentially infected pseudoaneurysm should not be treated with thrombin.
   C. Patients with failed thrombin injection should undergo ultrasound-guided compression repair.
   D. A pseudoaneurysm complicated by nerve compression should undergo stat thrombin injection.

See Supplemental Figures section for additional figures and legends for this case.

CASE 68

Thrombin Injection of Pseudoaneurysm

1. **A.** Thrombin injection of pseudoaneurysm is the most likely. There is a flow in a rounded structure in Figure S68-1. Seconds later there is no flow in the structure that is seen above the artery and vein (Fig. S68-2). Ultrasound-guided compression repair takes minutes rather than seconds to close a pseudoaneurysm. There is generally some flow in the pseudoaneurysm during diastole. An arteriovenous fistula has flow throughout the cardiac cycle as well.

2. **C.** Arteriovenous fistula does not complicate thrombin injection because the needle is not placed through a vein. Complications are rare but include arterial embolization of the thrombin distally in the leg, arterial and venous thrombosis, and abscess.

3. **B.** Failure to treat a pseudoaneurysm with thrombin may indicate there is a larger than usual hole in the vessel. The size of the neck is not related to treatment failure. The patient does not inactivate thrombin. Some, but not all, who treat pseudoaneurysm with thrombin, use local anesthesia, but it does not affect the success of the procedure.

4. **B.** Potentially infected pseudoaneurysms should generally undergo surgical exploration and repair. Nerve compression should also undergo surgery to repair the pseudoaneurysms and decompress the affected tissue and should be suspected when pain is out of proportion to the ultrasound findings. Brachial artery pseudoaneurysms can be treated by thrombin injection. Because ultrasound-guided compression repair is less successful than thrombin, it is generally not performed after thrombin has failed. Some use compression repair as a first-line treatment and use thrombin after a failed attempt.

Comment

Pseudoaneurysms are typically created after penetrating injury and are most frequently iatrogenic, typically after therapeutic or diagnostic angiography. Small pseudoaneurysms may close spontaneously but several methods of closure are available. Ultrasound-guided compression over the neck involves compression to occlude the pseudoaneurysm for 10 minutes. If still untreated, the procedure can be repeated. Compression is less likely to work if the patient is anticoagulated.

Thrombin injection into the pseudoaneurysm is effective (Figs. S68-1 and S68-2). Thrombin injection has a primary closure rate of 95% to 98%.

The volume of thrombin used is quite small, less than 1 mL. It is placed in the pseudoaneurysm away from the neck and injected (Fig. S68-3). Thrombosis occurs seconds after the injection. If a portion persists, targeted injection can be repeated in the residual area of flow. Color is typically turned off to position the needle tip and turned on after injection to document thrombosis. This is an off-label use of the agent but it has become the first treatment in many centers. Some (less than 10%) pseudoaneurysms will recur after treatment, and follow-up scans, typically after 1 day, are performed to confirm closure. Endovascular or surgical repair is available for those patients who fail thrombin injection.

Some conditions favor surgical treatment over percutaneous repair. If there is a concomitant arteriovenous fistula, thrombin injection may cause thrombin to enter the venous system and cause venous thrombosis or pulmonary embolism. It is, therefore, prudent to check for a fistula prior to repair. Rapidly expanding pseudoaneurysms are usually treated surgically as well. Infected pseudoaneurysms can occur and have been associated with skin tracking of bacteria from some closure devices. If infection is suspected, open repair is warranted to prevent rupture and abscess. Compression syndrome is rare but surgery is generally performed. Treatment above the inguinal ligament may be treated percutaneously with caution because compression is not available if bleeding occurs in the retroperitoneum.

In those patients who fail thrombin injection, one group found lacerations in the artery that were larger than usual. An occult infection should also be considered if thrombin fails.

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Tisi PV, Callam MJ. Treatment for femoral pseudoaneurysms. *Cochrane Database Syst Rev.* 2013;11:CD004981.

Cross-reference

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CASE 69

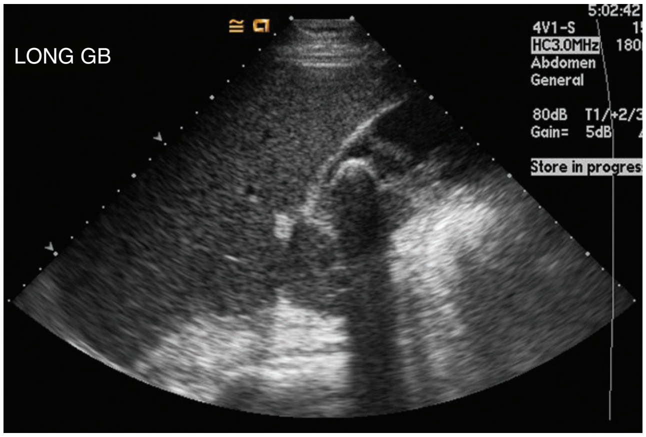

Figure 69-1

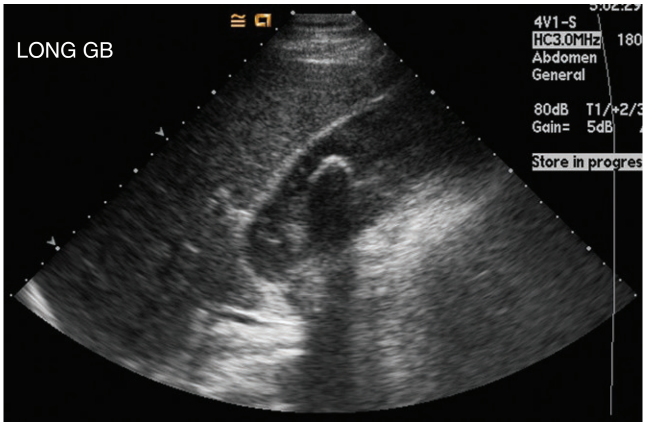

Figure 69-2

HISTORY: A 38-year-old male presents with right upper quadrant pain.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply)
   A. Emphysematous cholecystitis
   B. Gallstones
   C. Acute calculous cholecystitis
   D. Porcelain gallbladder
2. Cholesterol stones constitute approximately what percentage of gallstones?
   A. 20%
   B. 40%
   C. 80%
   D. 95%
3. Which imaging feature would not be compatible with a diagnosis of gallstones?
   A. Mobility on patient repositioning
   B. Posterior acoustic shadowing
   C. Vascularity on Doppler ultrasound
   D. Highly reflective anterior surface
4. Which of the following is not a risk factor associated with gallstone formation?
   A. Advanced age
   B. Male gender
   C. Obesity
   D. Parenteral nutrition

See Supplemental Figures section for additional figures and legends for this case.

CASE 69

Gallstones

1. **B and C.** Gallstones, biliary sludge, and mild gallbladder wall thickening are present. There is no dirty shadowing (curvilinear gas in the gallbladder wall) suggestive of emphysematous cholecystitis, or dense posterior acoustic shadowing of the gallbladder wall suggestive of porcelain gallbladder.
2. **C.** Approximately 75% of gallstones are cholesterol stones. Approximately 25% are calcium-bilirubinate stones.
3. **C.** Vascularity within an echogenic structure in the gallbladder would indicate perfused soft tissue and would be concerning for gallbladder carcinoma or polyp.
4. **B.** Female gender, not male, is associated with gallbladder formation. Women are thought to be more at risk due to estrogen's effect on the liver, causing it to remove more cholesterol from blood and secrete it in the bile.

Comment

Ultrasound Findings

The principal ultrasound imaging features of gallstones (Figs. S69-1 and S69-2) are: (1) highly reflective anterior surface, (2) posterior acoustic shadowing, and (3) mobility on patient repositioning. They may also demonstrate twinkle artifact on Doppler imaging; however, this is a less reliable and nonspecific finding. If a large gallstone occupies the gallbladder, the wall-echo-shadow sign may be encountered. This sign describes visualization of the gallbladder *wall*, an *echo* representing the highly reflective anterior surface of the gallstone, and the posterior acoustic *shadow* of the large gallstone. The wall-echo-shadow sign should be contrasted against the imaging findings of porcelain gallbladder, in which only a highly echogenic wall with dense posterior acoustic shadowing is seen.

Differential Diagnosis

Major differential considerations for gallstones include sludge balls and gallbladder polyps. Sludge balls can be mobile like gallstones, but unlike gallstones, would not typically cast a posterior acoustic shadow or demonstrate a highly reflective anterior surface. Sludge balls also tend to be larger than most gallstones. A small sludge ball would be difficult to distinguish from a gallstone, as small gallstones less than 5 mm do not tend to shadow. Gallbladder polyps are protrusions of soft tissue adherent to the gallbladder wall and do not move or shadow like gallstones. They tend to be hypovascular, so lack of vascularity on Doppler imaging would still be consistent with this diagnosis.

Prognosis

Gallstones are extremely common, especially in middle-aged, obese females. They are frequently also asymptomatic, and in that case require no specific management. Gallstones can present with several complications, including biliary colic due to passing of small stones through the cystic duct, acute cholecystitis, and chronic cholecystitis. Rarely, gallstones near the neck of the gallbladder can compress the common bile duct causing function obstruction, a clinical entity known as Mirizzi syndrome. Laparoscopic cholecystectomy is the most frequent definitive treatment for these ailments.

Reference

Bortoff GA, Chen MY, Ott DJ, Wolfman NT, Routh WD. Gallbladder stones: imaging and intervention. *Radiographics*. 2000;20(3):751–766.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 32–39.

Acknowledgment

Special thanks to Michael Jin, MD, for preparation in this case.

CASE 70

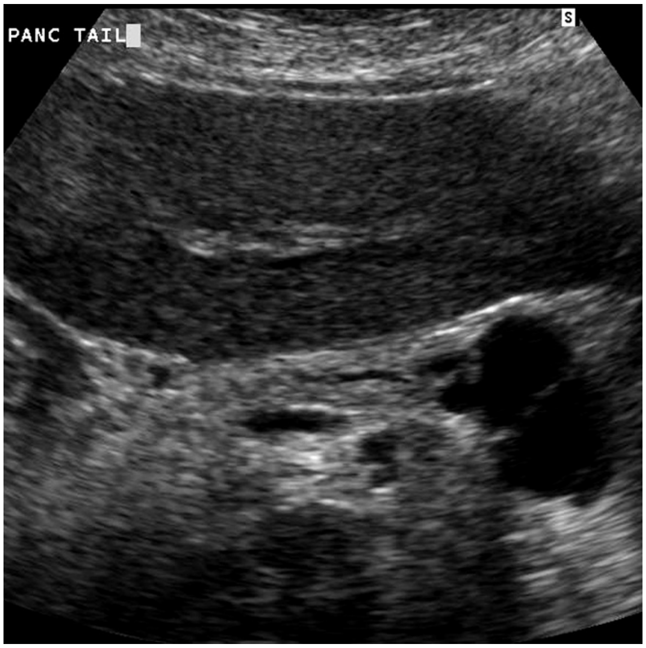

Figure 70-1

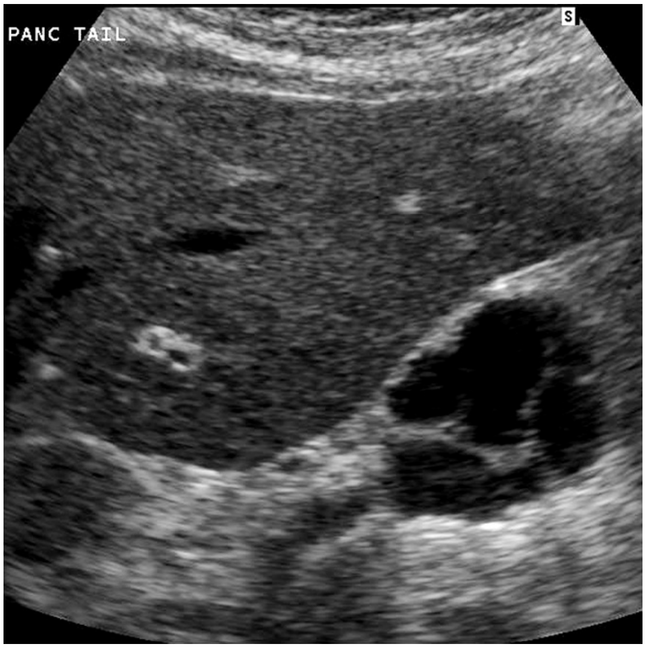

Figure 70-2

HISTORY: A 60-year-old female complains of abdominal pain and has an ultrasound of the upper abdomen.

1. Which one of the following would be included in the differential diagnosis for the imaging findings presented in Figures 70-1 and 70-2? (Choose one)
   A. Pancreatic pseudocyst
   B. Nonfunctioning islet cell tumor
   C. Mucinous cystic neoplasm (MCN) of the pancreas
   D. Serous cystadenoma of the pancreas
2. Which one of the following statements best describes MCNs?
   A. They are multiple.
   B. They have cysts less than 1 cm in diameter.
   C. They are potentially malignant.
   D. They should always have percutaneous biopsy.
3. Which one of the following statements best describes MCNs?
   A. They often have central calcifications.
   B. They occur most commonly in men.
   C. They rarely occur in the head of the pancreas.
   D. They never have mural nodules.
4. Concerning MCNs, all are true statements EXCEPT:
   A. They are usually 6 to 10 cm at the time of discovery.
   B. They may degenerate into mucinous cystadenoma carcinomas.
   C. They rarely need surgical excision.
   D. They are pathologically similar to ovarian mucinous neoplasms.

See Supplemental Figures section for additional figures and legends for this case.

CASE 70

MCN of the Pancreas

1. **C.** Either A or C could be considered, although with the numerous septations, an MCN seems most likely. A nonfunctioning islet cell is usually solid but may display some cystic components with necrosis. A serous cystadenoma of the pancreas has multiple small cysts but appears solid on ultrasound and may have a central calcification.
2. **C.** These tumors are usually single with multiple large locules and are potentially malignant. Most advocate endoscopic cyst aspiration rather than percutaneous cyst aspiration/biopsy.
3. **C.** These usually occur in the body and tail of the pancreas. They rarely occur in the head of the pancreas. When there are mural nodules, this may increase the frequency of malignancy. Central calcification adenomas are rare. MCNs are more common in women.
4. **C.** All are true statements except C. These tumors are not always malignant, but if the patient condition permits, surgical resection is the treatment of choice.

Comment

Differential Diagnosis

The differential diagnosis is rather limited. It could include a pancreatic pseudocyst with septations. Patients with von Hipple-Lindau disease with multiple pancreatic cysts could be considered. Other congenital pancreatic cysts may be included within the differential. Autosomal, dominant, polycystic disease is associated with pancreatic cysts. Intraductal papillary mucinous neoplasms (IPMN) are usually smaller but could be considered. Mucinous neoplasms seem the most likely diagnosis. A necrotic islet cell tumor may also be considered.

Sonographic Features

Typically these masses are most commonly located in the tail of the pancreas. Rarely may they appear as a unilocular anechoic mass. More commonly they appear as a multiloculated cystic mass with clearly echogenic internal septations (Figs. S70-1 and S70-2). They appear cystic with multiple septations with locules greater than 2 cm in diameter. They almost always occur in women at a mean age of 45 years old. They have a malignant potential.

Management

Treatment is usually directed at surgical resection of these potentially malignant neoplasms. Percutaneous biopsy is usually avoided as it may cause spillage of mucin into the peritoneal cavity. This may cause pseudomyoma peritonel; most advocate endoscopic cyst aspiration in equivocal cases. Evaluation and management of incidental pancreatic cysts are very complex. Magnetic resonance imaging (MRI) may be performed to see if the cyst connects to the pancreatic duct; if this occurs, this would be a side branch IPMN. The American College of Radiology has specific guidelines for an incidental pancreatic cyst usually identified on CT or MRI. If less than 2 cm, a 1-year follow-up with an MRI is recommended. If a cyst is 2 to 3 cm, then follow-up in 6 months to 2 years is recommended depending on the cyst's features. There are different recommendations including aspiration or removal of cysts greater than 3 cm in diameter.

References

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 186–190.

CASE 71

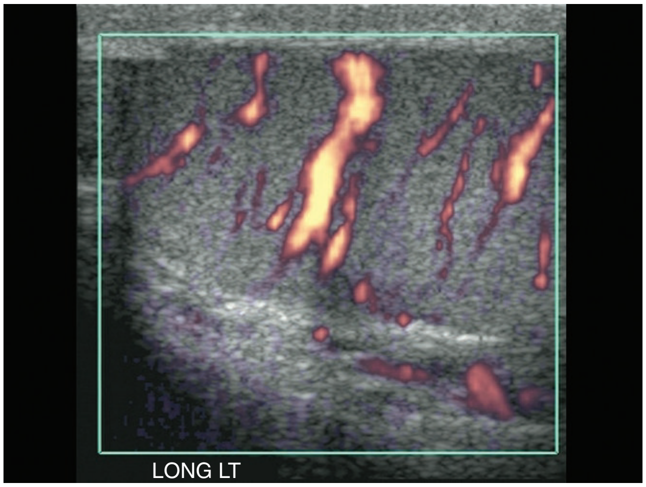

Figure 71-1

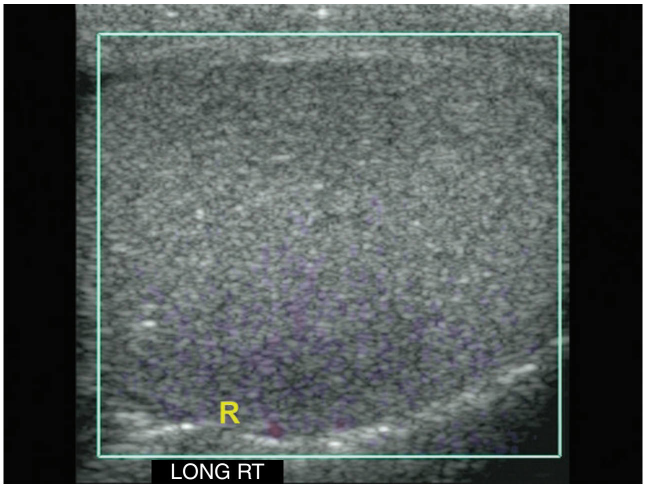

Figure 71-2

HISTORY: A 20-year-old male presents with right scrotal pain.

1. Which one of the following would be included in the differential diagnosis for the imaging findings presented in Figures 71-1 (left testis) and 71-2 (right testis)? (Choose one)
   A. Diffuse lymphoma
   B. Acute epididymal orchitis
   C. Acute testicular torsion
   D. Seminoma

2. Which of the following statements concerning patients who present with testicular torsion is NOT true?
   A. They usually experience pain.
   B. They may have swelling of the scrotum.
   C. They may have associated nausea and vomiting.
   D. They are usually "febrile."

3. Which of the following statements concerning testicular torsion is NOT true?
   A. It may be associated with torsion and detorsion of the testis.
   B. There can be incomplete torsion of the testes.
   C. Manual detorsion can be performed in cases of torsion of the testes.
   D. Torsion is not due to a congenital anatomical variation.

4. What is the most specific finding in acute testicular torsion?
   A. A small reactive hydrocele
   B. Thickening of the scrotal wall
   C. Diminished or absent color flow to the testis
   D. Diffuse enlargement of the testis

See Supplemental Figures section for additional figures and legends for this case.

CASE 71

Complete Testicular Torsion

1. **C.** In the early stages of acute testicular torsion, the symptomatic testes may appear fairly normal in appearance on gray scale images. However, there would be decreased color flow to the affected testis. This should be the best answer.
2. **D.** Unlike patients with epididymo-orchitis, these patients usually do not have a fever.
3. **D.** Usually the testis is anchored to the wall of the scrotum by a broad posterior attachment. When this does not occur, this is called "bell clapper" deformity and is a congenital variant. In this situation, the testis attachment to the scrotal wall is absent, thus making the testis susceptible to torsion.
4. **C.** This is the most specific finding in acute testicular torsion. The testes are examined on ultrasound side by side with color flow to ensure there is no technical parameter that may cause misdiagnosis of decrease or absent testicular flow.

Comment

Differential Diagnosis

The differential diagnosis for acute scrotal pain is broad. Torsion of the testicular appendix of the epididymis usually occurs in younger boys from ages 7 to 14. Clinically, it may mimic testicular torsion. Testicular torsion usually occurs in prepubertal boys or young adults. While most testicular torsion occurs between the ages of 12 and 18, there are a number of reported cases of neonatal testicular torsion. These often occur with an inguinal hernia. Epididymal orchitis would be considered within the differential. However, this usually occurs in older age group patients and has associated increased size of the epididymis and associated increased color flow to the epididymis and sometimes to the testis. Testicular tumors usually are not associated with scrotal pain, and obviously testicular rupture is associated with a history of trauma.

Ultrasound Findings

The most specific finding in testicular torsion is absent or diminishing blood flow to the affected testis on color Doppler. It is important to remember to examine the testes side by side to ensure there is no technical etiology for decreased or increased color flow (Figs. S71-1 and S71-2). Color Doppler ultrasound is extremely important for examining the asymptomatic testis first. This will serve as a baseline for assessment of color flow within the testis in which there is scrotal pain. Furthermore, power Doppler ultrasound can be combined with color Doppler ultrasound in accessing flow to the testes. Finally, some have advocated the use of a contrast agent to better assess flow to the testes. The affected testis itself may appear normal initially, but by 6 hours it usually becomes enlarged and later has a heterogeneous appearance. Finally, testicular infarction occurs. Focal ischemia of the testis can lead to a focal hypoechoic region, usually in the superior pole of the testis. This is a segmental infarction and may be difficult to exclude from true neoplasm or masses within the testis. Hydrocele and scrotal thickening are usually present with testicular torsion, but are nonspecific findings. Initially, there may be a "whirlpool" pattern identified within the spermatic cord, due to the rotation of the cord leading to torsion. This can also cause a lump within the cord or a "torsion knot." Sometimes, this can be difficult to exclude from an enlarged epididymal head.

Prognosis/Management

It is important to make this diagnosis rapidly. If the diagnosis is made within 6 hours, the testis may be salvaged. If between 6 and 24 hours it may be partial infarct of the testes. The longer the torsion remains, the greater the chance of complete testicular infarction.

Manual detorsion can be performed (Fig. S71-3). After obtaining an image of the right testis as seen in Figure S71-2, manual detorsion was performed and these images were obtained 3 minutes apart (Fig. S71-3). There is the return of color flow. However, the "bell clapper" deformity persists and the testis hanging by a cord can again rotate or torse. Thus, definitive treatment is surgical correction of this deformity. Surgery can include orchiopexy of the affected testis. However, if in fact there appears to be testicular infarction, orchiectomy is performed. In some cases, contralateral orchiopexy is performed as it is thought that this may be a bilateral congenital anomaly.

References

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Cross-reference

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CASE 72

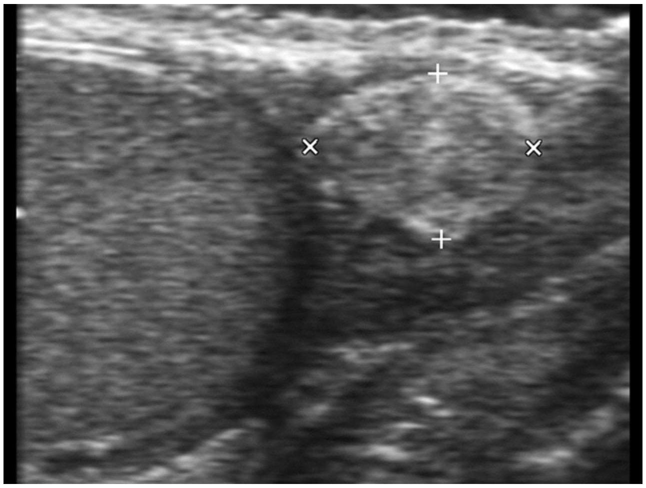

Figure 72-1

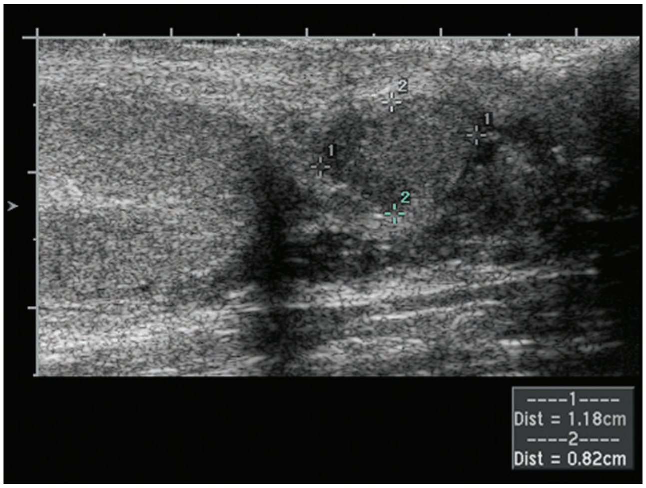

Figure 72-2

HISTORY: Two different 30-year-old males present with extra testicular palpable masses, shown in Figures 72-1 and 72-2.

1. Which one of the following would be included in the differential diagnosis for the imaging findings shown in this case? (Choose all that apply)
   A. Fibrous pseudotumor
   B. Sperm granulomas
   C. Adenomatoid tumor
   D. Extra testicular lipoma
   E. Liposarcoma
2. What is the most common location for adenomatoid tumor?
   A. The epididymal head
   B. The epididymal body
   C. The epididymal tail
   D. The testes
3. Concerning the ultrasound appearance of adenomatoid tumors, all of the following statements are true EXCEPT:
   A. They are usually homogenous.
   B. They are usually small.
   C. They have variable echogenicity and are most often hypoechoic to the testes.
   D. They often have calcifications.
4. Concerning extra testicular tumors, all of the following statements are true EXCEPT:
   A. Lipomas are the most common extra testicular tumors.
   B. Adenomatoid tumors are the most common epididymal tumors.
   C. Most extra testicular neoplasms are benign.
   D. These tumors do not extend to the testes.

See Supplemental Figures section for additional figures and legends for this case.

CASE 72

Adenomatoid Tumor

1. **A, B, C, and D.** Adenomatoid tumor certainly would be considered within the differential diagnosis of an extra testicular mass. A fibrous pseudotumor, representing reactive fibrosis related to inflammation and a sperm granuloma could be considered. Lipoma seems less likely, but is possible for Figure S72-1. Liposarcoma would not be as well circumscribed.
2. **C.** This is the most correct answer. Most are in the epididymal tail, but they can be in other locations.
3. **D.** This is not a true statement, as they rarely have calcifications. The other statements are true.
4. **D.** Most occur within the epididymis; they rarely occur in the tunica albuginea or the tunica vaginalis of the testes. When this occurs, it is very difficult to separate these masses from the testis. Lipomas are the most common extra testicular tumors, and adenomatoid tumors are the most common epididymal tumors.

Comment

Differential Diagnosis

The differential diagnosis of a solid extra testicular mass is broad. Extra testicular lipomas are the most common extra testicular masses. Adenomatoid tumors represent 30% of all extra testicular masses and usually arise from the epididymis. However, there are other benign tumors of the spermatic cord besides lipomas, including leiomyomas, lymphangiomas, and dermoids. These masses are much less common. Sperm granulomas and fibrous pseudotumor can also be considered in the differential. Epididymitis with diffuse enlargement of the epididymis certainly can be considered in the differential. There are malignant extra testicular tumors that could include metastases and various sarcomas of the spermatic cord. These are rarer and often more extensive.

Ultrasound Findings

Adenomatoid tumors usually are small extra testicular masses. Most are hypoechoic although they have been reported to be isoechoic or even hyperechoic to the testes (Figs. S72-1 and S72-2). Usually they are adjacent to the lower pole of the testes as they arise from the tail of the epididymis. They are thought to be of mesothelial origin and are diagnosed usually in patients 20 to 50 years of age. Typically they are unilateral.

Prognosis/Management

Magnetic resonance imaging has been advocated to help diagnose some cases. In most cases, conservative management is the treatment of choice. However, in tumors arising from tunica albuginea that may have the appearance of a testicular mass and a wedge of the testis, resection can be performed in lieu of radical orchiectomy.

References

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Park SB, Lee WC, Kim JK, et al. Imaging features of benign solid testicular and paratesticular lesions. *Eur Radiol*. 2011;21(10):2226–2234.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 149–153.

CASE 73

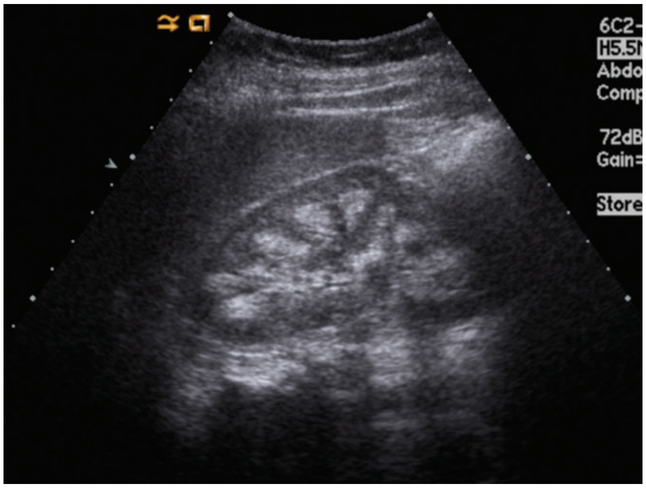

Figure 73-1

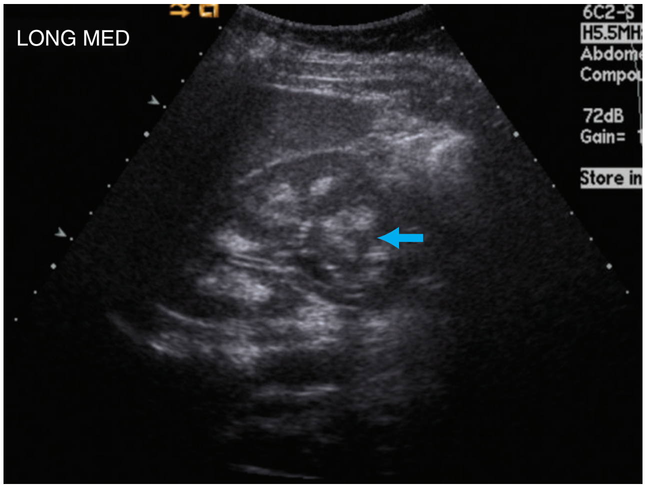

Figure 73-2

HISTORY: A 45-year-old male presents with renal failure. Lab analysis demonstrated hypercalcemia. (Choose one)

1. Which one of the following would be included in the differential diagnosis for the imaging findings presented?
   A. Renal sinus fat
   B. Medullary nephrocalcinosis
   C. Renal stones
   D. Lymphoma
2. Which of the following is a common etiology for this condition?
   A. Medullary sponge kidney
   B. Renal tubular acidosis
   C. Hyperparathyroidism
   D. All of the above
3. In this condition, where does the increased echogenicity begin in early stages of the disease?
   A. Periphery of the pyramids
   B. Center of the pyramids
   C. Entire pyramid is simultaneously involved
   D. Renal cortex
4. Which of the following is the most sensitive modality for detecting this condition?
   A. Abdomen radiographs
   B. Ultrasound
   C. Computed tomography (CT)
   D. Magnetic resonance imaging

See Supplemental Figures section for additional figures and legends for this case.

CASE 73

Medullary Nephrocalcinosis

1. **B.** Increased echogenicity of the renal pyramids is seen with medullary nephrocalcinosis. Normal pyramids are slightly hypoechoic compared to renal parenchyma (cortex). The renal sinus fat is the most echogenic structure in the kidney, but it is not located in this region. Renal stones are asymmetrical. Lymphoma presents as an isoechoic mass.
2. **D.** Medullary sponge kidney, hyperparathyroidism, and renal tubular acidosis are the top three causes of medullary nephrocalcinosis.
3. **A.** Early stages of the disease demonstrate increased echogenicity at the periphery and tip of the pyramids, progressing to involve the entire pyramid. With advanced disease, shadowing begins to develop.
4. **B.** Ultrasound is extremely sensitive in detecting medullary nephrocalcinosis, with the changes detectable earlier than on radiographs and more dramatic than on CT, for similar stages of disease.

Comment

Differential Imaging Findings

The differential diagnosis in this case is fairly straightforward. Renal pelvic lipomatosis and/or renal sinus fat appear more centrally within the kidney area. Increased echogenicity within the medullary pyramids is classic for medullary nephrocalcinosis. If severe, there may be accompanying calcifications which can be identified on ultrasound as acoustic shadowing. Nephrolithiasis is the occurrence of distinct renal stones buried within the renal collecting system.

Imaging Modalities/Treatment

Medullary nephrocalcinosis presents with increased echogenicity of the renal pyramids (Figs. S73-1 and S73-2). In a normal adult kidney, renal sinus fat is the most echogenic structure. Normal pyramids are hypoechoic to anechoic compared to the renal cortex. Calcium deposition in the pyramids with medullary nephrocalcinosis leads to progressively increased echogenicity, which begins at the tip and the periphery of the pyramids. It eventually progresses to involve the entire pyramid, and shadowing develops with advanced disease.

Management/Treatment

Ultrasound is exquisitely sensitive for early detection of medullary nephrocalcinosis, and findings precede those seen with radiographs. For a similar stage of disease, findings are more profound compared to CT. The best way to detect medullary nephrocalcinosis on ultrasound is to perform a longitudinal view of the kidney just lateral to the renal sinus to aid differentiation from echogenic renal sinus fat. In some cases, medullary nephrocalcinosis can be identified on plain films (Fig. S73-3). In adults, medullary sponge kidney, hyperparathyroidism, and renal tubular acidosis are the top three causes of medullary nephrocalcinosis. Other less common causes include milk alkali syndrome, sarcoidosis, and hypervitaminosis D. In neonates and infants, furosemide use is a common cause of medullary nephrocalcinosis. Ancillary findings, such as the "paintbrush" appearance of the pyramids (Fig. S73-4) on a CT urogram, as seen in medullary sponge kidney, may provide diagnostic clues. Treatment is focused on the underlying etiology of this nephrocalcinosis.

References

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Glazer GM, Callen PW, Filly RA. Medullary nephrocalcinosis: sonographic evaluation. *Am J Roentgenol.* 1982;138:55–57.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 130–132.

Acknowledgment

Special thanks to Priyanka Jha, MD, for preparation of this case.

CASE 74

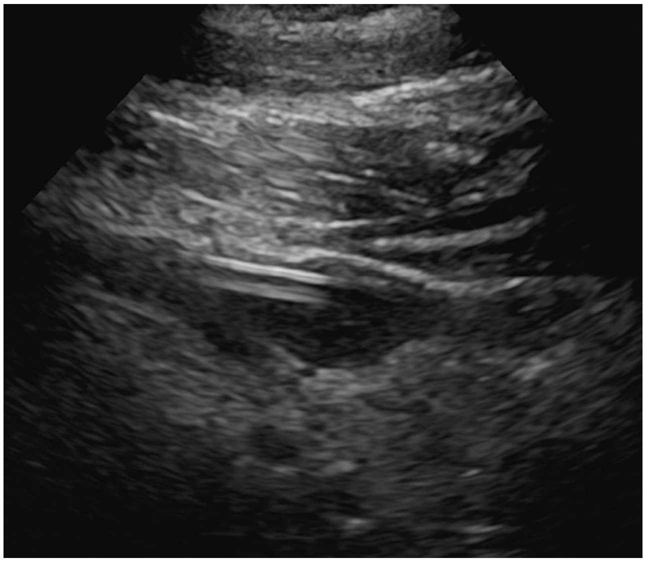

Figure 74-1

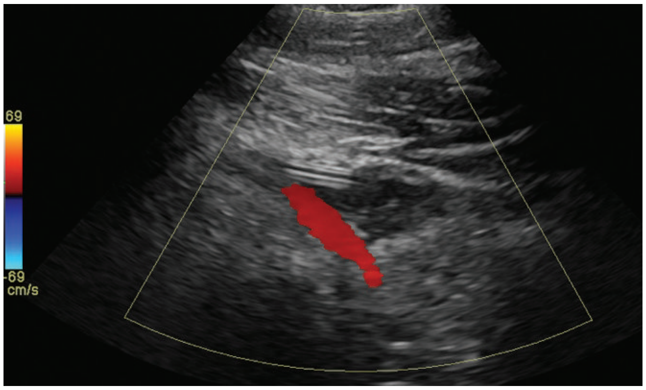

Figure 74-2

HISTORY: A 33-year-old with a left peripherally inserted central catheter line for long-term antibiotics presents with left arm swelling. A left upper extremity venous ultrasound was performed including gray scale and color Doppler of the mid left subclavian vein.

1. What is the diagnosis?
   A. Patent subclavian vein and central line
   B. Subclavian vein acute deep venous thrombosis (DVT) and occlusion
   C. Central line and subclavian scarring
   D. Metastatic lymphadenopathy compressing subclavian vein
2. What does the colored vein in Figure 74-2 represent?
   A. Subclavian vein
   B. Subclavian artery
   C. Collateral vein
   D. Axillary vein
3. With what is upper extremity DVT most commonly associated?
   A. Hypercoagulable state
   B. Central venous lines
   C. Upper extremity exercise
   D. Bed rest
4. Etiologies for a mass effect on the upper extremity vein include all of the following EXCEPT:
   A. Metastatic breast cancer
   B. Lung cancer
   C. Subclavian DVT
   D. Neurofibromatosis

See Supplemental Figures section for additional figures and legends for this case.

CASE 74

Upper Extremity Deep Venous Thrombosis

1. **B.** The subclavian vein is distended (Fig. S74-1) and contains low-level echoes indicating acute DVT rather than scarring. There is no flow in it by color Doppler (Fig. S74-2), indicating occlusion. While there is a central line, the vein is not patent. There is no compression on the vein.
2. **C.** There is a vein that comes into the subclavian vein and flow is medial to the DVT. It is not oriented in the same plane as the subclavian artery or vein and enters from the soft tissues of the chest. It is too medial for the axillary vein which lies to the right of the image.
3. **B.** Although hypercoagulable states, upper extremity exercise, and bed rest and stasis are associated with upper extremity DVTs, more upper extremity DVTs are associated with central lines due to stasis and vein damage the lines create. Patients getting lines may also have hypercoagulable states (e.g., cancer).
4. **C.** DVT does not produce a mass effect on the vein. There are many tissues in contact with the upper extremity veins; therefore, metastases, lymphadenopathy, apical lung tumors, and nerve masses may create mass effects on one or more upper extremity veins.

Comment

Presentation

Central upper extremity thrombosis was originally described from effort-induced thrombosis (Paget-von Schroetter syndrome) from excessive use of the arm in susceptible individuals. Upper extremity thrombosis is increasing due to more widespread use of indwelling catheters (e.g., for chemotherapy, total parenteral nutrition, and hemodialysis). Catheters cause venous damage and stasis. Individuals getting these lines may have a hypercoagulable state. Hypercoagulable states alone can cause upper extremity thrombosis.

Symptoms

Pain and swelling in the affected arm is typical when the subclavian and axillary veins are affected. Symptoms occur soon after the thrombosis but may be absent. Signs such as edema in the arms and hand or dilatation of subcutaneous veins over the chest and upper arm may be present. Pulmonary embolism may occur but is less frequent than from lower extremity DVT. If left untreated, venous obstruction may be associated with long-term pain and disability.

Imaging Findings and the Upper Extremity Venous Examination

Venous thrombosis is diagnosed using gray scale (Figs. S74-1 and S74-3), color (Figs. S74-2 and S74-4), and spectral Doppler.

In the central veins that can be compressed (the internal jugular, peripheral subclavian, and axillary veins), complete compression of the vein should be documented by gray scale images without and with probe compression. The arm veins (cephalic, basilic, and brachial) from axilla to antecubital fossa are also compressed. In veins that cannot be compressed, gray scale evaluation is more important. Intraluminal echoes from thrombus may or may not be appreciated based on the echogenicity of the thrombus (Figs. S74-1 and S74-3). Acute DVT echogenicity is variable (Figs. S74-1 and S74-3). Reverberation and noise may cause artifactual echoes in the veins.

Color is used to show complete filling in all of the central veins, but it is particularly important in veins that cannot be compressed (the mid and central subclavian and innominate veins). A filling defect in the color column is used to diagnose thrombosis (Fig. S74-4) but care must be taken to avoid overdiagnosis (undergained images may not fill the normal vein) and underdiagnosis (overgained images may overwrite abnormal veins). Collateral veins are common in upper extremity DVT with obstruction and may be seen as a vessel with an unusual course (Fig. S74-2).

Spectral Doppler is also used to determine if obstruction is present. Normal veins in the thorax vary with respiration (phasicity) and with the cardiac cycle (pulsatility).

Treatment

For minor symptoms, elevation and rest may be attempted. For the majority, long-term anticoagulation is used. Recurrence and disability are more common if the length of treatment is too short. For some, thrombolysis may be used to restore vein patency. Vein stenting may also be used to maintain patency after thrombolysis if the vein is scarred or small. If the cause is found to be an anatomic anomaly of the subclavius or scalene muscle, cervical rib, or anomalous insertion of the first rib, surgery may be indicated.

Reference

Chin EE, Zimmerman PT, Grant EG. Sonographic evaluation of upper extremity deep venous thrombosis. *J Ultrasound Med*. 2005;24:829–838.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 253–254.

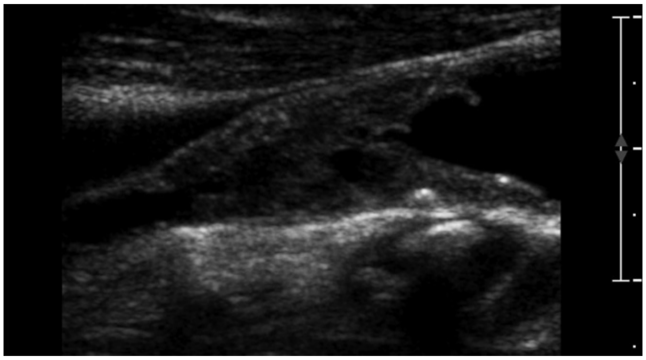

Figure 75-1

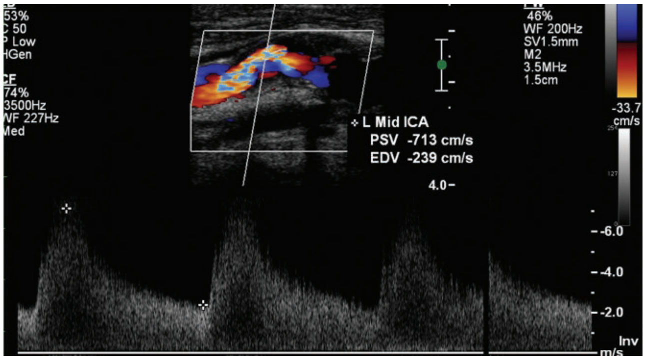

Figure 75-2

HISTORY: The patient is a 70-year-old with a history of hyperlipidemia who was found to have a carotid bruit on physical examination. The patient had no neurological abnormalities.

1. What is the degree of stenosis based on peak systolic velocity (PSV) using Society of Radiologists in Ultrasound (SRU) consensus criteria and North American Symptomatic Carotid Endarterectomy Trial (NASCET) grades?
   A. Mild, less than 50%
   B. 50% to 69%
   C. 70% to near occlusion
   D. Near occlusion
2. Internal to common carotid ratio (IC:CC ratio) is obtained from two measurements. Which of the following is one of the two measurements?
   A. PSV of the internal carotid at its origin
   B. PSV of the internal carotid after the bulb
   C. PSV of the common carotid at its origin
   D. PSV of the common carotid before the bulb
3. Which of the following is true about NASCET grades of carotid stenosis?
   A. Velocities are determined from digital subtraction angiograms.
   B. Near occlusions on ultrasound may have high or low velocities.
   C. The thresholds were determined based on hemodynamic principles.
   D. The measurement includes the minimum diameter of the internal carotid artery (ICA) stenosis as the numerator and the outside diameter of the ICA at that level.
4. Regarding Doppler measurements for stenosis, which of the following is true?
   A. End-diastolic velocities rise before systolic velocities.
   B. Spectral broadening is seen inside the stenosis.
   C. Peak systolic velocities drop after the stenosis.
   D. Tardus parvus waveforms are typical before the stenosis.

See Supplemental Figures section for additional figures and legends for this case.

CASE 75

Internal Carotid Artery Stenosis

1. **C.** There is obvious ICA plaque (Fig. S75-1) and the PSV in the stenosis is markedly elevated to 713 cm/s (Fig. S75-2). This is in excess of the threshold for a greater than 70% stenosis of 230 cm/s in the SRU consensus document. The color lumen is easily filled, although narrow, ruling out a near occlusion.
2. **D.** The numerator of the IC:CC ratio is obtained from the highest velocity in the ICA and may or may not be at its origin. The distal common carotid artery velocity is the denominator and it is obtained before the carotid bulb forms (generally 2 to 3 cm from the bulb). The bulb forms when the common carotid walls are no longer parallel.
3. **B.** The NASCET grades were originally measured on angiograms using length, not velocity. Since then, the grades have been correlated with ultrasounds and other techniques (e.g., computed tomography angiograms). Near occlusions can have high or low velocities with low values particularly when the obstruction is most marked. In all cases, there is little flow and the color and spectral signals are weak. The grades were determined by evaluating outcomes from carotid endarterectomy and were not based on hemodynamics. NASCET measurements use the minimum diameter of the ICA and the ICA diameter distal to the stenosis.
4. **C.** Velocities are high in a stenosis and drop off after the stenosis. Spectral broadening from turbulence is typical beyond the stenosis. Tardus parvus waveforms are seen more distal beyond the stenosis.

Comment

Diagnosis of Carotid Stenosis

The grades of carotid stenosis are taken from NASCET. After angiography, ICA stenoses were measured and divided into grades: less than 50%, 50% to 69% diameter stenosis, 70% to near occlusion, near occlusion, and total occlusion.

There are three modalities in Doppler: gray scale (Fig. S75-1), color Doppler (Fig. S75-3), and spectral Doppler (Figs. S75-2 and S75-4). All should be abnormal to diagnose a stenosis. Most ICA stenosis occurs at its origin and may extend from the distal common carotid artery. A stenotic vessel will demonstrate plaque on gray scale and narrowing on color Doppler. After these are present, spectral Doppler determines the exact amount of stenosis. The highest velocity in the ICA stenosis is used (Fig. S75-2).

The majority of laboratories use PSV as the primary criterion for grading stenosis. ICA stenosis with a PSV greater than 125 cm/s is greater than 50% stenosis and those with PSV greater than 230 cm/s are greater than 70%. Plaque with peak velocities less than 125 cm/s is considered mild. As the degree of stenosis approaches occlusion, the amount of flow in the ICA is diminished and the velocity may initially be high but will drop near occlusion as friction no longer allows velocity to be high.

Other Criteria

The PSV values were chosen at an SRU consensus conference as good starting points. The conference also offered secondary Doppler criteria: the IC:CC ratio and the end-diastolic velocity (EDV). The IC:CC ratio is particularly helpful in situations in which the PSV may be spurious. These include evaluating the ICA contralateral to a high-grade stenosis or occlusion, tandem lesions, and with altered cardiac output. EDV is initially not elevated but does rise in more severe stenosis and is used by some laboratories for greater than 70%.

Management of ICA Stenosis

Symptomatic patients in the NASCET trial with a greater than 70% stenosis were shown to have a benefit from carotid endarterectomy compared with medical management. For those with stenosis from 50% to 69%, the benefit was more marginal. Asymptomatic patients benefit if the stenosis is greater than 60%, although the benefit is less than for symptomatic patients.

Reference

Grant EG, Benson CB, Moneta GL, et al. Carotid artery stenosis: gray-scale and Doppler US diagnosis–Society of Radiologists in Ultrasound Consensus Conference. *Radiology*. 2003;229(2):340–346.

Cross-reference

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CASE 76

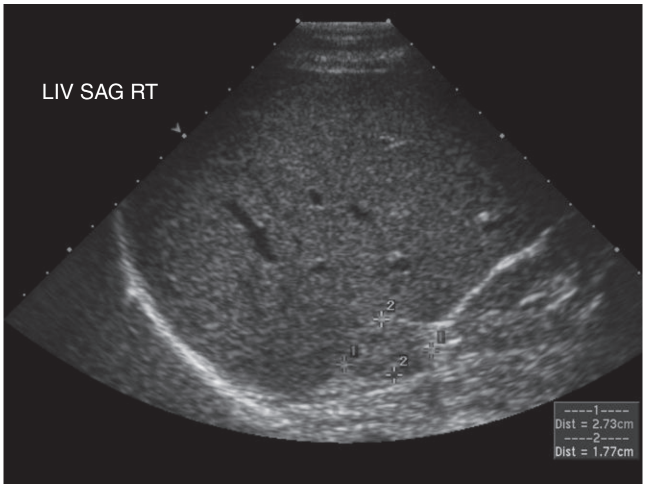

Figure 76-1

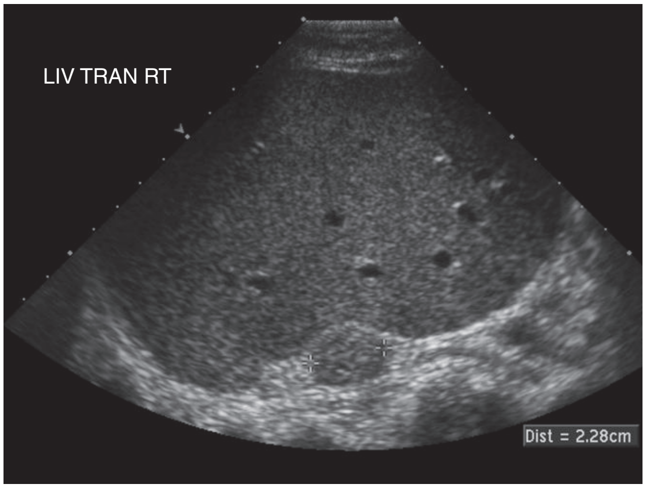

Figure 76-2

HISTORY: A 56-year-old woman is undergoing renal sonography of the right side of the abdomen for an acute kidney injury.

1. Which of the following would be considered on the differential of the longitudinal (Fig. 76-1) and the transverse (Fig. 76-2) images of the right upper quadrant of the abdomen? (Choose all that apply)
   A. Adrenal hemorrhage
   B. Adrenal myelolipoma
   C. Adrenal adenoma
   D. Adrenal metastasis
   E. Adrenal abscess
2. Which one of the following is the most common incidental adrenal cortical tumor?
   A. Lymphoma
   B. Adenoma
   C. Metastases
   D. Pheochromocytoma
3. Which one of the following statements about adrenal ultrasonography is FALSE?
   A. Distinguishing upper pole renal masses from adrenal masses may be difficult at times.
   B. The diaphragmatic crura and splenules may be confused for adrenal masses.
   C. The right adrenal gland is more easily visualized than the left.
   D. Most adrenal masses can be distinguished by their characteristic sonographic appearance.
4. What scanning techniques can be used to optimize imaging of the adrenal gland using ultrasound?
   A. Using a low frequency transducer in neonates
   B. Using a posterior approach in the lateral decubitus position
   C. Using the solid abdominal organs as acoustic windows
   D. Utilizing an anterior abdominal approach in obese individuals

See Supplemental Figures section for additional figures and legends for this case.

CASE 76

Adrenal Adenoma

1. **A, C, and D.** This is a homogenous solid adrenal mass. Most solid adrenal masses are indistinguishable on ultrasound and should be included on the differential. The exceptions to this are a myelolipoma and adrenal abscess. Abscesses are heterogeneously hypoechoic and evolve over time. Myelolipomas are diffusely echogenic due to the presence of fat and may have cystic degeneration and/or calcifications. A hemorrhage could be considered but seems less likely. An incidental adrenal adenoma is the most likely etiology in this case.
2. **B.** Adrenal adenomas are the most common incidental solid adrenal tumors.
3. **D.** With the exception of adrenal hemorrhage, adrenal cysts, and myelolipoma, sonographic findings of most adrenal masses are nonspecific and cannot reliably distinguish one entity from another. The right adrenal gland is more easily visualized using the liver as an acoustic window.
4. **C.** Using the liver or spleen as an acoustic window optimizes imaging of the adrenal glands. Higher frequency transducers should be used in neonates due to a relatively small amount of tissue to penetrate. An anterior abdominal approach is used for neonates and very thin individuals. A posterior approach is used to image kidneys but is not always as helpful in imaging the adrenal.

Comment

Differential Diagnosis

The differential diagnosis for a solid adrenal mass is lengthy and the diagnosis is rarely suggested by ultrasound alone. Cystic masses may be congenital, posttraumatic, or postinfectious and are not considered in the differential of this case. Mixed cystic and solid lesions can be secondary to trauma, infection, or cystic necrosis of an aggressive malignancy. A solid mass is either a benign adrenal tumor or a malignant adrenal or secondary neoplasm to metastatic disease.

Adrenal hemorrhage requires special attention. Acutely, the hemorrhage will appear as a homogenously hyperechoic mass. In the subacute phase, it will feature mixed echogenicity with a hypoechoic center from clot formation. Chronically, it may appear as anechoic, occasionally featuring calcifications.

Adrenal carcinomas are very rare but are critical to detect. They typically are large at the time of discovery. They are prone to both hemorrhage and necrosis.

Ultrasound Findings

Most adrenal adenomas are round, well circumscribed, and homogenous (Figs. S76-1 and S76-2). Evaluation of both adrenal glands is essential as the differential for unilateral versus bilateral adrenal masses is different. Evaluation of the remaining abdominal organs is also crucial to evaluate for disseminated metastases or findings related to disseminated infection. The spleen and liver should be used as acoustic windows to better evaluate the adrenal glands. Imaging in multiple planes should be performed, both to evaluate the lesion and to be certain the lesion's location is within the adrenal gland.

Adrenal adenomas in particular are discrete masses that are more commonly isoechoic or hypoechoic. They rarely feature small calcifications. Of note, these lesions are nearly always asymptomatic and, thus, are found incidentally. They account for more than 90% of adrenal "incidentalomas."

Prognosis and Management

Adrenal masses, mostly benign, are found in 10% of autopsies as incidental findings, and the overall incidence increases with age. Women are three times more likely than men to have an adrenal mass of any cause. Evaluation of an adrenal mass should first begin by determining if the patient is symptomatic. An asymptomatic adrenal mass is nearly always an adrenal adenoma.

The size of an adrenal mass can also guide management. Size less than 3 cm in an asymptomatic patient can be safely followed with ultrasound, though most practicing radiologists will recommend further imaging as the exact follow-up interval has not been determined. Size between 3 and 6 cm should be further evaluated with additional imaging. Size greater than 6 cm makes a lesion more likely to be malignant and warrants a surgical referral in addition to further imaging.

Adrenal masses can be evaluated with either computed tomography (CT) or magnetic resonance imaging (MRI). Measurement of Hounsfield units (HU) of an adrenal mass of less than 10 HU on noncontrast CT is practically diagnostic of an adenoma. On contrast CT, equivocal cases can be evaluated for washout characteristics with adenomas having more than 60% absolute washout after 15 minutes is consistent with an adenoma. MRI with chemical shift imaging can demonstrate loss of signal of the adrenal adenoma on opposed phase imaging (Figs. S76-3 and S76-4). This occurs in approximately 70% of adenomas, as they have microscopic fat. Functioning adenomas or carcinomas may be diagnosed by measuring serum cortisol, renin to aldosterone ratio, or adrenal androgens or urine metanephrine depending on the clinical picture. A history of trauma or anticoagulation can suggest prior adrenal hemorrhage.

References

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Dunnick NR, Korobkin M, Francis I. Adrenal radiology: distinguishing benign from malignant adrenal masses. *Am J Roentgenol.* 1996;167:861–867.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 221.

Acknowledgment

Special thanks to Ethan Neufeld, MD, for preparation of this case.

Figure 77-1

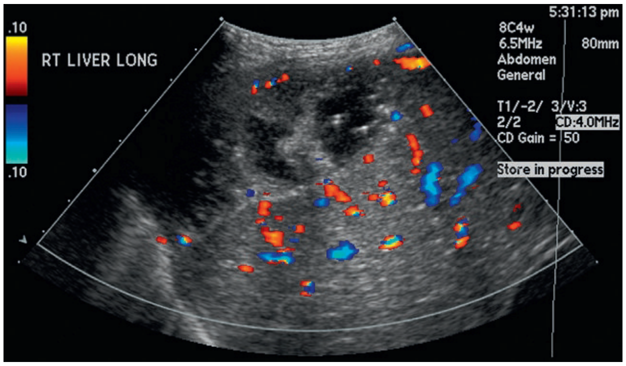

Figure 77-2

HISTORY: A 9-year-old boy with recent appendectomy presents with abdominal pain and fever.

1. Which one of the following is the most likely diagnosis for the findings shown in these ultrasound of the liver?
   A. Hepatic abscess
   B. Metastases
   C. Hematoma
   D. Necrotic or hemorrhagic primary liver tumor
   E. Lymphoma
   F. Hemorrhagic cyst
2. One of the better diagnostic clues for the presence of a bacterial abscess on computed tomography (CT) is which of the following?
   A. The "cluster" sign
   B. Sharply defined hypoechoic mass
   C. Right lower lobe atelectasis and right-sided pleural effusion
   D. Cystic appearance
3. The least common etiology of a pyogenic liver abscess would be which of the following?
   A. Diverticulitis
   B. Ascending cholangitis
   C. Infarcted tissue such as a necrotic tumor
   D. Spread from adjacent renal abscess
4. When a patient has diverticulitis and develops a hepatic abscess, how does (do) the abscess (or abscesses) present?
   A. Most commonly as a single abscess in the left lobe of the liver
   B. Most commonly as one to three abscesses in both lobes of the liver
   C. Predominantly in the right lobe of the liver
   D. Usually as multiple small abscesses scattered throughout the liver

See Supplemental Figures section for additional figures and legends for this case.

CASE 77

Hepatic Abscess

1. **A.** Given this specific history, the most likely diagnosis would be hepatic abscess. Certainly, all the other choices except for lymphoma could appear as a complex fluid collection and could be considered in a different setting.
2. **A.** Liver abscesses often appear more characteristic on CT than on ultrasound. One of the better diagnostic clues is the "cluster" sign. Small pyogenic liver abscesses coalesce into a single larger cavity. Amoebic abscesses are often sharply defined, round masses. Right lower atelectasis or pleural effusions are nonspecific findings. Hepatic abscesses usually do not appear purely cystic.
3. **D.** Common causes of a pyogenic liver abscess would be diverticulitis or appendicitis. Ascending cholangitis or infarcted tumors can be etiologies of a bacterial abscess. Spread from adjacent pyelonephritis or a renal abscess would be less likely.
4. **C.** Bacterial abscesses from diverticulitis spread via the portal vein into the right lobe of the liver in the majority of cases. Alternatively, biliary tract abscesses from ascending cholangitis usually involve both lobes of the liver.

Comment

Differential Diagnosis

The differential for a complex fluid collection could include a hepatic abscess, an infected or noninfected hematoma, a necrotic tumor, or a hemorrhagic cyst. Given this specific clinical setting, a pyogenic liver abscess would be the most likely consideration (Figs. S77-1 and S77-2). Pyogenic liver abscesses may be single or multiple and usually arise from hematogenous spread from the portal vein from an intestinal source including diverticulitis or appendicitis. There may be direct spread from the gallbladder in patients with acute cholecystitis. In westernized countries, most hepatic abscesses are bacterial (pyogenic) in origin.

Ultrasound Features

Sonographically, findings of liver abscesses can be nonspecific and they can vary in echogenicity. They may be complex fluid collections and may be anechoic, hyperechoic, hypoechoic, or mixed in echogenicity, depending on contents. They may mimic a solid hepatic mass or a hemorrhagic hepatic cyst. They may appear as discrete areas of hypoechoic nodules or ill-defined areas of altered hepatic echogenicity.

The presence of posterior acoustic enhancement may be helpful and indicates fluid contents. Some abscesses may have a fluid level, may contain debris, or may contain internal septae. The borders of pyogenic liver abscesses also vary and are often irregular. A helpful characteristic sign, if present, is reverberation artifact from echogenic foci within the abscess with "dirty shadowing," and may indicate presence of gas within the abscess. With color Doppler, an early abscess may have some internal flow due to multiple small abscesses, but these often coalesce into a single abscess and then demonstrate little internal flow. However, because of the surrounding edematous parenchyma, there may be peripheral hypervascularity. Smaller adjacent abscesses may eventually coalesce into a larger complex fluid collection and may demonstrate a "cluster" sign.

Management

Given this appearance within the liver and the history of appendicitis, usually a complimentary exam such as a contrast-enhanced CT scan of the abdomen would be performed to exclude other intraabdominal abscesses or the source of the infection. If, in fact, only a single liver abscess is identified, then percutaneous ultrasound or CT-guided drainage of the abscess may be performed. Patients are placed on antibiotics before drainage of the abscess, and an antibiotic regimen may be changed depending on culture and sensitivity after drainage. Percutaneous drainage is an accepted method of treatment of liver abscess, thus the decreasing need for surgical intervention.

Reference

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 67–68.

Acknowledgment

Special thanks to Jennifer Chang, MD, for preparation in this case.

CASE 78

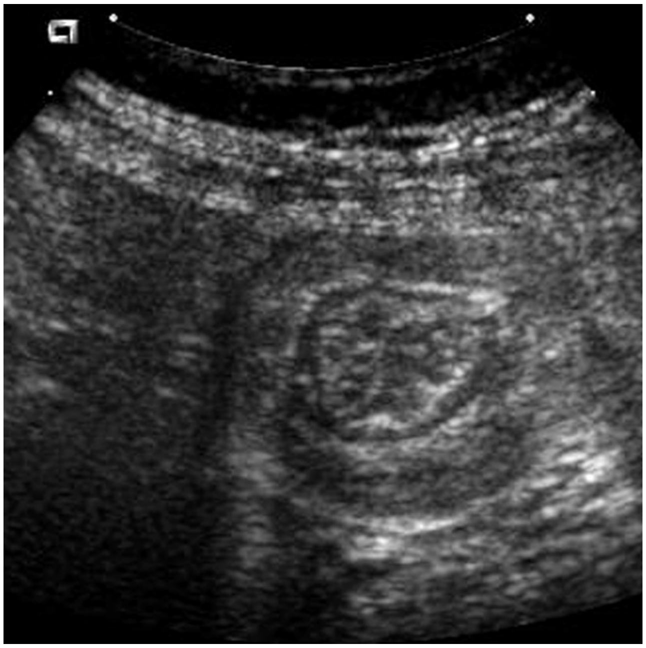

Figure 78-1

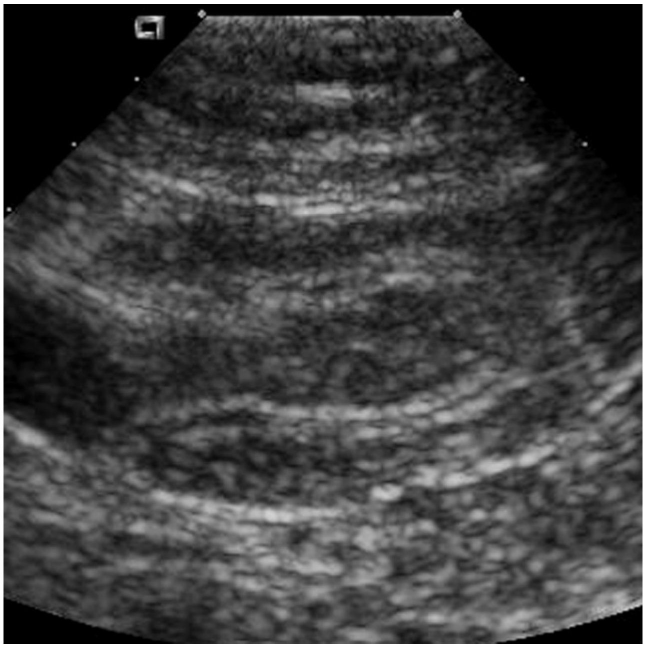

Figure 78-2

HISTORY: A 3-year-old boy presents with acute onset, intermittent abdominal pain.

1. The differential diagnosis for the ultrasound findings of the abdominal bowel in Figures 78-1 and 78-2 includes which one of the following? (Choose one)
   A. Infectious enteritis
   B. Intramural hematoma
   C. Intussusception
   D. Acute appendicitis
   E. Meckel's diverticulitis

2. What is the most common location of intussusception in children?
   A. Entero-enteric
   B. Ileocolic
   C. Colo-colic
   D. None of the above

3. What is the most common cause of this entity in children?
   A. Inflammatory polyp
   B. Lymphoma
   C. Lipoma
   D. Idiopathic

4. Use of color Doppler in evaluation of this entity is useful for which purpose?
   A. Improved sensitivity
   B. Improved specificity
   C. Predict bowel necrosis
   D. Predict spontaneous reduction

See Supplemental Figures section for additional figures and legends for this case.

CASE 78

Intussusception

1. **C.** The differential diagnosis includes bowel wall thickening from any cause including infectious enteritis, acute appendicitis, or Meckel's diverticulitis. However, a target-like lesion with multiple concentric rings is the typical appearance for an intussusception.
2. **B.** The most common location in children is ileocolic.
3. **D.** In children, intussusceptions are most often idiopathic. In adults, they are often associated with a lead mass.
4. **C.** Color Doppler can help to detect color flow. Lack of detectable blood flow predicts the need for surgery and increases the likelihood of bowel wall necrosis.

Comment

Differential Diagnosis

The initial imaging in this case is that of a diffuse bowel wall thickening. Certainly, there are a number of different etiologies for diffuse bowel wall thickening including either inflammatory or infectious etiologies. Also, if there is a blind ending tubular structure, acute appendicitis would be considered. Depending on the exact location, Meckel's diverticulitis which occurs in the more distal ileum also might be considered. In this case, it almost appears as if there is a central mass within the bowel lumen, and, as such, intramural hematoma might be considered but is less likely. The most likely diagnosis in this case would be intussusception. This is a target-like appearance with multiple concentric rings, and, in this case, it is the typical appearance of intussusception.

Ultrasound Findings

Intussusception represents the invagination of a segment of bowel into the bowel lumen. The proximal segment that enters the intussusceptions is called the intussusceptum, and the distal segment that receives the intussusceptum is called the intussuscipiens. Intussusception is much more common in early childhood than in adulthood. In children, it is most often idiopathic. In adults, it is often associated with a lead mass (polyps, lipomas, gastrointestinal stromal tumor, venous malformations, metastases, lymphomas, and cancer), Meckel's diverticulum, or celiac disease. Many of these masses may be detected on sonography. Intussusception with a lead point tends to be persistent or recurrent, with bowel obstruction seen more often than in the transient form. In Figure S78-3, a lead mass (inflammatory polyp) was diagnosed as the cause of intussusceptions, upon surgical resection. The sonographic appearance of an intussusception is predictable. Three overlapping mucosal and muscular layers of the intussuscipiens and intussusceptum result in multiple concentric, hypoechoic, and echogenic rings. In many cases, the intussuscepted mesentery can be seen in the proximal aspect of the intussusceptions as a slightly eccentric echogenic structure. The appearance of an intussusception has been variously compared to a target, a bull's-eye, a doughnut, a pseudokidney, and a sandwich (Figs. S78-1 and S78-2).

Prognosis and Management

Inability to detect blood flow in the intussusceptions increases the likelihood of necrosis and predicts need for surgery. Detection of blood flow is reassuring (Fig. S78-4). Intussusception may be reduced under fluoroscopic control. However, sonography has been widely used to reduce an intussusception and is felt to be safer than fluoroscopically guided reduction. Additionally, use of ultrasound eliminates any radiation exposure. Prognosis and management of intussusceptions in adults depend on the presence and the etiology of the lead mass. The distinction between intussusceptions with and without a lead point is made on the basis of clinical history and presence of bowel obstruction.

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Marinis A, Yiallourou A, Samanides L, et al. Intussusception of the bowel in adults: a review. *World J Gastroenterol*. 2009;15(4):407–411.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 208–209.

Acknowledgment

Special thanks to Shruthi Ram, MD, for preparation of this case.

Challenge

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CASE 79

Figure 79-1

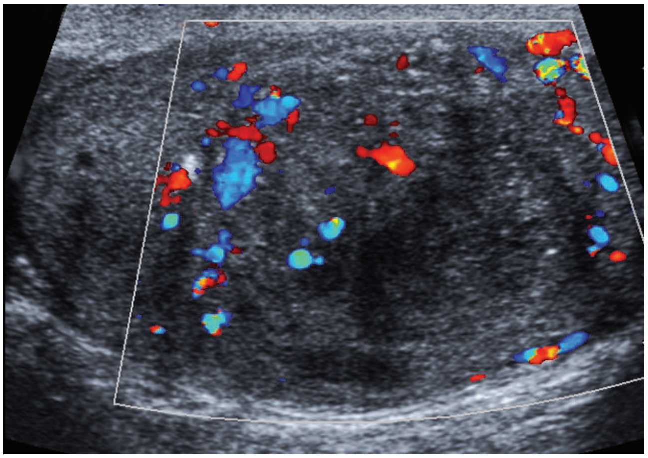

Figure 79-2

HISTORY: A 35-year-old male presents with a painless, palpable testicular mass for 2 months.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Seminoma
   B. Focal orchitis
   C. Nonseminomatous germ cell tumor (NSGCT)
   D. Adenomatoid tumor
2. Which of the following is true regarding NSGCT?
   A. Embryonal cell elements cause cystic changes in an NSGCT.
   B. A teratocarcinoma is a combination of embryonal cell and yolk sac tumor.
   C. When a testicular tumor is diagnosed, an ultrasound should be performed to evaluate for lymphadenopathy in the retroperitoneum.
   D. Twenty percent of testicular tumors are NSGCTs.
3. Which of the following is true regarding NSGCT?
   A. Left-sided tumors can spread to contralateral nodes only.
   B. Germ cell tumors (GCTs) are more common in African-Americans than Caucasians.
   C. NSGCTs occur in adults greater than or equal to 50 years of age.
   D. Risk factors for GCTs include gonadal dysgenesis, cryptorchidism, infertility, intersex syndromes (hermaphroditism, Klinefelter's syndrome), and testicular atrophy.
4. Which of the following is true regarding NSGCT?
   A. Tumor markers are usually negative in NSGCTs but positive in seminomas.
   B. On ultrasound, an NSGCT is homogeneous but may contain calcification and has ill-defined margins.
   C. On ultrasound, a seminoma is heterogeneous but may contain calcification and has ill-defined margins.
   D. The differential diagnosis for an NSGCT includes stromal tumor, metastasis, lymphoma/leukemia, and rarer tumors such as epidermoid cyst, fibrous tumor, and adenomatoid tumor.

See Supplemental Figures section for additional figures and legends for this case.

CASE 79

Nonseminomatous Germ Cell Tumors

1. **C.** There is a solid, heterogeneous mass in the testis (Fig. S79-1) with flow on color Doppler (Fig. S79-2). Given the patient's age and asymptomatic state, a testicular tumor is the correct diagnosis. Heterogeneity suggests an NSGCT, which is caused by the different components (embryonal cell, choriocarcinoma, teratoma, yolk sac) of the tumor, and cystic change, necrosis, or hemorrhage. A seminoma (A) is possible though the ultrasound appearance is not typical. Seminomas tend to be homogeneous and well defined on ultrasound.
2. **C.** The retroperitoneum should be examined with ultrasound at the renal vein level because testicular lymphatic drainage follows the gonadal veins. Left-sided tumors spread to the left paraaortic and preaortic nodes and right-sided tumors to the paracaval, precaval, aortocaval, and preaortic nodes.
3. **D.** Right-sided tumors can spread to ipsilateral and contralateral nodes in 13% of cases; left-sided tumors spread to ipsilateral and contralateral nodes in 20% of cases. A small percent of right-sided tumors can metastasize to the contralateral side only. Acute testicular pain may occur from hemorrhage or tumor infarction. Dyspnea or hemoptysis may occur from pulmonary metastases and back pain or an abdominal mass from retroperitoneal lymphadenopathy.
4. **D.** In addition, focal vasculitis, orchitis, and infarction should be considered. Patient demographics, symptoms/exam findings (unilateral scrotal pain, urinary tract symptoms), clinical history (tuberculosis, sarcoidosis, sickle cell anemia, polyarteritis nodosa, polycythemia vera), and sonographic appearance/associated findings (epididymitis) can help to narrow the differential.

Comment

Introduction

Forty percent of GCTs are nonseminomatous (mixed); embryonal cell and teratoma (teratocarcinoma) being the most common. The incidence of GCTs has more than doubled in the past four decades and most commonly occurs in Caucasians of northern European descent. Patients usually present with a painless mass but may experience a heavy, dull aching pain or acute pain secondary to tumor or infarction.

Sonographic Findings

Seminomas account for 40% of GCTs and NSGCTs for 60%. Seminomas tend not to undergo necrosis and are characteristically homogeneous solid, hypoechoic, with well-defined margins and internal vascularity. NSGCTs are more aggressive than seminomas and can invade the tunica. On ultrasound, they are typically solid, heterogeneous with bizarre internal vascularity, cystic spaces (if teratomatous elements are present), and may have calcifications (Figs. S79-1 and S79-2).

Treatment

Patients with testicular GCTs have an excellent long-term outcome. Primary treatment is radical orchiectomy. Further treatment is based on stage; tumors limited to the testis are stage I, retroperitoneal lymphadenopathy indicates stage II, and distant metastases, stage III. Clinical stage I patients with NSGCTs are increasingly being followed with active surveillance (abdominal computed tomography, tumor markers, chest radiograph), because 72% are cured with radical orchiectomy and do not have retroperitoneal disease or distant metastases. If relapse occurs, chemotherapy is highly effective; survival approaches 98%. Stage II patients undergo chemotherapy followed by retroperitoneal lymph node dissection for residual disease greater than 1 cm. Such nodes contain mature teratoma in 50% of cases and viable cancer in 35%. Stage III patients are treated with chemotherapy and often entered into clinical trials.

References

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Woodward PJ, Sohaey R, O'Donoghue MJ, Green DE. Tumors and tumor-like lesions of the testes: radiologic-pathologic correlation. *Radiographics*. 2002;22:189–216.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 154–156.

CASE 80

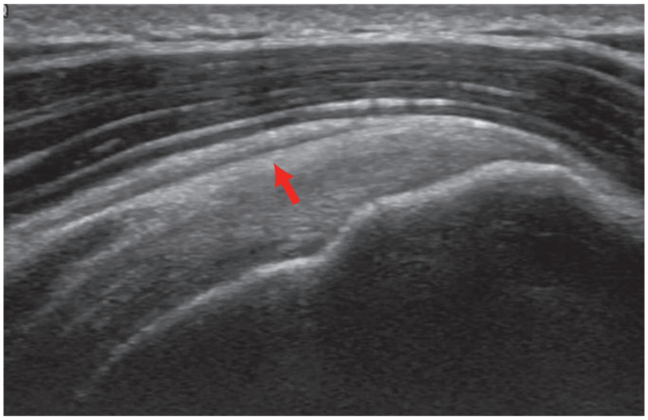

Figure 80-1

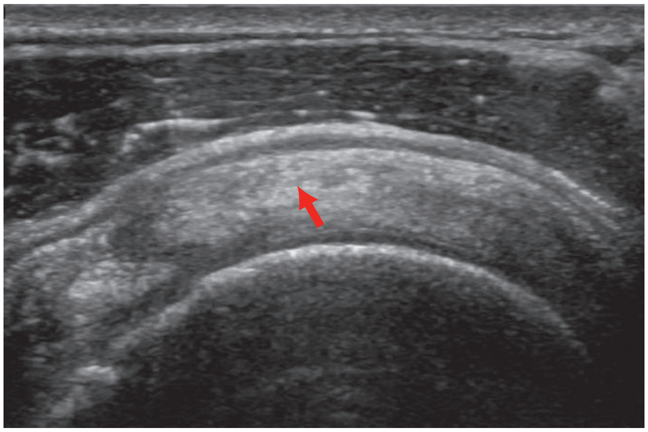

Figure 80-2

HISTORY: A 35-year-old woman presents complaining of shoulder pain.

1. The arrow points to what structure? (Choose all that apply)
   A. The arrow points to the rotator cuff in Figure 80-1.
   B. The arrow points to the deltoid muscle in Figure 80-1.
   C. The arrow points to the biceps tendon in Figure 80-2.
   D. The arrow points to the subscapularis tendon in Figure 80-2.
2. Concerning the rotator cuff and sonographic technique, which statement is true?
   A. The rotator cuff should be imaged with a linear array high frequency transducer.
   B. The biceps tendon is imaged with the arm internally rotated.
   C. The rotator cuff is best visualized with the arm in neutral position.
   D. The rotator cuff is composed of three muscles and their corresponding tendons.
3. Concerning shoulder anatomy, which statement is true?
   A. The short head of the biceps tendon arises from the humerus.
   B. The supraspinatus bursa lies between the deltoid muscle and rotator cuff.
   C. The teres minor tendon inserts on the inferior aspect of the greater tuberosity and surgical neck of the humerus.
   D. The subscapularis tendon attaches to the anterior aspect of the greater tuberosity.
4. Concerning the demographics and morphology of rotator cuff disease, which statement is true?
   A. The prevalence of rotator cuff disease does not increase with age.
   B. There is a correlation between age and cuff thickness in patients with a normal cuff.
   C. The mean rotator cuff thickness in men with normal shoulders is 4.5 to 5.0 mm.
   D. Asymptomatic cuff tears are rare.

See Supplemental Figures section for additional figures and legends for this case.

CASE 80

Normal Shoulder Anatomy, Sonographic Technique, Demographics, and Morphology

1. **A and C.** The arrow in Figure S80-1 points to the echogenic rotator cuff that overlies the humeral head cartilage and tapers to insert on the greater tuberosity. The deltoid muscle overlies the cuff (yellow arrow). The arrow in Figure S80-2 points to the biceps tendon. The biceps tendon lies in the intertubercular sulcus between the lesser and greater tuberosities and is surrounded by a tendon sheath. It arises from the postero-superior aspect of the glenoid labrum or supraglenoid tubercle.
2. **A.** A high frequency linear array transducer should be used to image the rotator cuff. It provides high resolution in the near field and a wide field of view of the cuff. If a low frequency transducer were used, resolution would be decreased and pathologic changes could be missed.
3. **C.** The teres minor muscle-tendon unit has a predominantly muscular, broad insertion onto the inferior greater tuberosity and the surgical neck of the humerus. It is quadrangular in shape and can be distinguished from the infraspinatus muscle-tendon unit on ultrasound.
4. **C.** The mean rotator cuff thickness is 4.5 to 5.5 mm. Thickness beyond 5.5 mm raises suspicion for cuff tendinopathy (degeneration), which can be an important cause of shoulder pain. There is no correlation between cuff thickness and age. The prevalence of cuff tears does increase with age; many of these cuff tears are asymptomatic.

Comment

Introduction

Shoulder ultrasound is an accepted imaging test to evaluate the patient with shoulder pain. Common findings include cuff tears, tendinopathy, biceps tendon rupture, subluxation, dislocation, tenosynovitis, and subdeltoid effusion or bursitis. Ultrasound has many benefits; it is nonionizing, rapid, less expensive than magnetic resonance imaging, allows direct interaction with the patient, and is preferred by most patients. It has been shown to be very accurate for diagnosing rotator cuff tears, and comparable to magnetic resonance in both sensitivity and specificity.

Sonographic Technique

The patient should be seated on a rotatable stool. At our institution, the radiologist would stand behind the patient to scan. The biceps tendon and the rotator cuff and its muscles are scanned in short and long axis. When scanning the biceps tendon in the transverse plane, it is important to gently rock the transducer to maintain the normal echogenicity of the tendon. To visualize the biceps tendon's normal fibrillar pattern in the longitudinal plane, the inferior aspect of the transducer should be gently pushed against the arm. The subscapularis tendon is best visualized with the arm in external rotation. To scan the supraspinatus and infraspinatus tendons, the patient should reach behind and place her palm on her pocket. The transducer should be rocked to visualize the various portions of the cuff in a plane perpendicular to the ultrasound beam so as not to mistake anisotropy for a tear.

Demographics and Morphology of Rotator Cuff Disease

A substantial number of adults over the age of 60 have rotator cuff tears, many of which are asymptomatic. In one study, there was a 10-year difference between the average age of patients with no cuff tear (48.7 years), a unilateral cuff tear (58.7 years), and bilateral cuff tears (67.8 years). Furthermore, there is a correlation between the presence of a cuff tear on the symptomatic side and the chance of having an asymptomatic cuff tear on the contralateral side. It is important to monitor such patients for the development of symptoms and tear size progression.

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CASE 81

Figure 81-1

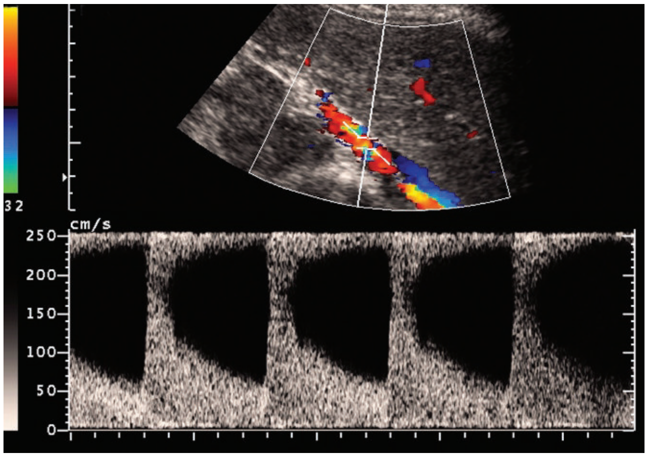

Figure 81-2

HISTORY: A 44-year-old female presents with abrupt onset of hypertension.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented?
   A. Ostial renal artery stenosis
   B. Intimal dissection of the renal artery
   C. Fibromuscular dysplasia (FMD)
   D. Vasculitis of the renal artery
2. To what are the pathologic changes in FMD due?
   A. Atherosclerosis
   B. Inflammation
   C. Degenerative vasculopathy
   D. Medial hypertrophy
3. What are the demographics of FMD?
   A. More common in men than women, age range 40 to 60 years
   B. More common in women than men, age range 20 to 60 years
   C. More common in women than men, age range 40 to 60 years
   D. Equally common in women and men, age range 20 to 60 years
4. Which statement is true regarding FMD?
   A. FMD causes turbulence and velocity shifts in the renal artery.
   B. On ultrasound, the artery is smoothly narrowed from its mid aspect to the hilum.
   C. Intimal dysplasia is the most common histologic type of FMD.
   D. FMD is treated with angioplasty and a stent.

See Supplemental Figures section for additional figures and legends for this case.

CASE 81

Fibromuscular Dysplasia

1. **C.** FMD occurs distal to the renal ostium (origin) in the mid to distal renal artery. On angiography, it appears as a "string of beads." Answer D is also a consideration because it can occur in multiple locations and cause accelerated hypertension and renal insufficiency. However, it is an inflammatory process of the vessel, and acute-phase reactants would be elevated.
2. **C.** FMD is a nonatherosclerotic, noninflammatory, degenerative vasculopathy. There are three histologic subtypes, intimal, medial, and adventitial. The medial subtype is the most common.
3. **B.** FMD is more common in women than men, 9:1. It has a wider age range than previously reported, 20 to 60 years.
4. **A.** FMD causes multiple stenoses and poststenotic dilatation causing turbulence and velocity shifts. Because of the sequential stenoses, it is not possible to calculate a percent stenosis.

Comment

Introduction

FMD occurs most commonly in women and has a wider age range than previously reported. It is not due to atherosclerosis or inflammation of the vessel wall but rather is a degenerative vasculopathy. It is also thought to, at least in part, have a genetic component. Renal artery FMD may also be associated with aneurysms, dissection, and occlusion of the renal artery. Seventy-five percent of cases affect the renal artery, and it can be bilateral in greater than or equal to 35% of cases. Other arteries may be involved, such as the carotid artery (25% to 35% of cases) or, less commonly, the vertebral artery. Involvement of the visceral or peripheral vessels and coronary arteries has also been reported.

Ultrasound Findings

FMD causes multiple stenoses or "webs" and poststenotic dilatation. A "string of beads" appearance is evident on angiography. The mid to distal renal artery is typically involved, but the segmental renal artery branches may also have changes of FMD. On gray scale, areas of stenosis and poststenotic dilatation may be seen if the patient is thin (Fig. S81-1). On color Doppler, there will be aliasing in the involved portions of the artery (Fig. S81-2). Although turbulence and elevated velocities are present, it is not possible to determine a percent stenosis due to the presence of multiple consecutive stenoses and the flow dynamics.

Treatment of FMD

FMD is best treated with angioplasty, which has been shown to be very successful, especially in younger patients with hypertension of short duration. There is almost no indication for placement of a stent. Two reported indications for stent placement include failure to obliterate the pressure gradient with angiography alone and to treat a dissection.

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Olin JW, Sealove BA. Diagnosis, management, and future developments of fibromuscular dysplasia. *J Vasc Surg*. 2011;53:826–836.

CASE 82

Figure 82-1

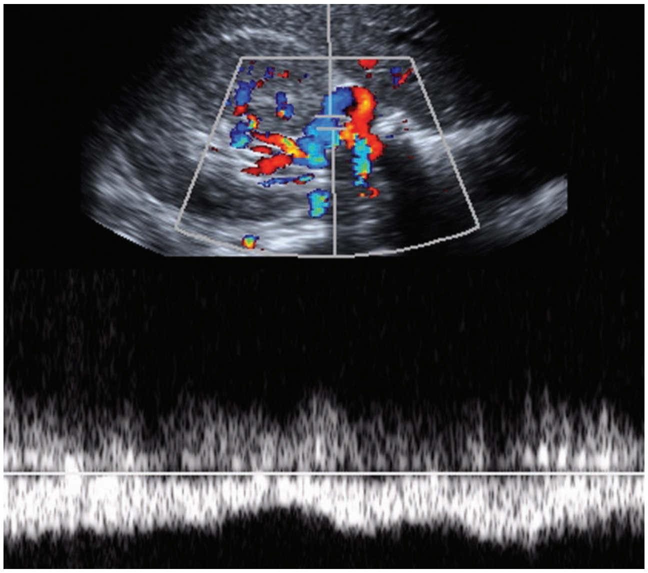

Figure 82-2

HISTORY: A 40-year-old man presents with chronic inferior vena cava (IVC) thrombosis of unknown etiology.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Right renal vein collaterals
   B. Acute right renal vein thrombosis
   C. Malignant renal vein thrombosis
   D. Chronic renal vein thrombosis
2. Renal vein thrombosis may be caused by which of the following?
   A. Renal cell carcinoma
   B. Renal artery thrombosis
   C. Thrombosed right varicocele with retrograde extension of the thrombus
   D. Oncocytoma
3. What are the sonographic findings of acute native renal vein thrombosis?
   A. The renal vein is sclerotic and cannot be visualized.
   B. The renal artery dilates and blood flow increases to compensate for the venous thrombosis.
   C. The thrombus is usually not visualized and can only be surmised by absence of flow on color Doppler.
   D. The sonographic appearance of thrombus is variable and may be echogenic or isoechoic to renal parenchyma and visible on gray scale images.
4. In what percent of cases does renal cell carcinoma invade the renal vein, IVC, or right atrium?
   A. Main renal vein invasion occurs in 40% of cases.
   B. Main renal vein invasion occurs in 10% to 15% of cases.
   C. IVC invasion occurs in 20% of cases.
   D. Right atrial invasion occurs in 10% to 15% of cases.

See Supplemental Figures section for additional figures and legends for this case.

CASE 82

Renal Vein Thrombosis

1. **D.** The right renal vein is not visible on gray scale, indicating chronic renal vein thrombosis. Venous collaterals (arrow, Fig. S82-1) are also present; thus A is also correct. If acute renal vein thrombosis were present, the renal vein would be visible as a structure containing thrombus. Color Doppler is often helpful to visualize the tortuous venous collaterals (arrow, Fig. S82-2). The tumor grows into the renal vein dragging its blood supply with it; this can be seen on color Doppler.

2. **A.** Renal cell carcinoma can invade the renal vein, dragging its blood supply with it; the neovascularity can be seen on color Doppler. The malignant thrombus can extend into the IVC and hepatic veins and the right atrium. An oncocytoma is a benign tumor and does not invade the renal vein. Dilated veins in the pampiniform plexus can thrombose but the thrombus does not extend into the gonadal veins or IVC.

3. **D.** Acute renal vein thrombosis may distend the vein if occlusive. The thrombus has a variable echogenicity and may or may not be visible on gray scale images. Color Doppler is useful to identify the thrombus. Venous collaterals form rapidly within 24 hours in a native kidney. A narrowed, sclerosed, or nonvisualized renal vein indicates chronic venous thrombosis. Venous collaterals are present in this setting.

4. **B.** Renal cell carcinoma invades the renal vein in 10% to 15% of cases, the IVC in 4% to 12% of cases, and the right atrium in 0.5% to 2% of cases.

Comment

Introduction

Renal vein thrombosis has many causes including nephrotic syndrome, membranous glomerulonephritis, systemic lupus erythematosus, malignancy, a hypercoagulable state, and trauma. The renal vein can also be externally compressed and thrombose—for example, from retroperitoneal hemorrhage or neoplasm. Inflammatory changes from acute pancreatitis can also extend across fascial planes and compress the renal vein. Patients with acute renal vein thrombosis may develop flank pain or hematuria, but if the thrombosis is chronic, patients may be asymptomatic.

Ultrasound Findings

Renal vein thrombosis may be anechoic, isoechoic, or hyperechoic. It may be obstructive or nonobstructive. The renal vein may distend if the thrombus is acute, but if chronic, it may be difficult to identify the renal vein because it scleroses and is surrounded by venous collaterals (arrows, Figs. S82-1 and S82-2) that can obscure it. It is important not to mistake collaterals for a patent renal vein. The renal veins must be visualized in their entirety with gray scale and color Doppler, and a waveform should be obtained to exclude thrombus on the right or left. It is very difficult to visualize the left renal vein in its entirety due to its long course and overlying bowel gas. Renal cell carcinoma can expand the renal vein dramatically, and color Doppler flow can be detected in the malignant thrombus because of neovascularity; in other words, the tumor drags its blood supply into the vein.

Treatment

Most patients with benign renal vein thrombosis will be treated with anticoagulants as long as there are no contraindications. The decision to prophylactically anticoagulate patients predisposed to developing renal vein thrombosis is controversial, and there is a paucity of randomized trials or guidelines to support either view. Patients with malignant renal vein thrombosis and IVC extension secondary to renal cell carcinoma require staging with computed tomography. If appropriate, patients should undergo radical surgical resection and IVC thrombectomy. Surgical technique will vary depending on the level of the IVC thrombus.

References

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 138, 139.

CASE 83

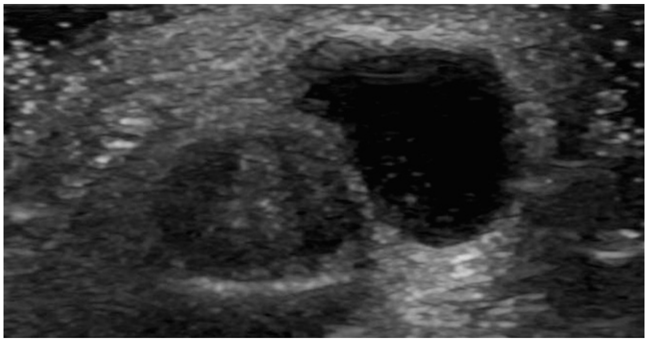

Figure 83-1

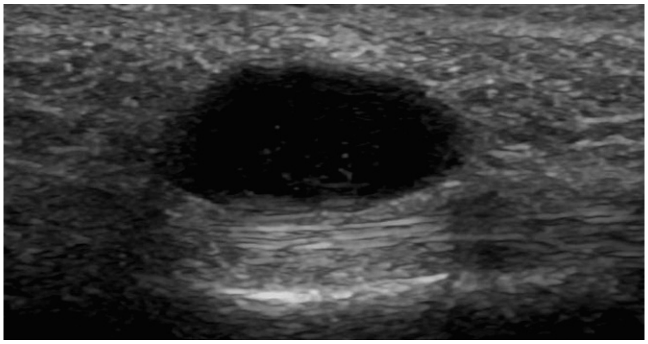

Figure 83-2

HISTORY: A 30-year-old woman presents with a nontender, palpable lesion on the dorsum of the wrist.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Giant cell tumor
   B. Ganglion
   C. Epidermal inclusion cyst
   D. Abscess
2. Concerning ganglions, which statement is true?
   A. Ganglions have a simple, cystic appearance on ultrasound.
   B. Ganglions can have a solid, hypoechoic appearance on ultrasound.
   C. Ganglions arise from an extensor or flexor tendon.
   D. Ganglions have peripheral blood flow on color Doppler due to an inflammatory response.
3. Concerning ganglions, which statement is true?
   A. Ganglions are lined with synovium.
   B. Ganglions are filled with serous fluid.
   C. Ganglions are filled with a mucin.
   D. Ganglions most commonly occur on the volar surface of the wrist.
4. Concerning ganglions, which statement is true?
   A. Ganglions occur more commonly in manual laborers.
   B. Volar retinacular ganglions move with flexor tendon motion.
   C. Ganglions cause more pain when they are large.
   D. Ganglions most commonly occur on the dorsum of the wrist.

See Supplemental Figures section for additional figures and legends for this case.

CASE 83

Ganglions of the Hand and Wrist

1. **B.** The lesion is a complex, cystic lesion located on the dorsum of the hand, and the appearance is most consistent with a ganglion. A ganglion more often has a complex cystic appearance on ultrasound. Without a history, an abscess (D) might be a consideration, but associated findings of erythema, tenderness, and cellulitis would be present. Giant cell tumors are solid hypervascular lesions.
2. **B.** A small percentage of ganglions can be solid in appearance on ultrasound; this occurs if a ganglion ruptures and collapses.
3. **C.** Ganglions are mucin-filled, fibrous-lined cysts.
4. **D.** Ganglions occur most commonly on the dorsum of the wrist and arise from the portion of the joint capsule that attaches to the scapholunate ligament. Pain on the dorsum of the wrist in the absence of a palpable lesion may be due to an occult (nonpalpable) ganglion. These small lesions are best visualized on ultrasound or magnetic resonance imaging.

Comment

Introduction

Ganglions can occur on the dorsal or volar aspect of the wrist or arise from a flexor tendon sheath (flexor carpi radialis) or joint capsule (radio-scaphoid, scapho-trapezial). Less commonly, they can arise due to osteoarthritis of the distal interphalangeal joint and will lie to one side of the extensor tendon. These ganglions are known as mucous cysts and can cause nail deformity due to pressure on the nail matrix. Volar retinacular (flexor tendon sheath) ganglions usually arise at the A1 or A2 pulley level of the finger and are attached to the tendon sheath. When the finger is flexed, there is no cyst movement because the pulley tethers the ganglion and it does not arise from the tendon but the sheath. Ganglions occur more commonly in women with a peak incidence at 10 to 40 years. Ganglions may cause local pain or be asymptomatic.

Sonographic Findings

Only about one third of ganglions are simple in appearance, that is, anechoic with a well-defined but imperceptible wall, and posterior acoustic enhancement. Nearly two thirds of ganglions are complex and may contain internal echoes (Fig. S83-1), septations, locules, and a thick wall. If a ganglion ruptures, it can have a solid appearance, although this is unusual. Complex appearing ganglions tend to be larger than simple ganglions and occur most commonly on the dorsal or volar wrist. Volar retinacular ganglions are smaller and tend to be simple, likely because of the more restrictive space of the flexor tendon sheath compared to the wrist (Fig. S83-2).

Treatment

Ganglions can be managed conservatively or surgically. Conservative treatment involves splinting, nonsteroidal antiinflammatory drugs, and aspiration with or without steroid injection. However, ganglions can recur after aspiration. Cure rates have been reported between 15% and 89%. Surgical excision of the cyst and its neck is also an option, especially in patients who fail nonoperative treatment. It is important during the ultrasound exam to try to identify the neck of the cyst to ensure complete resection; otherwise, it may recur. In some cases, the neck may be remote from the cyst and difficult to trace.

References

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 273–276.

CASE 84

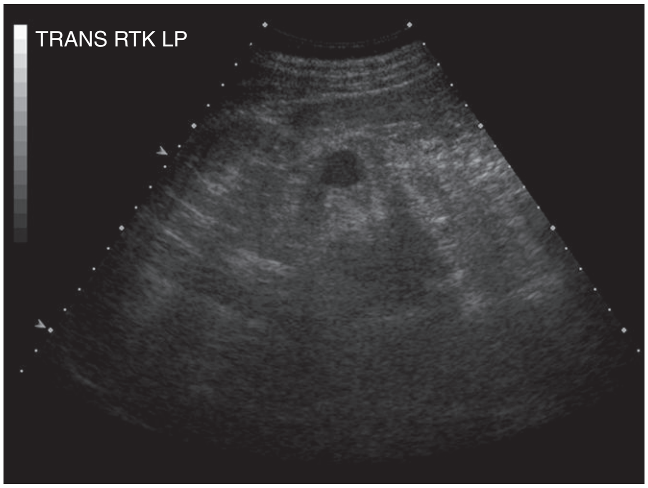

Figure 84-1

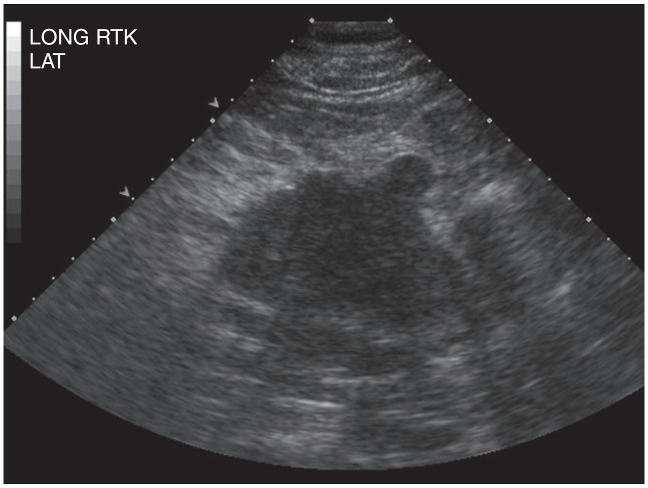

Figure 84-2

HISTORY: A 60-year-old presenting with acute renal failure has an ultrasound exam of the kidney.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented in Figures 84-1 and 84-2? (Choose all that apply.)
   A. Simple renal cyst
   B. Hemorrhagic cyst
   C. Renal oncocytoma
   D. Papillary renal carcinoma
2. After identifying the hypoechoic renal mass, what's the next best step to perform?
   A. Color Doppler ultrasound
   B. Contrast-enhanced computed tomography (CT) scan
   C. Contrast-enhanced magnetic resonance imaging (MRI)
   D. Contrast-enhanced ultrasound
3. What is the one most typical sonographic appearance of clear cell renal cell carcinoma (RCC)?
   A. Very hyperechoic
   B. Isoechoic or slightly hyperechoic
   C. Cystic
   D. Hypoechoic
4. All of the following are true statements EXCEPT:
   A. Currently the majority of RCCs are discovered incidentally.
   B. Papillary carcinomas are the most common type of RCC.
   C. Tumor ablation with percutaneous techniques, whether with radiofrequency ablation, microwave, or cryoablation, is an acceptable means of treatment for small RCCs.
   D. Oncocytomas can be difficult to distinguish from renal carcinoma on ultrasound.

See Supplemental Figures section for additional figures and legends for this case.

CASE 84

Renal Cyst Versus Mass

1. **B, C, and D.** Most papillary renal carcinomas are isoechoic compared to renal parenchyma, but some are hypoechoic and could be considered. Renal oncocytomas could also be considered. Hemorrhagic cysts may have low level echoes, while simple cysts would not. In this case, the gain settings are so low they make the renal parenchyma appear hypoechoic (Fig. S84-2).
2. **A.** This would be the simplest and best answer (Figs. S84-3 and S84-4). If this patient is in renal failure, then contrast MRI should not be performed. In a patient with renal failure, unless he or she is on dialysis, contrast-enhanced CT should not be performed. Contrast-enhanced ultrasound could be considered in this patient with chronic renal failure, if color Doppler is indeterminate.
3. **B.** Solid RCC, especially the clear cell type, are slightly hyperechoic or isoechoic compared to the adjacent renal parenchyma. This is the best answer. Clear cell carcinomas may have other appearances and may be hyperechoic, hypoechoic, or even partially cystic (if necrotic).
4. **B.** Clear cell carcinomas are the most common type of RCC. Papillary carcinomas are the second most common type. All others are true statements.

Comment

Differential Diagnosis

The differential diagnosis in this case could include hemorrhagic cyst, oncocytoma, renal carcinoma, or, less likely, renal metastasis. Lymphoma would be considered, but also less likely. Transitional cell carcinomas are usually localized more centrally within the collecting system.

Ultrasound Findings

This case demonstrates that, in fact, when evaluating a renal mass ultrasound, technique is very important. When examining a mass by ultrasound, the mass should not be compared to surrounding perirenal fat, which is very echogenic. This is the mistake made in Figure S84-1. In this case, the solid renal mass appears hypoechoic and almost cystic in Figures S84-1 and S84-2. In this situation, the examiner initially felt this mass was more likely a cystic renal mass rather than a solid renal mass. When examining a renal mass, it is important to compare the mass to the adjacent parenchyma as illustrated in Figure S84-3. Furthermore, if there is any doubt whether this is a cystic/solid mass, color Doppler ultrasound is imperative, as illustrated in Figure S84-4. This is a case of an RCC. In this situation, contrast-enhanced CT or MRI may be helpful unless there is renal failure. Contrast-enhanced ultrasound, if available, may be useful.

Prognosis/Management

In this case, renal biopsy was performed and revealed RCC. The patient was in renal failure, and partial nephrectomy was not considered. A complete nephrectomy was performed. However, in other cases, where there is normal renal function and renal parenchyma preservation is desired, then partial nephrectomy is usually the accepted technique. More recently, other techniques such as ultrasound or CT-guided radiofrequency ablation, cryoablation, or microwave ablation have shown excellent results in complete tumor ablation.

References

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 109–114.

CASE 85

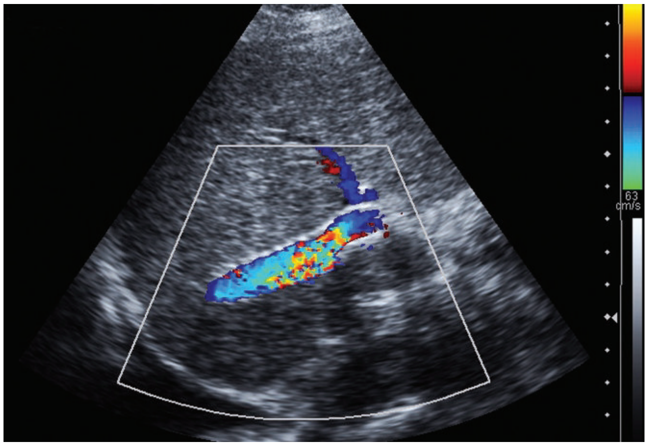

Figure 85-1

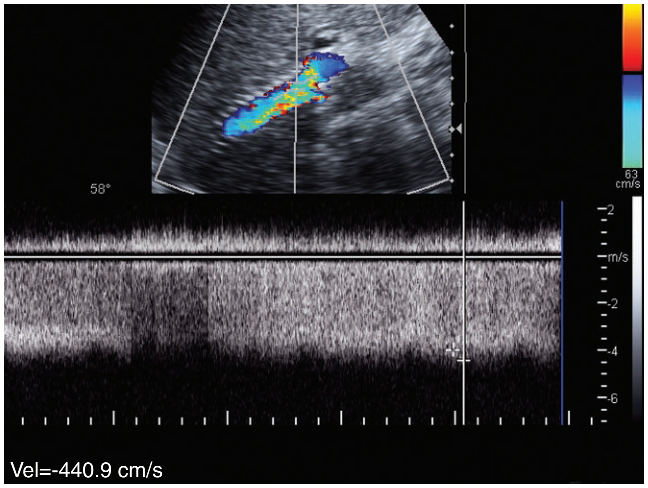

Figure 85-2

HISTORY: A 50-year-old male presents with recurrent variceal bleeding after placement of a stent graft (transjugular intrahepatic portosystemic shunt [TIPS]) 3 months ago.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Patent stent graft (TIPS)
   B. Occluded stent graft
   C. Reversal of flow in the stent graft
   D. Stenosis of the stent graft

2. Which of the following is true regarding portal hypertension?
   A. Esophageal varices are present in 10% of cirrhotic patients at the time of diagnosis.
   B. Hemorrhage occurs in 5% of patients with esophageal varices, and the 6 week mortality after each bleeding episode is 15% to 20%.
   C. Patients with esophageal varices are initially treated with band ligation of the varices.
   D. MR imaging is the best modality to diagnose stent graft stenosis.

3. Which of the following is true regarding TIPS?
   A. Band ligation has a failure rate of 10% to 15%.
   B. The indications for placement of a stent graft (TIPS) include cirrhosis.
   C. There are no contraindications to stent graft placement.
   D. The Viatorr stent graft is an uncovered stent graft.

4. Which of the following is true regarding TIPS?
   A. The covered portion of a stent graft should be placed along the entire parenchymal tract to prevent hepatic vein stenosis.
   B. The stenosis rate of uncovered and covered stent grafts is the same.
   C. The rate of recurrent variceal bleed is the same in covered and uncovered stent grafts.
   D. The mortality rate for covered and uncovered stent grafts is the same.

See Supplemental Figures section for additional figures and legends for this case.

CASE 85

Sonography of TIPS

1. **D.** Figure S85-1 shows aliasing (yellow arrow) in the stent graft; the high velocity of 441 cm/s (Fig. S85-2) is indicative of a stenosis. A is also true but more important is to recognize the focal stenosis.
2. **C.** Band ligation is the first line of therapy. A splanchnic vasoconstrictor (octreotide) may also be administered in the inpatient setting. At the time of diagnosis of cirrhosis, approximately 50% have esophageal varices and the rate increases with the Child class. Hemorrhage occurs in 30% of patients with esophageal varices, and the 6 week mortality after each bleeding episode is 15% to 20%.
3. **A.** When band ligation fails, patients go on to placement of a stent graft. The most common indications include ascites, bleeding esophageal varices, hydrothorax, and Budd-Chiari syndrome. Contraindications include severe hepatic encephalopathy, pulmonary hypertension, right heart failure, and sepsis. The Viatorr stent graft is covered (polytetrafluoroethylene-Gore-Tex), antithrombogenic, and prevents pseudointimal hyperplasia due to the impermeability of the cover to bile. It is the only FDA approved covered stent graft.
4. **A.** The hepatic vein end of a covered stent graft needs to land at the hepatic vein-caval junction to prevent stenosis at the hepatic vein end of the stent graft. The restenosis rate is much higher in uncovered stent grafts because of pseudointimal hyperplasia that develops from leakage of bile into the stent graft. The rate of recurrent variceal bleed in uncovered stent grafts averages 28% ranging up to 47%, but in covered stent grafts it is 2.3%.

Comment

Introduction

With the introduction of stent grafts, the care of cirrhotic patients with variceal bleeding has dramatically improved. A recent study showed that in Child class B or C patients with an acute variceal bleed, stent graft placement within 24 to 72 hours improved survival and decreased the risk of rebleed, suggesting that stent graft placement should be considered as first line therapy. A recent metaanalysis comparing uncovered and covered stent grafts showed a significant reduction in mortality, recurrent bleeding, and ascites with covered stent grafts.

Sonographic Findings

Ultrasound is an excellent technique for evaluating stent grafts. Usually, a curvilinear or more frequently phased array transducer is required due to the deep abdominal location of the stent graft and the need to penetrate to obtain a Doppler signal and show flow on color Doppler. Typically, the portal vein end of the stent graft is visualized using a high lateral intercostal or subxyphoid/subcostal approach and the hepatic vein end is visualized using a high or low lateral intercostal or subxyphoid/subcostal approach. The patient is usually supine although a slight left lateral decubitus position may improve visualization. Prior to obtaining velocities, color Doppler flow within the stent graft should be optimized; usually, a high velocity is required. If the velocity is set too low, the entire stent graft will be aliased and a stenosis may be missed. The typical exam includes obtaining an angle corrected main portal vein velocity proximal to the stent graft, velocities within the proximal and mid/distal stent graft (as well as in any area of focal aliasing), and determination of flow direction in the right and left portal vein branches and draining hepatic vein into which the stent graft was placed. Normal values will be discussed in part 2. It is also important to assess for the presence of portosystemic collaterals, ascites, and hydrothorax.

Treatment

Stent graft complications include thrombosis, migration, stenosis, and obstruction. As mentioned, these complications occur much less frequently in covered stent grafts. These complications are treated in interventional radiology; an angiogram is performed and the stent graft revised as needed.

References

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 84–87.

CASE 86

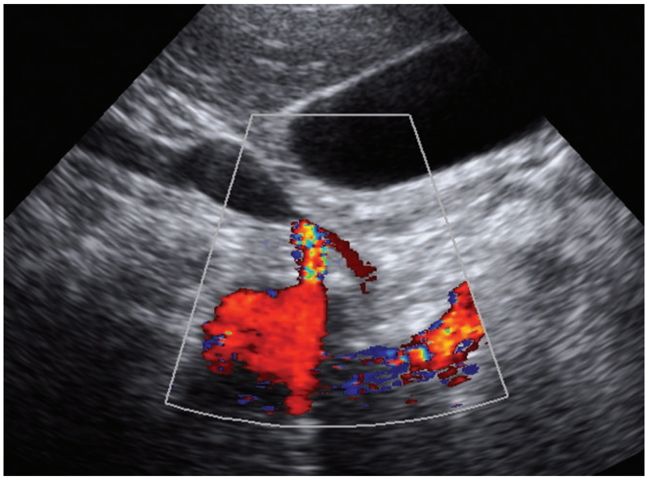

Figure 86-1

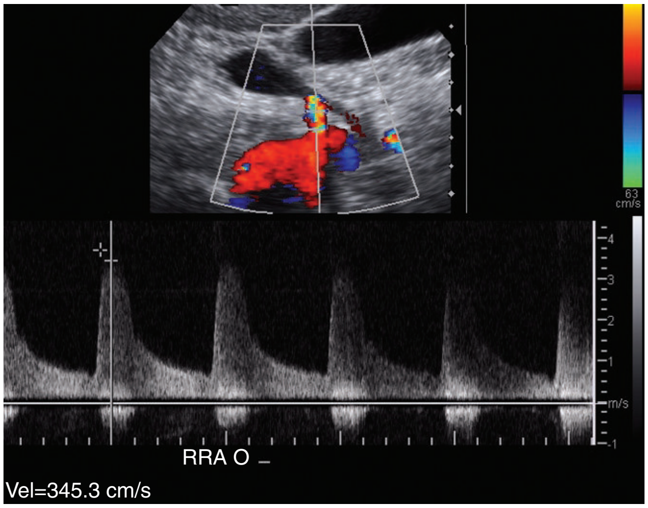

Figure 86-2

HISTORY: A 65-year-old diabetic male presents with difficult-to-control hypertension.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Renal artery arteriovenous fistula
   B. Renal artery stenosis
   C. Fibromuscular dysplasia
   D. Renal artery pseudoaneurysm
2. Concerning renovascular hypertension, which statement is true?
   A. Focal aliasing is an artifact and therefore not useful for diagnosing an arterial stenosis.
   B. A luminal occlusion of 75% to 80% is required to produce a “critical” stenosis.
   C. A luminal occlusion of 50% is required to produce a “critical” stenosis.
   D. A luminal occlusion of 90% is required to produce a “critical” stenosis.
3. Concerning renovascular hypertension, which statement is true?
   A. A peak systolic velocity of 100 to 120 cm/s indicates renal artery stenosis.
   B. A peak systolic velocity of 140 to 160 cm/s indicates renal artery stenosis.
   C. A peak systolic velocity of 180 to 200 cm/s indicates renal artery stenosis.
   D. A peak systolic velocity of 250 to 300 cm/s indicates renal artery stenosis.
4. Concerning renovascular hypertension, which statement is true?
   A. The renal artery to aortic ratio measures the ratio of the peak systolic velocity in the main renal artery to the peak systolic velocity in the aorta at the renal artery level.
   B. The normal renal artery to aortic ratio is 5:1.
   C. A tardus-parvus waveform occurs proximal to a stenosis.
   D. A tardus-parvus waveform has enhanced early systolic acceleration (tardus) and increased amplitude (parvus).

See Supplemental Figures section for additional figures and legends for this case.

CASE 86

Renovascular Hypertension

1. **B.** There is focal aliasing at the origin of the right renal artery (arrow, Fig. S86-1) on color Doppler indicating a stenosis. At this location, a stenosis is almost always due to atherosclerosis. Fibromuscular dysplasia (C) might be considered, but the location of the stenosis negates this diagnosis.
2. **B.** A luminal occlusion of 75% to 80% is required to produce a "critical" stenosis. When present, the renin-angiotensin system is activated as are complex intrarenal pathways that cause microvascular loss leading to cortical atrophy; an irreversible change. Aliasing is depicted on pulsed Doppler as negative frequency shift information because of wrap-around of the Doppler signal (i.e., the peaks of the arterial signals wrap around below the baseline). Aliasing can be reduced by increasing the Doppler angle, using a lower frequency transducer, lowering the baseline, and increasing the velocity scale.
3. **C.** An appropriately angle-corrected peak systolic velocity of 180 to 200 cm/s or greater acquired in a native renal artery indicates a stenosis greater than and equal to 60% (Fig. S86-2). A metaanalysis of 88 studies involving over 8000 patients found that peak systolic velocity had the highest performance with a sensitivity of 85% and a specificity of 92% compared to other parameters such as the renal artery to aortic ratio, acceleration index, and acceleration time.
4. **A.** Initially, a ratio of 3.5 was reported to indicate an arterial stenosis greater than 60%, but later a study using an endovascular flow wire to obtain measurements suggested the value may be as low as 2.0.

Comment

Introduction

The natural history of renovascular hypertension is one of variable progression. In one prospective study of patients 65 years of age or older with renovascular hypertension, only 4% of patients progressed to a clinically significant stenosis. Clinical indicators of renovascular hypertension include onset of hypertension less than 30 years (fibromuscular dysplasia) or greater than 50 years (atherosclerosis) of age, accelerated malignant hypertension, decreased renal function in response to an angiotensin-converting enzyme inhibitor or angiotensin receptor blocker, asymmetric renal size and/or decreased renal function, and sudden unexplained pulmonary edema in the setting of heart failure.

Sonographic Findings

Renal artery stenosis is evaluated by direct interrogation of the main renal arteries from their origins to the hila. Angle-corrected peak systolic velocities should be obtained at the origin, mid, and distal renal artery and at any area of focal aliasing (arrow, Fig. S86-1). Obesity, bowel gas, a suboptimal Doppler angle, and the "difficult" patient can limit evaluation; in such a case, computed tomography or magnetic resonance angiography may be required. The renal arteries should also be evaluated for tardus-parvus changes that occur distal to a stenosis. A tardus-parvus waveform has a delayed early systolic acceleration (tardus) and diminished amplitude causing rounding of the systolic peak (parvus). To evaluate for tardus-parvus changes, three waveforms should be obtained in the upper and lower poles and mid zone using a fast sweep speed and optimized velocity scale. Positive findings indicate severe renal artery stenosis or occlusion; the two cannot be differentiated based on indirect analysis alone.

Treatment

It is important to treat renovascular hypertension before irreversible renal damage occurs from microvascular loss and inflammatory and immune mediators. The results of recent prospective treatment trials have failed to show a clinical benefit (blood pressure control or improved renal function) from revascularization; thus, most clinicians favor instituting aggressive antihypertensive therapy. In most patients, optimal blood pressure control is achieved. If blood pressure control is poorly achieved, progressive loss of renal function occurs, or patients experience recurrent congestive heart failure and flash pulmonary edema, some would argue that revascularization is indicated.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 134–138.

CASE 87

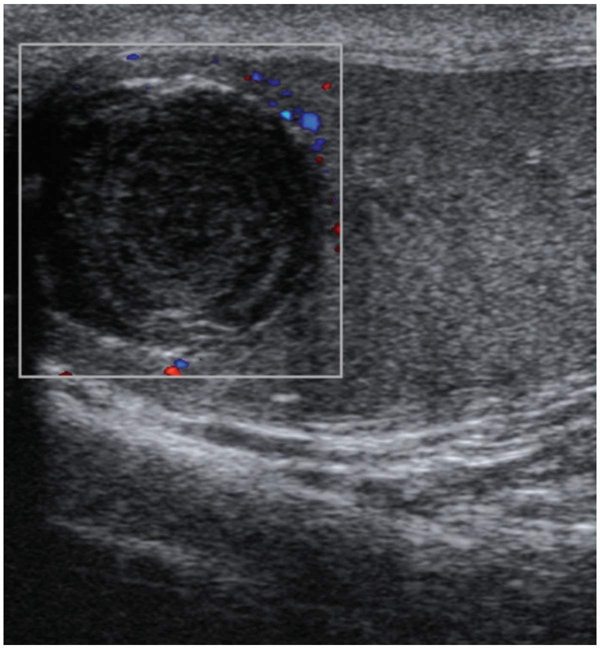

Figure 87-1

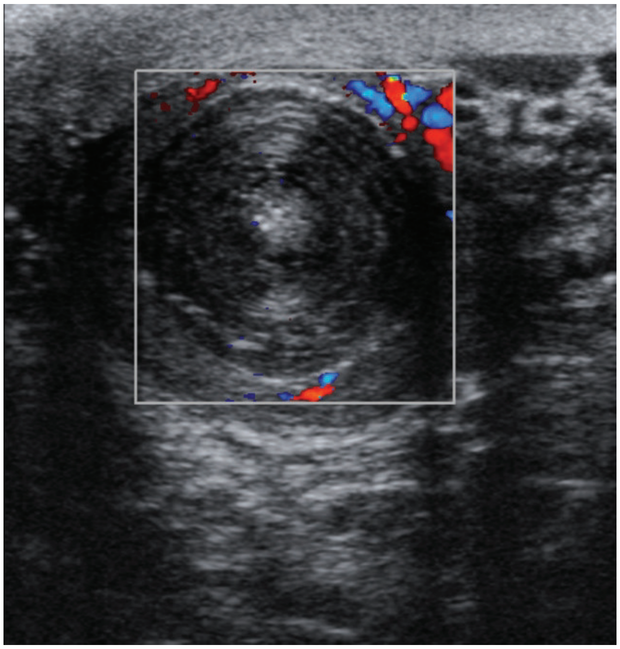

Figure 87-2

HISTORY: A male presents with painless left testicular swelling. Transverse and longitudinal ultrasound images of the left testicle were obtained (Figs. 87-1 and 87-2).

1. Which one of the following should be included in the differential diagnosis? (Choose one.)
   A. Spermatocele
   B. Germ cell tumor
   C. Lymphoma
   D. Epidermoid cyst
2. What laboratory tests and imaging should be ordered in the work-up of this condition?
   A. Alpha-fetoprotein (αFP) and beta-human chorionic gonadotropin (βhCG), no other imaging required
   B. No laboratory tests, computed tomography (CT) abdomen
   C. CMP, positron emission tomography–computed tomography
   D. No laboratory tests, no other imaging required
3. Which one of the following statements regarding testicular masses is NOT true?
   A. Testicular carcinoma accounts for 1% of all cancers in men.
   B. Painful testicular masses are more commonly benign than malignant.
   C. Peripheral hypervascularity on color Doppler is seen with testicular abscesses.
   D. Bilateral involvement is indicative of a benign process.
4. Which one of the following best describes the most common presentation, malignant potential, and preferred treatment of this condition?
   A. Painless, no malignant potential, orchiectomy
   B. Painless, malignant potential, orchiectomy
   C. Painless, no malignant potential, enucleation
   D. Painful, no malignant potential, enucleation

See Supplemental Figures section for additional figures and legends for this case.

CASE 87

Epidermoid Cyst

1. **D.** Intratesticular spermatoceles, germ cell tumors, and epidermoid cysts are all well-circumscribed masses that have a variable sonographic appearance. However, epidermoid cysts often have an onion skin appearance as in this case. This is the most likely diagnosis. Germ cell tumors are often vascular. Testicular lymphoma occurs in older males and appears as a solid often hypoechoic mass.
2. **A.** No other imaging is required when characteristic imaging findings are present. αFP and βhCG should be ordered as part of the work-up of any painless testicular mass to evaluate for a functioning germ cell tumor.
3. **D.** Both germ cell tumors and testicular lymphoma can present as bilateral testicular masses with painless testicular enlargement.
4. **C.** Epidermoid cysts present as a painless testicular mass and have no malignant potential. They are treated with enucleation as they are often difficult to distinguish from atypical germ cell tumors.

Comment

Differential Diagnosis

The differential diagnosis includes neoplastic and nonneoplastic lesions. Correlation with clinical exam, symptomology, and serum tumor markers is critical for differentiating equivocal cases. Intratesticular cysts include simple cysts and tunica albuginea cysts. Testicular cysts are present in approximately 10% of men. True simple cysts are nonpalpable and centrally located whereas tunica albuginea cysts are located peripherally within the tunica albuginea. Both are commonly found incidentally and meet all criteria for simple cysts, though on occasion tunica albuginea cysts may be multilocular. Tubular ectasia of the rete testis will be found in older patients in the fifth to sixth decades, will be adjacent to the mediastinum testis, and are more commonly bilateral. They are also differentiated by their tubular appearance. An intratesticular spermatocele is likewise adjacent to the mediastinum testis but is cystic appearing and is found to communicate with the efferent tubules. Classically, they feature the “falling snow” sign where particulate matter within the spermatocele is moved by the waves of the ultrasound probe.

The most critical distinction to make is between an epidermoid cyst and a germ cell tumor. The most common germ cell tumor in the second to fourth decades is a seminoma, which most commonly presents as a homogeneous, hypoechoic, solid intratesticular mass. They rarely calcify but can undergo cystic necrotic degeneration. They similarly present as painless testicular masses. An important distinguishing feature is hypervascularity on color Doppler.

Ultrasound Findings

Epidermoid cysts are well-circumscribed intratesticular masses. They range in size from 1 to 3 cm, but have rarely been found as large as 10 cm. The sonographic appearance of epidermoid cysts varies based on the degree of maturation. They classically are described as having an “onion skin” appearance with alternating hypoechoic and hyperechoic rings (Figs. S87-1 and S87-2). They may also appear as target lesions with an echogenic center and hypoechoic rim. They often feature a fibrous wall that is hyperechoic and can either partially or completely calcify with variable shadowing. Central cyst contents are most commonly hypoechoic and irregular due to keratinaceous contents. Central calcification can also be seen due to calcific deposition with the central keratin. Epidermoid cysts are avascular on color Doppler (Fig. S87-2), an important distinguishing feature from germ cell tumors or other intratesticular malignancies.

Prognosis and Management

The most common presentation is a young (second to fourth decade) male with a painless testicular mass. Ultrasound (US) examination should be performed along with assessment of serum tumor markers. High resolution US (>7.5 MHz) is often required to have high enough resolution to demonstrate the alternating tissue layers that produce the onion skin appearance.

Epidermoid cysts represent 1% of testicular tumors and have no malignant potential. They are ectodermal teratomas without neoplastic features on pathology. They are often found on ultrasound examination for a painless testicular mass and may be found incidentally when testicular ultrasound is performed to evaluate for infection or trauma. Unfortunately, the distinction between epidermoid cysts and germ cell tumors or other testicular neoplasms is not always clear. Correlation with tumor markers such as αFP and βhCG is requisite. In most cases, enucleation is performed with biopsy of the adjacent parenchyma. This strategy prevents orchiectomy and allows for pathologic verification of the benign nature of the lesion.

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Cross-reference

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Acknowledgment

Special thanks to Ethan Neufeld, MD, for preparation in this case.

CASE 88

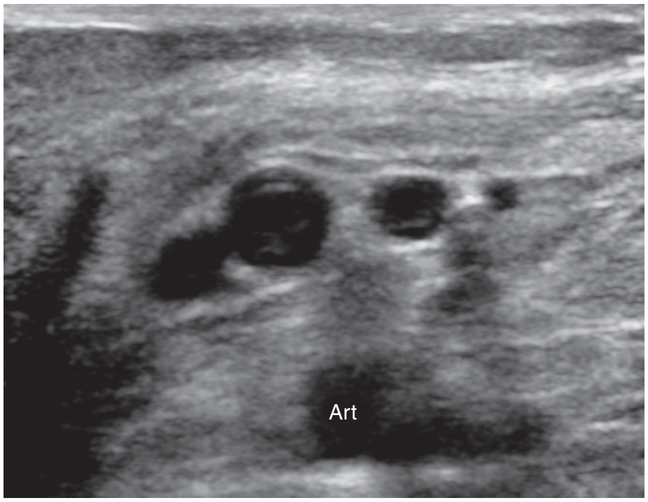

Figure 88-1

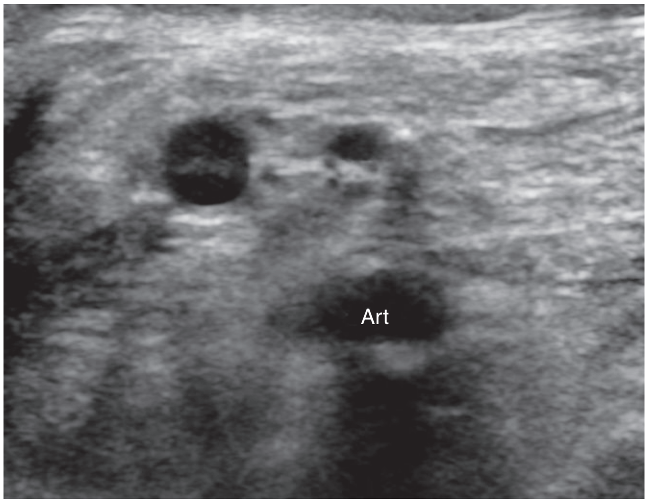

Figure 88-2

HISTORY: A 34-year-old with recent plane flight presents to the emergency room with calf tightness. A lower extremity venous ultrasound was performed to exclude deep venous thrombosis (DVT). Transverse images of the popliteal fossa on the affected side without and with compression were obtained.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Acute popliteal DVT
   B. Acute saphenous superficial thrombophlebitis
   C. Acute gastrocnemius DVT
   D. Chronic popliteal thrombosis

2. Which of the following is true of calf deep vein thrombosis?
   A. It is ultrasonically similar to femoropopliteal DVT.
   B. It is treated unless there is a contraindication.
   C. It is self-limited in 50% of cases.
   D. It more frequently presents with swelling than pain.

3. Which of the following is characteristic of calf DVT?
   A. It causes symptomatic pulmonary embolism.
   B. It is associated with development of chronic venous insufficiency.
   C. It clears completely in 6 months.
   D. It is more common in the anterior tibial vein than the soleal vein.

4. Regarding the anatomy and physiology of the veins of the calf, which of the following is true?
   A. Soleal and small saphenous veins lie deep to the muscular fascia.
   B. Soleal veins are drained by ankle movement.
   C. Walking causes blood to flow toward the small saphenous vein.
   D. Gastrocnemius veins drain primarily into the posterior tibial vein.

See Supplemental Figures section for additional figures and legends for this case.

CASE 88

Calf Deep Venous Thrombosis

1. **C.** Acute gastrocnemius DVT is correct. The popliteal vein adjacent to the popliteal artery compresses and is normal. The noncompressible veins are in the muscle in the upper calf. The gastrocnemius veins are deep veins; they lie below the muscular fascia. There are four gastrocnemius veins in the images. Two compress and two are noncompressible (Figs. S88-1 and S88-2).
2. **A.** That calf DVT is ultrasonically similar to femoropopliteal DVT is true. Treatment of calf DVT is not standardized; many patients are followed and only treated if there is progression to the central deep veins. Calf DVT is self-limited in at least 80% of patients and, therefore, does not progress frequently into the central deep veins. Calf DVT is frequently asymptomatic; when there are symptoms, pain is more common than swelling.
3. **B.** Calf clots, because they are small, rarely cause symptomatic pulmonary embolism. They can affect valve function and a sequela can be chronic venous insufficiency. Either resolution or scarring can occur after calf DVT. The soleal vein is the most common site of calf DVT.
4. **B.** The soleal veins are drained by ankle movement. The small saphenous vein lies superficial to the muscular fascia, the soleal vein lies in muscle deep to the fascia. Walking causes blood to flow toward the heart, and valves prevent flow toward the superficial veins. The gastrocnemius veins drain into the popliteal vein.

Comment

Imaging Findings

Noncompressible veins indicate acute DVT, scarring, or inadequate compression. Although there are many calf veins, calf DVT tends to present with localized pain so the ultrasound can be utilized over the area of interest.

Anatomy and Pathophysiology

The deep veins lie deep to the muscular fascia and consist of the veins above the knee (central veins) and the calf veins (distal veins). Deep veins below the knee either lie between the muscles (the posterior tibial, perineal, and anterior tibial veins) or inside the calf muscles (the soleal and gastrocnemius veins) (Figs. S88-1 and S88-2).

The earliest location for acute DVT are the calf veins, particularly the soleal and gastrocnemius veins. DVT does not grow continuously from the distal to the proximal veins. Instead DVT begins in the calf and then is formed in other veins usually separated by normal veins unless the DVT becomes extensive.

Test of Choice

Because not all patients with calf DVT require treatment, imaging the calf veins is not universally performed. The American College of Radiology guidelines recommend the test from the inguinal ligament to the tibioperoneal trunk. The guidelines do not mandate calf imaging in all. Calf imaging may be warranted if there are symptoms and the standard examination does not indicate a cause (for example, those with calf pain and without femoropopliteal DVT).

Treatment and Follow-up

Only about 20% of patients with calf DVT progress to central DVT (Fig. S88-3); the rest regress or do not propagate. The majority of patients do not need treatment. Calf DVT patients at high risk for recurrence, with severe symptoms, or who cannot return for follow-up ultrasound are candidates for treatment.

If calf DVT is diagnosed and the patient is treated, no follow-up ultrasound is warranted. If the patient is not treated, a follow-up ultrasound is recommended to rule out progression (once a week for a total of 2 weeks unless the DVT has disappeared or it has progressed and been treated).

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Cross-reference

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CASE 89

Figure 89-1

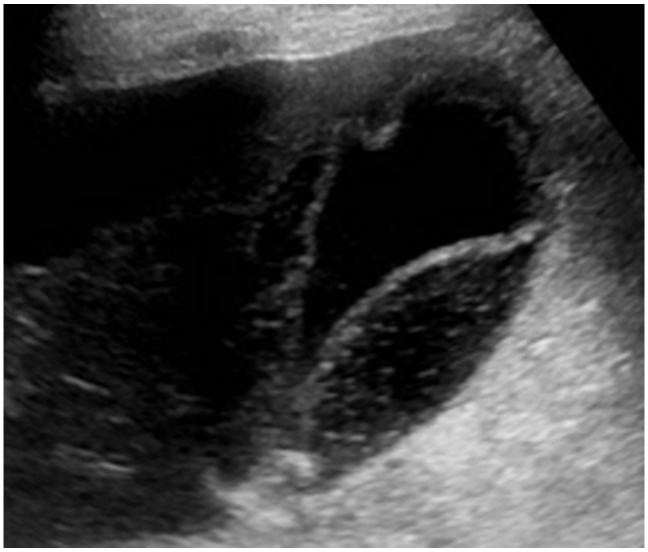

Figure 89-2

HISTORY: A 75-year-old male presents with a normal white blood cell count and acute right upper quadrant pain and tenderness.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Acute cholecystitis
   B. Gangrenous cholecystitis
   C. Chronic cholecystitis
   D. Emphysematous cholecystitis

2. Which of the following is true regarding gangrenous cholecystitis?
   A. Gangrenous cholecystitis is defined as transmural necrosis of the gallbladder wall on gross pathologic exam.
   B. On ultrasound, a striated wall (alternating hypoechoic and hyperechoic layers) is indicative of gangrenous change.
   C. Gangrenous cholecystitis usually occurs in middle-aged, obese women.
   D. Gangrenous cholecystitis has the same morbidity and mortality as acute cholecystitis.

3. Which of the following is true regarding gangrenous cholecystitis?
   A. Gallbladder wall striations can occur in a variety of disease states unrelated to primary gallbladder disease.
   B. Gallbladder wall striations occur in the submucosal layer of the wall.
   C. A sonographic Murphy sign is absent in most patients with gangrenous cholecystitis because the gallbladder is necrotic.
   D. Patients with gangrenous cholecystitis most commonly present with severe right upper quadrant pain.

4. Which of the following is true regarding gangrenous cholecystitis?
   A. Gallbladder wall irregularity or ulceration on ultrasound is a nonspecific finding.
   B. Gallbladder wall perforation most commonly occurs in the fundus of the gallbladder.
   C. Gallbladder wall perforation most commonly causes bile peritonitis.
   D. On ultrasound, a simple crescentic fluid collection surrounding the gallbladder wall is suggestive of perforation.

See Supplemental Figures section for additional figures and legends for this case.

CASE 89

Gangrenous Cholecystitis

1. **B.** Ultrasound Figures S89-1 and S89-2 show intraluminal membranes (arrow); the membranes represent sloughed mucosa in this patient with gangrenous cholecystitis. Acute cholecystitis (**A**) is also correct; gangrenous cholecystitis is an advanced form of acute cholecystitis and occurs in 2% to 30% of patients with acute cholecystitis.
2. **A.** Pathologists make the diagnosis of gangrenous cholecystitis on gross exam, not on histologic exam. Gallbladder wall striations are not associated with gangrenous cholecystitis and can occur with acute or chronic cholecystitis. Striations are due to a combination of histologic findings (edema, inflammation, hemorrhage, and fibrosis).
3. **A.** Gallbladder wall striations can occur with right heart failure, chronic liver disease, cirrhosis, acute hepatitis, acute pancreatitis, chronic renal failure, and hypoalbuminemia. Wall striations are most evident along the hepatic surface of the gallbladder. The gallbladder does not have a submucosa. It is unique and has a mucosa, fibromuscular layer, subserosa, and serosa (except along the hepatic surface where only loose areolar connective tissue exists).
4. **B.** The cystic artery branches are end arteries at the fundus; there are no collaterals. Thus, this area is prone to ischemia/necrosis. There are three types of gallbladder wall perforations: acute (rare) into the peritoneal cavity; subacute (most common), which causes a walled off pericholecystic abscess; and chronic (unusual), which causes a fistulous communication with the duodenum or hepatic flexure. A simple, thin, anechoic crescent of pericholecystic fluid can be seen in cases of nongangrenous cholecystitis and does not indicate perforation.

Comment

Introduction

Gangrenous cholecystitis occurs most commonly in elderly diabetic African American men. Associated risk factors include an immunocompromised state (malignancy, chronic steroid use), cardiovascular disease, and diabetes. Most patients have gallstones. The presentation can be very subtle; the patient may be afebrile, the WBC may be normal, and right upper quadrant pain/tenderness may be absent, especially if the gallbladder has perforated and decompressed.

Sonographic Findings

Gangrenous cholecystitis can be a difficult diagnosis on ultrasound. Intraluminal membranes (Figs. S89-1 and S89-2), though rare, strongly suggest the diagnosis; however, inspissated mucous strands or inflammatory exudate may have a similar appearance. One helpful clue is that sloughed mucosa parallels the gallbladder wall whereas inspissated mucous strands or inflammatory exudate has a more random orientation. A multiseptate gallbladder is also a consideration, but this entity is exceedingly rare and the septae are perpendicular to the gallbladder wall. Gangrenous cholecystitis should also be considered when an irregular, thickened wall is present on ultrasound; this finding correlates with mural ulceration, hemorrhage, necrosis, and abscess formation. Wall thickness itself is not helpful in differentiating gangrenous from nongangrenous cholecystitis on ultrasound as there is considerable overlap. The absence of a sonographic Murphy sign is also not predictive of gangrenous cholecystitis; it was present in 70% of patients with gangrenous cholecystitis in one study. An important differential is gallbladder carcinoma. Loss of visualization of the normal echogenic gallbladder wall and the presence of a hypoechoic, solid mass invading the liver favor carcinoma. However, gangrenous cholecystitis can perforate into the liver and also have a hypoechoic mass-like appearance on ultrasound. In such cases, biopsy is required. Xanthogranulomatous cholecystitis may also have a similar, infiltrative appearance. Hypoechoic “nodules” in the gallbladder wall representing xanthogranulomatous deposits may suggest this latter diagnosis.

Treatment

Gangrenous cholecystitis has a mortality rate of 5% to 10%. Wall perforation occurs in up to 10% of patients and increases morbidity and mortality. Patients with gangrenous cholecystitis may have comorbidities precluding surgery. In such cases, a percutaneous cholecystostomy drainage catheter is placed. Laparoscopic cholecystectomy can also be safely performed, but conversion to an open procedure may be required to reduce local complications.

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Cross-reference

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CASE 90

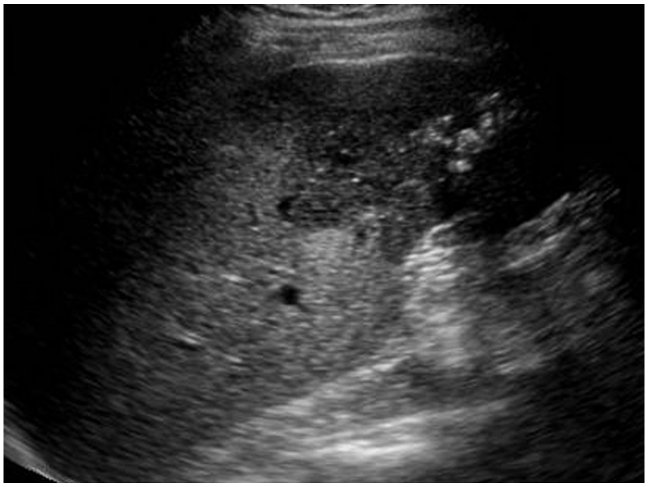

Figure 90-1

Figure 90-2

HISTORY: A 70-year-old female presents with vague right upper quadrant pain and weight loss.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Gallbladder carcinoma
   B. Gallbladder sludge
   C. Acute cholecystitis
   D. Cholelithiasis

2. Concerning gallbladder carcinoma, which statement is true?
   A. Cholelithiasis is not a risk factor for gallbladder carcinoma.
   B. Risk factors for gallbladder carcinoma include porcelain gallbladder, gallbladder polyp, anomalous pancreaticobiliary junction, choledochal cyst, ethnicity (Caucasian, southwest Native American), and geographic distribution (South America, India, Pakistan, Japan, Korea).
   C. It is not possible to differentiate an adenomyoma from a fundal gallbladder carcinoma on ultrasound.
   D. It is possible to differentiate a gallbladder adenoma from a carcinoma on ultrasound.

3. Concerning gallbladder carcinoma, which statement is true?
   A. The prevalence of gallbladder carcinoma in polyps is more common when polyps are multiple.
   B. The risk of gallbladder carcinoma in polyps less than or equal to 6 mm is low.
   C. On ultrasound, gallbladder carcinoma most commonly presents as an intraluminal polypoid mass.
   D. Gallbladder wall thickening from carcinoma cannot be differentiated from benign wall thickening on ultrasound.

4. Concerning gallbladder carcinoma, which statement is true?
   A. All gallbladder carcinomas are adenocarcinomas.
   B. On ultrasound, gallbladder carcinoma has one of three appearances: a mass that replaces the gallbladder, thickening of the gallbladder wall, or a polypoid mass.
   C. The most common mode of gallbladder carcinoma spread is hematogenous.
   D. Lymphatic spread is uncommon in gallbladder carcinoma.

See Supplemental Figures section for additional figures and legends for this case.

CASE 90

Gallbladder Carcinoma

1. **A.** There is gallbladder wall thickening along the hepatic surface invading into the liver most consistent with gallbladder carcinoma. While gallstones are present, the hypoechoic mass invading the liver excludes acute cholecystitis (**C**). However, xanthanogranulomatous cholecystitis could have a near identical appearance.
2. **B.** Cholelithiasis is present in 70% to 90% of patients with gallbladder carcinoma and is one of the strongest risk factors. Chronic inflammation in the setting of cholelithiasis leads to mucosal dysplasia and subsequent development of gallbladder carcinoma. A recent review of 13 studies showed that while gallbladder wall calcifications are a risk factor for carcinoma, the risk is substantially less than previously reported (up to 25%) and is closer to 6%.
3. **B.** The prevalence of gallbladder carcinoma in polyps is a function of size, number, and shape. Most polyps on ultrasound are less than 10 mm, often 2 to 3 mm, and non-neoplastic (cholesterol or inflammatory). One large series showed that incidentally detected polyps less than 6 mm may require no further ultrasound follow-up. Most polypoid carcinomas are solitary, sessile, and greater than 10 mm but cannot be differentiated from an adenoma or large hyperplastic polyp.
4. **B.** The gallbladder is replaced by a mass in 40% to 65% of cases, wall thickening occurs in 20% to 30%, and an intraluminal mass occurs in 15% to 25%. Gallbladder carcinoma tends to invade the liver and porta hepatis, causing bile duct obstruction. Lymphatic spread is common to peripancreatic, pericholedochal, and cystic duct nodes, which are hypoechoic and rounded on ultrasound.

Comment

Introduction

Gallbladder carcinoma is two to six times more common in women than men. Most gallbladder carcinomas are adenocarcinomas although unusual histologic variants (signet ring, squamous/adenosquamous, small cell, sarcoma, and lymphoma) occur but portend a worse prognosis. Melanoma is the most common metastasis to the gallbladder. Other benign and malignant tumors can also have a polypoid appearance (neurofibroma, heterotopic gastric mucosa, adenomyoma, carcinoid, lymphoma). Symptoms are fairly nonspecific (vague abdominal pain, anorexia, weight loss, and jaundice).

Sonographic Findings

On ultrasound, a polypoid carcinoma can be hyperechoic, isoechoic, or hypoechoic and may have color Doppler flow. A fundal polypoid carcinoma is difficult to differentiate from a fundal adenomyoma; the presence of Rokintansky-Aschoff sinuses and comet tail artifact (from cholesterol crystals in the sinuses) can help to differentiate the two. A mass replacing the gallbladder may encase gallstones and is hypoechoic and heterogeneous with color Doppler flow. Invasion into the liver occurs in advanced cases. Gallbladder wall thickening may be diffuse or focal and difficult to differentiate from benign thickening. On ultrasound, malignant wall thickening is often greater than or equal to 1 cm, hypoechoic, asymmetric, and irregular; benign thickening is more symmetric and diffuse (Figs. S90-1 and S90-2). However, xanthogranulomatous cholecystitis and gangrenous cholecystitis with perforation can appear very similar to gallbladder carcinoma and an ultrasound-guided biopsy of the wall or involved liver, if invasion is apparent, may be necessary.

Treatment

Most patients present in advanced stages; 5-year survival is only 5% to 10%. Therapy is palliative in inoperable patients and includes a biliary stent to relieve jaundice. Palliative chemotherapy may also be considered; recently, genetic mutations have been identified in gallbladder carcinoma and targeted agents have been used. Surgical resection offers the only chance for cure. A simple cholecystectomy may be adequate if invasion is limited to the lamina propria; survival has been reported near 90%. More aggressive surgery (cholecystectomy with en bloc segmental liver resection, lymph node dissection, common bile duct resection and reconstruction) is required when tumor invades beyond the gallbladder wall or less than or equal to 2 cm into the liver, increasing survival by several months. Chemoradiation after surgery has also been shown to extend survival.

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Cross-reference

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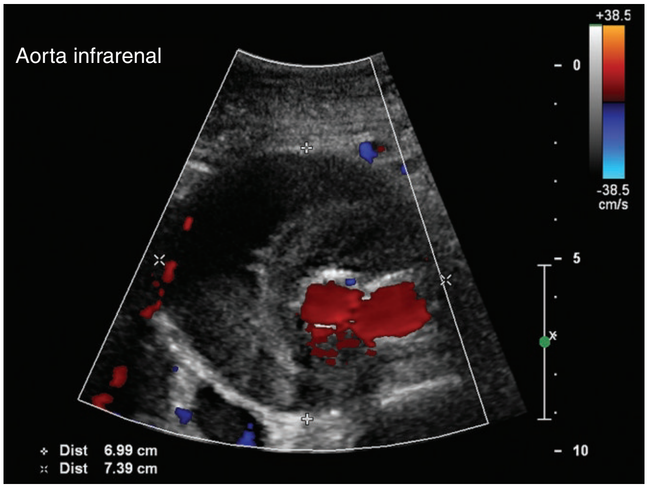

Figure 91-1

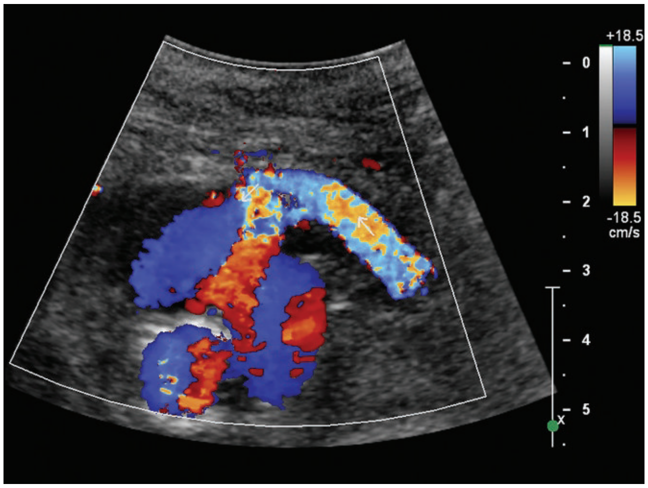

Figure 91-2

HISTORY: This is a 67-year-old male with a history of abdominal aortic aneurysm who has had a recent procedure. He is presenting for ultrasound evaluation.

1. Which one of the following would be included in the differential diagnosis for the imaging findings shown in Figures 91-1 and 91-2? (Choose one)
   A. Untreated abdominal aortic aneurysm
   B. Dissecting aortic aneurysm
   C. Successful endovascular aneurysm repair
   D. Type II endoleak with endovascular repair of abdominal aneurysm
2. Patients with abdominal aortic aneurysms are considered for elective repair EXCEPT in which case?
   A. When the aneurysm is rapidly enlarging
   B. When there is a source of emboli from debris in the aneurysm that then travels to distal arteries
   C. When the aneurysm diameter reaches greater than 4 cm
   D. When the patient experiences abdominal pain and tenderness
3. What is the one most common type of endoleak after abdominal aortic aneurysm endovascular repair?
   A. Type I
   B. Type II
   C. Type III
   D. Type IV
4. Currently, what is the one technique most widely used in the United States for imaging of endoleaks?
   A. Computed tomography (CT) angiography
   B. Magnetic resonance (MR) angiography
   C. Ultrasound
   D. Nuclear medicine

See Supplemental Figures section for additional figures and legends for this case.

CASE 91

Type II Endoleak

1. **D.** This is the best answer. The inferior mesenteric artery fills the aneurysmal sac in a retrograde fashion in this patient with an endovascular repair of an abdominal aortic aneurysm.
2. **C.** Many consider the upper limit in which repair is considered to be 5.5 cm and not 4 cm. Certainly, other considerations, including patient's age, their operative condition, and the stability of the aneurysm must be taken into consideration before a repair.
3. **B.** These are aneurysms in which the sac fills via a branch vessel, such as the inferior mesenteric artery or lumbar artery and is the most common type of endoleak after abdominal aortic aneurysm repair. Type I leaks are at the graft ends due to inadequate seal. Type III leaks are through the defect in the graft fabric. Type IV leaks are due to the porosity of the graft fabric causing blood to pass through from the graft into the aneurysmal sac.
4. **A.** Certainly, in the United States, the performance of CT angiography for aneurysm imaging and endoleak detection is well established and utilized. This is the most correct answer. Ultrasound is used to screen for abdominal aortic aneurysms. Ultrasound has been shown to be helpful in detecting endoleaks. MR angiography is capable of detecting endoleaks, and both technetium 99m and technetium-tagged red blood cell scans have been shown to be helpful in detecting of endoleaks.

Comment

Differential Diagnosis

The differential diagnosis in this case is fairly straightforward. The patient has had an endovascular repair with the two limbs of the endograft identified on color flow on Figure S91-1. The aneurysmal sac is identified as a hypoechoic structure surrounding the endograft limbs. On Figure S91-2, the inferior mesenteric artery is noted, which supplies the aneurysmal sac in a retrograde fashion. Given these two features, there is little else that could be considered within the differential diagnosis of this case, except for a Type II endoleak.

Ultrasound Findings

Type II endoleaks are the most common endoleaks. Sonographic detection is dependent on the acoustic window and the size of the patient. Abdominal aortic aneurysms are often so large they displace the bowel, thus optimizing imaging. Color Doppler ultrasound with pulse Doppler is helpful in detection of endoleaks such as the Type II endoleak. The imaging findings are dependent on the type of endoleak. In Type II endoleaks, there is usually retrograde color flow from a lumbar artery and/or inferior mesenteric artery into the sac surrounding the endograft (Figs. S91-2 and S91-3). Furthermore, more recent data has shown there is improved detection of endoleaks with contrast-enhanced ultrasound. In some situations, contrast-enhanced ultrasound has been shown to be nearly as effective as CT angiography in detecting and classifying endoleaks. Sonography also has the advantage of not using either ionizing radiation as with CT and not using iodinated CT contrast.

Prognosis/Management

There are different treatment strategies for different types of endoleaks.

In Type I endoleaks, where there is a leak where the graft attaches to the aorta, it is repaired immediately. Likewise, Type III endoleaks, where there is a failure of the graft material, need to be fixed immediately, as there is a direct communication between the systemic arterial blood and the aneurysmal sac. This would create increasing pressure within the aneurysmal sac. Type IV endoleaks are very uncommon. Type V endoleaks are very rare. The most common type of endoleak is a Type II endoleak, where a collateral vessel is supplying the aneurysmal sac. It's treatment is debated. Some feel this type of endoleak should be followed, and if, in fact, the aneurysmal sac does not increase in size, then no treatment is necessary. In many cases, there will be spontaneous thrombosis of the supplying artery to the aneurysm. If it is determined that the Type II endoleak should be repaired, then a transarterial technique is utilized with small microcoils placed through collateral vessels into an inferior mesenteric artery.

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CASE 92

Figure 92-1

Figure 92-2

HISTORY: A 16-year-old female presents with right lower quadrant pain.

1. Which one of the following would be included in the most likely differential diagnosis for the imaging findings presented in Figures 92-1 and 92-2? (Choose all that apply.)
   A. Crohn's disease with involvement of the terminal ileum and appendix
   B. Acute appendicitis
   C. Mucocele of the appendix
   D. Intussusception of a terminal ileum with the involvement of the appendix
   E. Acute mesenteric adenitis
2. Which one of the following statements concerning the appendiceal involvement in Crohn's disease is NOT true?
   A. This is a common event occurring in approximately 80% of patients with Crohn's disease.
   B. Thickening of the terminal ileum is common in patients with Crohn's appendicitis.
   C. Appendiceal hyperemia can be identified in this patient group.
   D. Appendiceal thickness in Crohn's appendicitis is greater than 6 cm.
3. Which of the following statements concerning Crohn's disease is NOT true?
   A. In Crohn's appendicitis, ileal thickness of more than 5 mm is a valuable sign in the diagnosis of Crohn's disease differentiated from acute appendicitis.
   B. Demonstrating increased color flow on ultrasound in the terminal ileum with Crohn's appendicitis is a valuable sign for differentiating this entity from acute appendicitis.
   C. In active Crohn's disease, lymphadenopathy is uncommon.
   D. In Crohn's disease, there may be associated increased mesentery fat seen on ultrasound.
4. Which of the following statements is NOT true of Crohn's disease?
   A. Edema of adjacent mesentery is a classical sign of Crohn's disease.
   B. Bowel wall thickening is nearly always present in active Crohn's disease.
   C. Increased color flow of the bowel is common in active involvement in Crohn's disease.
   D. Abscess and fistulas are uncommon in Crohn's disease.

See Supplemental Figures section for additional figures and legends for this case.

CASE 92

Crohn's Disease

1. **A and B.** Crohn's disease is the most likely diagnosis with involvement of both the appendix and thickening of the terminal ileum. The appearance of acute appendicitis is a blind ending noncompressible tubular structure. In this case the terminal ileum was involved, and thus acute appendicitis would be considered less likely. A mucocele of the appendix is usually a larger, more hypoechoic structure. Mesenteric adenitis usually consists of enlarged mesenteric lymph nodes and can have some increased thickness of terminal ileum but usually not of the appendix.
2. **A.** In one series of the Crohn's appendicitis, the appendiceal wall thickness averaged 8 mm in Crohn's appendicitis. Appendiceal involvement in Crohn's disease is approximately 20%. Other statements are true.
3. **C.** Lymphadenopathy is encountered in virtually all patients in the active phase of inflammation of Crohn's disease.
4. **D.** Both abscess formation and the occurrence of fistulas are common in this entity. All other choices are true.

Comment

Differential Diagnosis

The differential diagnosis in this case is fairly interesting. The fluid-filled blind ending structure in Figure S92-1 appears to be the appendix. Then the question is whether the appendix is normal or abnormal? In some series, an appendiceal diameter greater than 6 mm is considered abnormal with ultrasound. In our case, the appendix was compressible but was fairly large on noncompressed scan. There was thickening of the mesentery fat. This could be seen with acute appendicitis. There is an adjacent loop of ileum that appears to be thick and hyperemic (Figs. S92-2 and S92-3). Acute appendicitis would seem less likely given the fact there was a loop of thickened hyperemic terminal ileum. The differential becomes fairly limited to infectious or inflammatory bowel disease involving terminal ileum, cecum, and appendix. There are a number of other entities that may cause right lower quadrant pain, including right-sided diverticulitis, acute typhlitis, mesenteric adenitis, or right-sided omental infarction. They would not have the findings seen in this case.

Ultrasound Findings

Sonographic features of Crohn's appendicitis are that of a blind ending fluid-filled tubular structure with some hyperemia. In this case, there was some compression of the appendix. Distinguishing acute appendicitis from Crohn's appendicitis is the observation of involvement of the terminal ileum. There was thickening of the terminal ileum (Figs. S92-2 and S92-4) on the initial scan and there was hyperemia of the terminal ileum as noted by increased color flow (Fig. S92-3). All of these findings are helpful in diagnosis of Crohn's disease. Other findings include wall thickening, hyperemia, adjacent nodal enlargement, mesentery edema, and "creeping" fat. Perforation and fistulas are common in Crohn's disease.

Prognosis/Management

Treatment in Crohn's disease first includes diet. Certain foods may trigger Crohn's disease such as alcohol, coffee, vegetables, or spicy food. Obviously these should be avoided. Symptoms in Crohn's disease usually include abdominal pain and tenderness, often in the right lower quadrant because of involvement of the ileum. Chronic diarrhea and weight loss are common. Complications such as fistulas and abscesses may results in other more serious complications. Patients also may have other system manifestations, including arthritis, inflammation of the eye, and skin rashes. Treatment usually involves medication and nutrition supplements to reduce inflammation and relieve symptoms. Dietary supplements are given to eliminate nutritional deficiency. There are a variety of medications used for Crohn's disease, including corticosteroids as well as immunosuppressive drugs. Other drugs may be used in certain situations for treatment of Crohn's disease. Percutaneous drainage and/or surgery may be needed for treatment of abscesses developing in these patients. Contrast ultrasound is helpful to better identify the active phase of Crohn's disease and for identifying such complications including abscess formation. Contrast-enhanced ultrasound is helpful in differentiating between active disease and regions of fibrosis.

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Cross-reference

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CASE 93

Figure 93-1

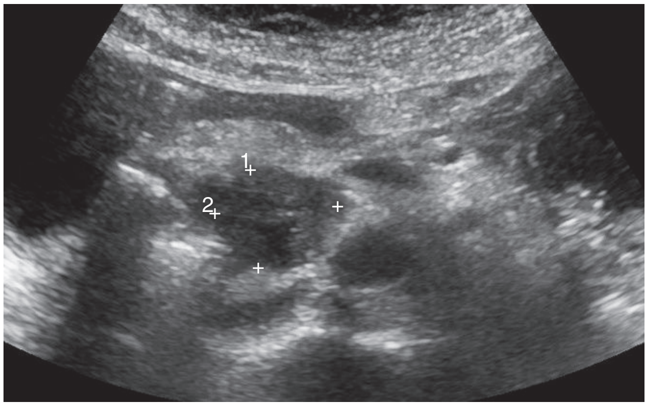

Figure 93-2

HISTORY: A 70-year-old woman presents with painless jaundice and significant weight loss.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Peripancreatic lymphadenopathy
   B. Acute pancreatitis
   C. Chronic pancreatitis
   D. Pancreatic carcinoma

2. What is the sonographic appearance of pancreatic carcinoma?
   A. A focal hyperechoic mass
   B. A well-defined cystic mass
   C. A focal hypoechoic mass
   D. A hypervascular mass on color Doppler

3. What is an indirect finding of pancreatic carcinoma?
   A. Atrophy of the pancreas upstream from the mass
   B. Enlargement of the pancreas upstream from the mass due to reactive inflammation and edema
   C. Narrowing of the pancreatic duct upstream from tumor infiltration
   D. Irregular dilatation of the pancreatic duct with tiny echoic foci (calcifications) in the duct and its side branches

4. Which statement is true regarding pancreatic carcinoma?
   A. Pancreatic carcinoma encases but does not narrow the surrounding vasculature.
   B. Pancreatic carcinoma narrows and can obstruct the surrounding vasculature.
   C. Hematogenous spread is common; especially to the lungs, bones, and brain.
   D. Carcinomatosis is an unusual finding at initial presentation.

See Supplemental Figures section for additional figures and legends for this case.

CASE 93

Pancreatic Carcinoma

1. **D.** There is a focal hypoechoic mass in the head of the pancreas. Given the patient's clinical signs and symptoms, pancreatic carcinoma should be strongly considered. However, if clinical history was not known, acute pancreatitis could also appear as a focal, hypoechoic mass (**B**). A focal hypoechoic mass may also occur in chronic pancreatitis (**C**) and could represent acute or chronic pancreatitis or a carcinoma; biopsy may be required to differentiate the two. There is some literature to support an increased incidence of pancreatic carcinoma in patients with chronic pancreatitis.
2. **C.** Pancreatic carcinoma typically appears as a hypoechoic, solid mass. It may undergo necrosis, but it is predominantly solid. Pancreatic carcinoma is hypovascular as opposed to a neuroendocrine tumor that is hypervascular. Pancreatic metastases, primary lymphoma, and neuroendocrine tumors can also appear hypoechoic; clinical history and computed tomography (CT) or magnetic resonance (MR) imaging characteristics would be helpful in distinguishing among these diagnoses.
3. **A.** Pancreatic carcinomas that occur in the head obstruct the upstream duct due to a desmoplastic reaction causing dilatation and parenchymal atrophy. The pancreatic duct can also be dilated in chronic pancreatitis, but the duct is irregular and the side branches often contain tiny calculi (echogenic foci on ultrasound); the pancreas itself is usually heterogeneous and atrophic.
4. **B.** Because of the desmoplastic nature of pancreatic carcinoma, the portal vein, portosplenic confluence, and superior mesenteric vein may be narrowed or obstructed by the tumor. Pancreatic carcinoma often presents in an advanced stage with peritoneal spread, ascites, lymphadenopathy, and liver metastases.

Comment

Introduction

Pancreatic carcinoma is the fourth leading cause of cancer-related deaths. Less than 20% of patients present with potentially resectable disease. Liver metastases, peritoneal disease, and/or regional lymph node metastases are present in the majority of patients at presentation or develop with time. Five-year survival is 25% in patients with completely resectable disease. Presenting symptoms depend on tumor location and stage. Most tumors occur in the pancreatic head and cause obstructive jaundice, vague epigastric pain, anorexia, nausea, and weight loss.

Sonographic Findings

Although CT with intravenous contrast is the imaging test of choice to stage the newly diagnosed patient, ultrasound is often the initial test ordered in the patient who presents with jaundice or abdominal pain. Pancreatic carcinoma appears as a solid, hypoechoic, ill-defined mass although it may undergo necrosis and appear partially cystic (Figs. S93-1 and S93-2). Most tumors are homogeneous but, if large, may be heterogeneous. Calcifications and a hyperechoic appearance are rare. Because it causes desmoplasia, it can obstruct the pancreatic duct, causing upstream dilatation and atrophy of the parenchyma. It also can abut, encase, and/or obstruct the surrounding vasculature (superior mesenteric artery or vein, portal vein) and abut or encase the celiac trunk and proximal common hepatic artery (depending on the tumor's location). CT and MR are the best tests to determine vascular encasement/obstruction and stage the patient.

Treatment

Surgery is the treatment of choice for patients with pancreatic carcinoma who are deemed resectable. Borderline resectable patients may undergo neoadjuvant therapy (chemotherapy or chemoradiation) in an attempt to improve chances for complete resection. The standard procedure for a tumor in the pancreatic head is a Whipple procedure (pancreaticoduodenectomy). If the tumor is in the more distal neck, body, or tail, a distal pancreatectomy as well as a splenectomy is performed. Pancreatic body carcinomas are often unresectable due to invasion of the celiac axis. However, a radical procedure (Appleby procedure) can be performed; the body/tail of the pancreas is resected with en bloc resection of the celiac axis.

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Cross-reference

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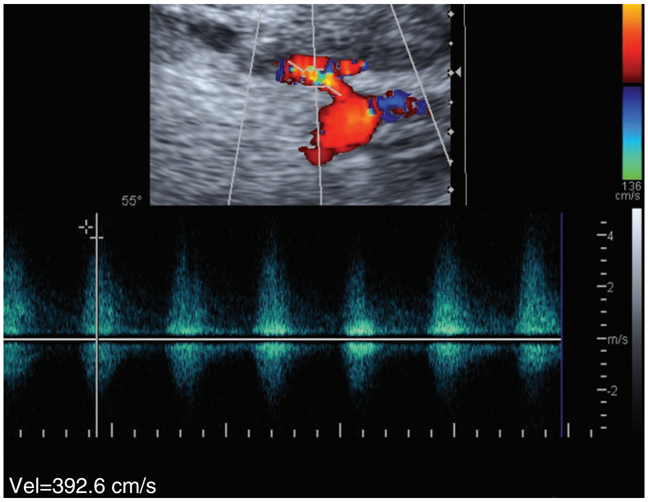

Figure 94-1

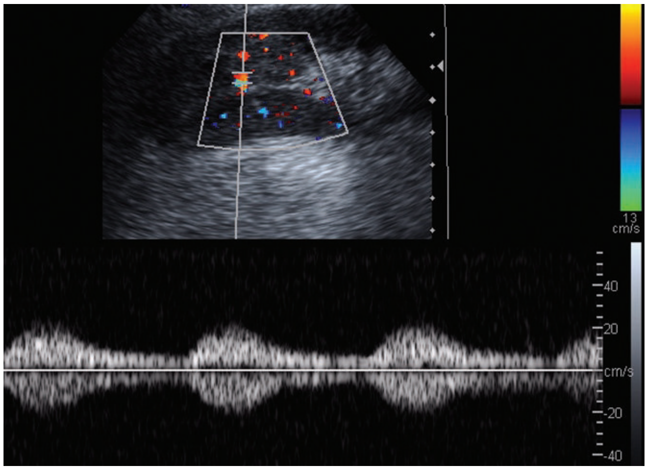

Figure 94-2

HISTORY: A 40-year-old woman presents with a renal transplant and difficult-to-control hypertension.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Renal transplant artery stenosis
   B. Renal transplant artery thrombosis
   C. Normal transplant renal artery
   D. Segmental renal artery tardus parvus changes

2. The peak systolic velocity to diagnose transplant renal artery stenosis falls into which of the following ranges?
   A. 150 to 180 cm/s
   B. 180 to 200 cm/s
   C. 250 to 300 cm/s
   D. Greater than or equal to 300 cm/s

3. What is a cause of arterial diastolic flow reversal in the transplant kidney?
   A. Renal artery stenosis
   B. Renal vein thrombosis
   C. Renal artery thrombosis
   D. Renal vein stenosis

4. Which of the following statements is true?
   A. Renal artery stenosis occurs after the first year of transplantation.
   B. Renal artery stenosis causes oliguria, graft swelling, and tenderness.
   C. Renal vein thrombosis causes oliguria, graft swelling, and tenderness.
   D. Renal vein thrombosis is a late transplant complication.

See Supplemental Figures section for additional figures and legends for this case.

CASE 94

Duplex and Color Doppler of Renal Transplants

1. **A.** The arterial waveform near the origin of the transplant renal artery has a very high peak systolic velocity consistent with a stenosis. The tardus parvus changes (delayed early systolic acceleration [tardus] and diminished amplitude causing a rounding of the systolic peak [parvus]) in the segmental renal artery are indirect findings of a more proximal stenosis (**D**).
2. **D.** The threshold for diagnosing renal artery stenosis in a transplant kidney is higher than that used for the native kidney (180 to 200 cm/s). It has been reported that greater than or equal to 300 cm/s should be used. If it ranges between 250 and 300 cm/s, the patient should be closely followed with repeat Doppler studies. The sensitivity for a peak systolic velocity greater than or equal to 300 cm/s was reported at 80% and the specificity was 93%.
3. **B.** Arterial diastolic flow reversal in the transplant kidney has multiple causes including renal vein thrombosis, acute rejection, acute tubular necrosis, subcapsular hematoma, and vascular kink. Many of these etiologies occur in the early postoperative period, often during the first 10 days.
4. **C.** Renal vein thrombosis causes sudden onset of graft swelling, oliguria, and graft tenderness. It usually occurs within the first week of transplant. Causes include faulty surgical technique, compression of the transplant vein by a fluid collection, hypovolemia, or rejection. On color Doppler, flow cannot be demonstrated in the renal vein.

Comment

Introduction

Renal transplantation is an accepted treatment and often the treatment of choice for patients with end-stage kidney disease. The transplant kidney is usually placed extraperitoneally in the right lower quadrant. The donor vein and artery are usually anastomosed to the recipient external iliac vein and artery, respectively, in an end to side anastomosis. The ureter is implanted into the bladder dome. One-year survival rates for mismatched cadaveric grafts are 80% and, for nonidentical living related grafts, 90%.

Sonographic Findings

Ultrasound is an excellent modality to detect transplant vascular complications. Vascular complications include stenosis, thrombosis, or kinking at or near the anastomosis. Renal artery stenosis usually occurs within the first year of transplantation. Stenoses may occur for many reasons including faulty surgical technique, arterial kinking, or donor atherosclerosis. More recent Doppler criteria for diagnosing a stenosis include a peak systolic velocity of greater than or equal to 300 cm/s (Fig. S94-1). Renal artery thrombosis may occur due to hyperacute rejection, intimal dissection, or anastomotic occlusion. If there is complete renal transplant arterial occlusion, no arterial or venous blood flow will be detected on color Doppler. Renal vein stenosis is usually due to fibrosis and should be suggested if a threefold to fourfold increase in velocity is detected at the site of the stenosis. Renal vein thrombosis appears as absent venous blood flow on ultrasound. The renal artery has diastolic flow reversal. Though this latter finding has a differential, the combination of absent venous blood flow and diastolic flow reversal in the artery is diagnostic of renal vein thrombosis (Fig. S94-2).

Treatment

Percutaneous angioplasty with or without stent placement is the primary treatment of choice for transplant renal artery stenosis and is successful in up to 73% of patients. Significant improvement in hypertension and creatinine has been reported. Renal artery thrombosis, if complete, usually leads to loss of the renal graft. It has been reported that these findings may mimic severe rejection; thus angiography may be indicated in some cases. Renal vein thrombosis has a poor outcome, often with loss of the graft, necessitating a nephrectomy. If discovered early, thrombectomy may salvage the graft.

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CASE 95

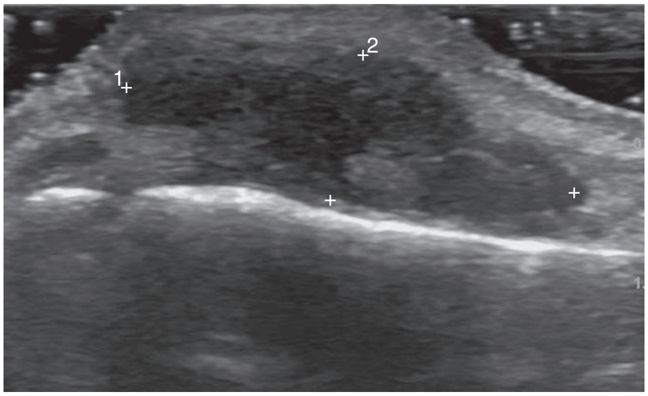

Figure 95-1

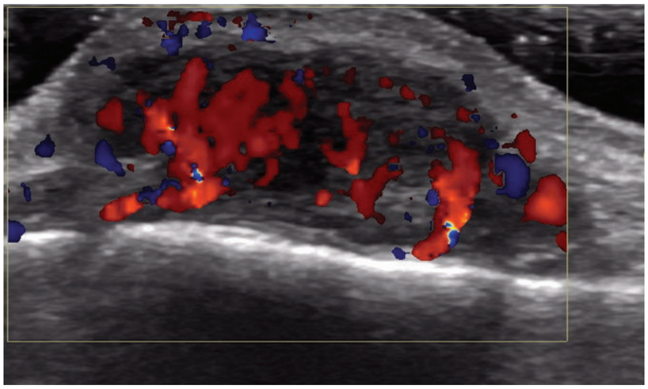

Figure 95-2

HISTORY: A 40-year-old female presents with a "bump" on the flexor side of the index finger.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Ganglion of the tendon sheath
   B. Fibroma of the tendon sheath
   C. Giant cell tumor (GCT) of the tendon sheath
   D. Hemangioma of the tendon sheath
2. Concerning GCTs of the tendon sheath, which statement is true?
   A. GCTs are more common in women.
   B. GCTs are the most common hand lesion.
   C. GCTs have a premalignant potential.
   D. GCTs are reactive nonneoplastic lesions.
3. Concerning GCTs, which statement is true?
   A. GCTs are slow-growing and nontender.
   B. GCTs usually arise from the extensor tendon sheath.
   C. GCTs can be cystic.
   D. GCTs are usually hyperechoic.
4. Concerning GCTs, which statement is true?
   A. GCTs are hypovascular on color Doppler flow.
   B. GCTs may cause bony erosion of the adjacent phalanx.
   C. With flexion of the finger, the tumor moves with the tendon.
   D. Because these tumors are asymptomatic, the usual treatment for GCTs is observation.

See Supplemental Figures section for additional figures and legends for this case.

CASE 95

Giant Cell Tumors of the Tendon Sheath

1. **C.** Figures S95-1 and S95-2 show a GCT of the tendon sheath. GCTs are hypoechoic on gray scale ultrasound with internal flow on color Doppler. A fibroma of the tendon sheath (**B**) is also a consideration and can have an identical appearance, but fibromas are rare. GCTs and fibromas may represent the two endpoints of a spectrum of fibrous proliferation. Ganglions are complex cystic lesions on ultrasound. Hemangiomas do not occur in the tendon sheath.
2. **A.** GCTs are more common in women than in men: the ratio is 2:1. GCTs are benign tumors with no premalignant potential but are not the most common lesion of the hand; ganglions are the most common hand lesions.
3. **A.** GCTs are typically slow-growing and asymptomatic. Although they can arise from an extensor tendon, they more commonly arise from a flexor tendon. GCTs are hypoechoic and solid on ultrasound.
4. **B.** Because GCTs are slow-growing and asymptomatic, patients may delay treatment; thus, as the lesion grows, it may cause bony erosion of the phalanx from pressure. GCTs have internal vascularity on color Doppler. Standard treatment is surgical resection.

Comment

Introduction

GCTs of the tendon sheath are the second most common lesion of the hand and wrist. They are benign tumors that arise from the tendon sheath and, because they are slow-growing, may grow around and encase the tendon. However, GCTs do not move with the tendon when the finger is flexed because the tumor arises from the tendon sheath, not the tendon. Their cells resemble synoviocytes. GCTs are more common in women and have a peak incidence between 20 and 40 years. GCTs most commonly arise from the flexor tendon sheath, often at the interphalangeal or metacarpophalangeal joint levels. Dorsal and more proximal involvement is not uncommon.

Sonographic Findings

GCTs are solid, hypoechoic lesions with well-defined margins. GCTs are vascular and may have peripheral, central, or peripheral and central flow on color or power Doppler. When evaluating for blood flow on color Doppler, it is important to use a high frequency transducer with low flow settings to maximize color sensitivity. It is also important to use a large amount of gel and not compress the tumor with the transducer. If too much pressure is applied with the transducer, the blood vessels within the tumor will be compressed and blood flow will not be demonstrated.

Treatment

When a patient sees a hand surgeon for a palpable lesion along the flexor surface of the finger, the differential diagnosis is usually between a ganglion (cystic) or GCT (solid). Ultrasound is very accurate in distinguishing a solid from a cystic lesion. This is important because GCTs are surgically resected and ganglions can be treated with aspiration and steroid injection or surgical resection.

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Cross-reference

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CASE 96

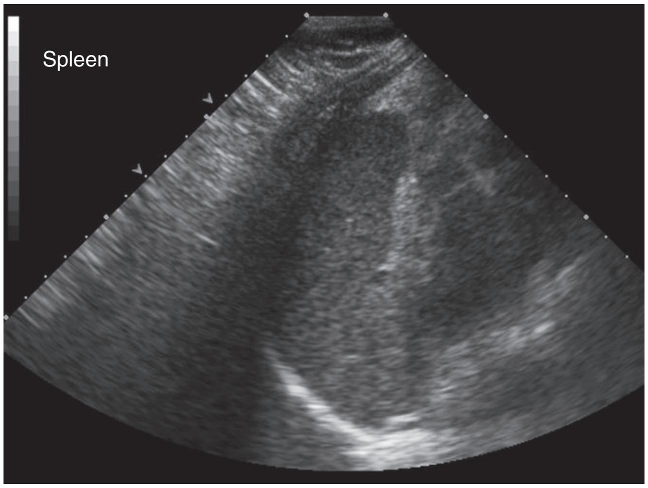

Figure 96-1

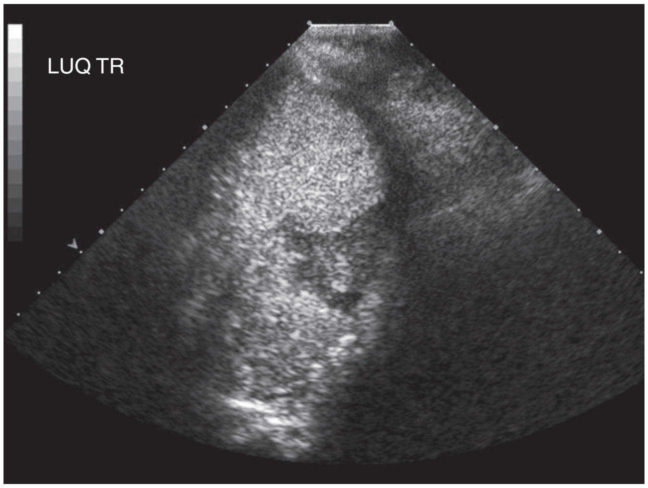

Figure 96-2

HISTORY: A 24-year-old female presents with blunt abdominal trauma.

1. Ultrasound images of the spleen without contrast (Fig. 96-1) and with contrast (Fig. 96-2) are obtained. What is the most likely splenic injury grade in this case?
   A. Grade I splenic injury
   B. Grade II splenic injury
   C. Grade III splenic injury
   D. Grade IV splenic injury
   E. Grade V splenic injury

2. Concerning the use of ultrasound in a patient with a splenic injury, all of the following are true statements EXCEPT:
   A. Free fluid in the left upper quadrant is associated with splenic injuries.
   B. Subcapsular fluid or hematoma is associated with splenic injuries.
   C. Isolated free fluid in the pelvis of a female patient is associated with splenic injuries.
   D. Free fluid in the hepatorenal fossa is associated with splenic injuries.

3. Concerning the use of ultrasound in blunt abdominal trauma, all of the following are true statements EXCEPT:
   A. Identification of free fluid on ultrasound has a high sensitivity in detecting splenic injury when compared to computed tomography (CT).
   B. Ultrasound identification of free fluid in the abdomen has a very high specificity in patients with solid organ injury.
   C. Free fluid in the abdomen of patients with splenic injuries may also be due to other concomitant injuries.
   D. The more severe the splenic injury the higher the likelihood of associated free fluid.

4. Concerning identification of splenic laceration by sonography, all of the following are true statements EXCEPT:
   A. Ultrasound is highly sensitive in identification of Grade I and Grade II splenic lacerations.
   B. Ultrasound may be helpful to identify perisplenic hematoma.
   C. The use of ultrasound contrast agents has been shown to be highly sensitive in identification of splenic injuries.
   D. Use of ultrasound contrast can be utilized to monitor patients with known splenic laceration.

See Supplemental Figures section for additional figures and legends for this case.

CASE 96

Splenic Laceration

1. **C.** Grade III splenic injury is a laceration greater than 3 cm in depth, and this case is most likely classified as a Grade III injury.
2. **C.** This is not necessarily a true statement. A small amount of free fluid in the pelvis can be identified in a female patient and can be a normal finding. However, greater degrees of free fluid in the pelvis may be associated with a splenic injury.
3. **A.** This is a false statement as free fluid is identified in only approximately two-thirds of the patients with splenic injuries. Many splenic injuries are contained injuries without free fluid. All other statements are true, remembering free fluid may be secondary to other injuries other than a splenic injury.
4. **A.** Identification of free fluid rarely occurs with Grade I to Grade II splenic injuries. These are often contained injuries that may be difficult to detect. Free fluid occurs with the greater severity of splenic injuries.

Comment

Differential Diagnosis

The differential diagnosis in this case is fairly straightforward. This is a patient with blunt abdominal trauma. The noncontrast ultrasound images of the spleen appear normal (Fig. S96-1). However, with the use of contrast-enhanced ultrasound there is a wedge-shaped defect identified within the spleen as seen in Figure S96-2.

Ultrasound Findings

Sonographic findings associated with splenic injuries include free fluid within the abdomen or the pelvis. In this case, there is free fluid noted within the pelvis as identified in Figure S96-3. There was also free fluid noted in the hepatorenal fossa. Free fluid is a key finding in the focused abdominal sonography for trauma (FAST) scan. After identifying free fluid, solid organs may be evaluated. In some solid organ injuries, the solid organ will appear fairly normal. It has been shown that with the use of contrast-enhanced sonography, splenic injuries, as well as other intra-abdominal injuries, are more easily identified. This is because contrast is seen within the normal spleen, but where there is a laceration there may be a leak of contrast or an avascular region (Fig. S96-2). Correlating CT is seen in Figure S96-4. Recently, the FAST scan has been incorporated into a more comprehensive ultrasound exam called the rapid ultrasound in shock protocol.

Prognosis/Management

Prognosis or management is dependent on severity of splenic injury. There are different grading systems used for splenic injuries. One system that is commonly used is the American Association for the Surgery of Trauma Splenic Injury Grading Scale. Grade I injuries are very small injuries with lacerations that are less than 1 cm. Grade II injuries are lacerations that are 1 to 3 cm or with a subcapsular hematoma less than 50%. Grade III injuries are injuries that are more than 3 cm in depth or more than 50% of the surface area. Grade IV injuries are more severe and include a vessel injury producing major devascularization. Grade V injuries indicate a completely shattered spleen.

This surgical system does not always match the radiographic findings. For instance, if in fact there is a vascular blush on contrast CT or contrast-enhanced ultrasound, this type of injury is not classified under this surgical system. In general, the higher the grade of splenic injury, the more likely operative or angiographic embolization will be needed.

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CASE 97

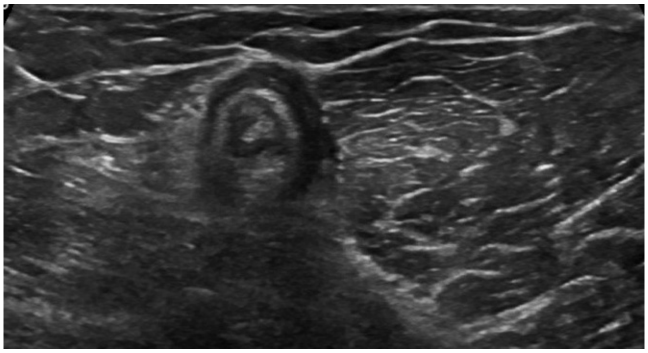

Figure 97-1

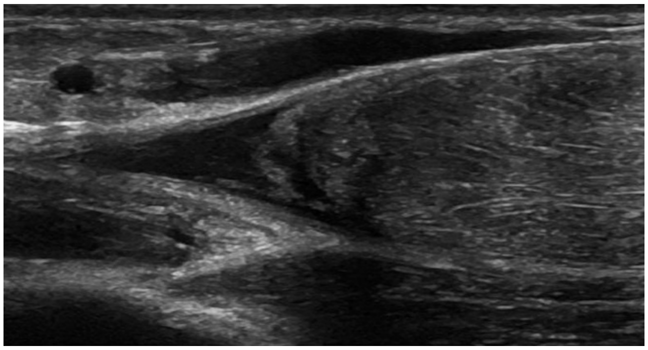

Figure 97-2

HISTORY: A 57-year-old male presents with sudden onset of anterior arm pain.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Biceps tendon subluxation
   B. Biceps tendon dislocation
   C. Biceps tendon rupture
   D. High grade (70%) partial thickness biceps tendon tear
2. Concerning biceps tendon pathology, which statement is true?
   A. The long head of the biceps tendon pathology is not commonly associated with a rotator cuff tear.
   B. The normal biceps tendon is hypoechoic.
   C. If the biceps tendon is not visualized along its course, it should be presumed to be torn.
   D. With biceps tendon rupture, the biceps muscle contracts and refractive shadowing is visualized at the level of the torn tendon end.
3. Concerning biceps tendon pathology, which statement is true?
   A. Biceps tendon dislocation is diagnosed when the tendon is located lateral to the greater tuberosity.
   B. Dislocation of the biceps tendon can occur when a rotator interval tear is present.
   C. Biceps tendon subluxation is diagnosed when the tendon is perched on the greater tuberosity.
   D. Dislocation of the biceps tendon occurs with an infraspinatus tendon tear.
4. Concerning biceps tendon pathology, which statement is true?
   A. Tenosynovitis of the biceps tendon sheath is accurately diagnosed with ultrasound.
   B. Increased color or power Doppler flow must be present to diagnose biceps tendon sheath tenosynovitis (tendon sheath fluid and synovial thickening).
   C. When a biceps tendon sheath effusion is detected, one should also evaluate the tendon sheath with color or power Doppler.
   D. Fluid is not normally present in the biceps tendon sheath.

See Supplemental Figures section for additional figures and legends for this case.

CASE 97

Biceps Tendon Pathology

1. **C.** The biceps tendon is ruptured; however, D, a high grade partial thickness tear, is in the differential because ultrasound cannot differentiate between the two. In one study, high grade partial thickness tears were misdiagnosed as rupture if 70% or more of the tendon was torn.
2. **D.** When the biceps tendon ruptures, it often retracts to the level of the biceps muscle, and the groove has an "empty" appearance on ultrasound. The biceps muscle is usually contracted and has a rounded appearance. Because the tendon is no longer taut but "wavy," it causes refractive shadowing. An "empty" groove can also be caused by medial dislocation of the biceps tendon.
3. **B.** The rotator interval includes the coracohumeral and superior glenohumeral ligaments; these ligaments surround the superior subscapularis tendon and anterior portion of the supraspinatus tendon, and if disrupted, dislocation of the biceps tendon can occur. A subscapularis tendon tear can also result in dislocation of the biceps tendon. A dislocated biceps tendon is diagnosed when it is either perched on, or located medial to, the lesser tuberosity.
4. **C.** With the high resolution transducers available, it is possible to visualize fluid and synovial thickening within the biceps tendon sheath. Color Doppler flow need not be present to diagnose tenosynovitis; if inflammation is mild or changes are chronic, color or power Doppler flow may not be detected.

Comment

Introduction

A biceps tendon pathologic condition can be a significant source of shoulder pain. Pathologic changes include tendinopathy, partial tear, rupture, tenosynovitis, and instability (subluxation/dislocation). Tendinopathy may be degenerative in nature and is often related to overuse or may be inflammatory. Both predispose to the development of partial tear and rupture. Rupture usually occurs near the tendon muscle junction or at the tendon origin. Biceps tendon instability (subluxation/dislocation) is associated with rotator interval or subscapularis tendon tears. Tenosynovitis is usually a secondary process associated with rotator cuff pathologic condition.

Sonographic Findings

The normal biceps tendon has an echogenic fibrillar pattern. If it is not imaged perpendicular to the ultrasound beam, it will not act as a strong specular reflector and will appear hypoechoic, leading to a misdiagnosis of rupture. Ultrasound is very accurate for diagnosing biceps tendon rupture but much less accurate for diagnosing tendinopathy and partial thickness tears (Figs. S97-1 and S97-2). A degenerated tendon may hypertrophy (measure greater than 5 mm) or thin and develop intrasubstance tears. Due to equipment improvements, hypoechoic, linear intrasubstance tears can be detected. Ultrasound is not as accurate for diagnosing tenosynovitis and can miss mild inflammatory changes. If changes in the tendon sheath such as hypoechoic synovial thickening, fluid, and hypervascularity are visualized, the diagnosis can be made on ultrasound. Ultrasound is accurate for diagnosing biceps tendon subluxation/dislocation; with subluxation, the biceps tendon is half in-half out of the groove, and with dislocation, it is perched on the lesser tuberosity or dislocated medially.

Treatment

A biceps tendon pathologic condition can be treated conservatively or surgically. The long head of the biceps rupture is typically not repaired unless there is persistent muscle spasm. Repair would also be considered in a young, physically active patient or in a patient who requires supination strength for his or her job. Tendinopathy can initially be treated with rest, nonsteroidal anti-inflammatory drugs, and physical therapy. If there is marked tendon sheath inflammation, corticosteroid injection may be helpful. Surgery is indicated if conservative management fails. The most commonly performed procedure is tenodesis or tenotomy. Tenodesis involves tacking the proximal biceps to the proximal humerus, whereas with tenotomy, the tendon is released (cut) and dropped.

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CASE 98

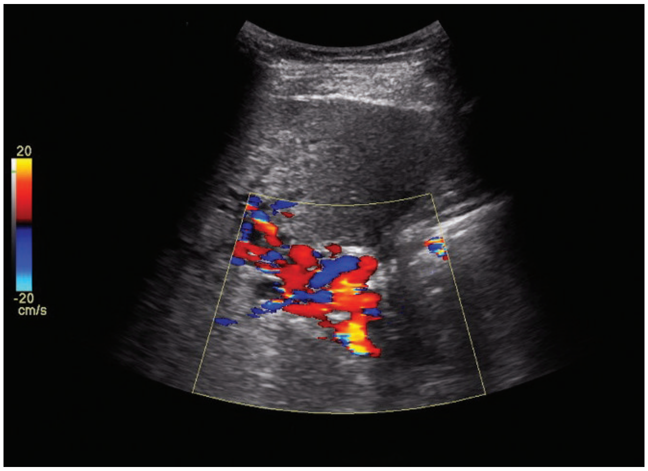

Figure 98-1

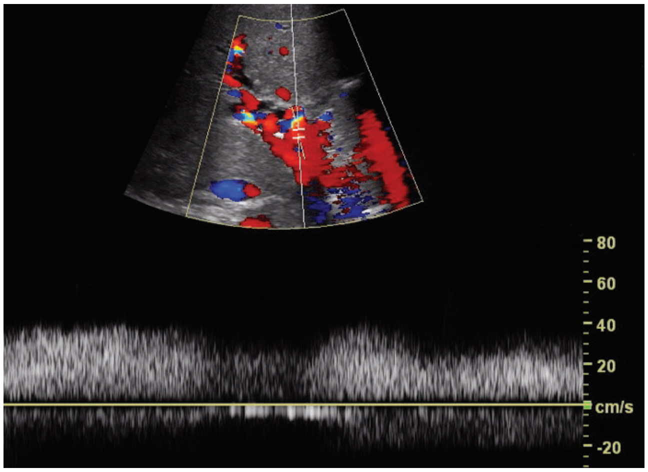

Figure 98-2

HISTORY: A 30-year-old female presents with a hypercoagulable state and ascites.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Occlusive portal vein thrombosis
   B. Hepatic vein thrombosis
   C. Cavernous transformation
   D. Nonocclusive portal vein thrombosis

2. Concerning cavernous transformation, which statement is true?
   A. The gray scale ultrasound findings of cavernous transformation include nonvisualization of the portal vein.
   B. Cavernous transformation usually develops 3 to 6 months after the portal vein thrombosis.
   C. Cavernous transformation commonly occurs in cirrhotic patients.
   D. Cavernous transformation commonly occurs in the setting of malignant portal vein thrombosis.

3. Concerning cavernous transformation, which statement is true?
   A. Periportal venous collaterals can arise from the vasa vasorum of the portal vein wall, or channels can recanalize within the portal vein.
   B. Periportal collaterals can arise from the inferior vena cava or right renal vein.
   C. Periportal collateral color Doppler flow is hepatofugal (away from the liver).
   D. Arterial periportal collaterals also develop in the setting of cavernous transformation.

4. Concerning cavernous transformation, which statement is true?
   A. Portosystemic collaterals do not develop in the setting of cavernous transformation.
   B. Portosystemic collaterals develop in the setting of cavernous transformation.
   C. Gallbladder wall varices develop only in the presence of cavernous transformation.
   D. Of patients who develop portal vein thrombosis, 60% will also develop cavernous transformation.

See Supplemental Figures section for additional figures and legends for this case.

CASE 98

Cavernous Transformation

1. **C.** The portal vein is not visualized on the gray scale (Fig. S98-1) or the color Doppler image (Fig. S98-2). The tubular channels filled with color represent periportal venous collaterals in this patient with cavernous transformation. A is also correct: the portal vein is completely thrombosed causing periportal collaterals to develop.
2. **A.** A thrombosed, sclerotic cord representing the main portal vein may also be visible on gray scale images as well as multiple, anechoic, cystic, or tubular channels representing the periportal collaterals. These tubular channels often extend into the liver along the right and left portal venous branches.
3. **A.** Collaterals can also develop adjacent to (paracholedochal) and within (epicholedochal) the bile duct wall, causing the bile duct wall to appear thickened with tiny anechoic tubular channels on gray scale ultrasound. This can lead to intrahepatic bile duct dilatation. If the portal vein thrombus extends into the proximal superior mesenteric vein, pancreaticoduodenal veins that originate around the pancreatic head can function as collaterals.
4. **B.** Despite the development of cavernous transformation, patients nevertheless develop portosystemic collaterals and subsequent portal hypertension. The most common collaterals to develop are left gastric (coronary) or perisplenic collaterals. Pericholecystic collaterals can also shunt venous blood into the liver, usually to a patent right portal vein branch.

Comment

Introduction

Cavernous transformation usually occurs in the setting of acquired benign portal vein thrombosis. It is much less common in patients with cirrhosis or malignant portal vein thrombosis due to hepatocellular carcinoma. It can develop in as little as 1 week after the development of portal vein thrombosis.

Sonographic Findings

In the setting of cavernous transformation, the main portal vein is either not visualized or it appears as a narrow, sclerotic cord on gray scale ultrasound. Multiple cystic or tubular anechoic collateral vessels can be seen within the porta extending into the liver toward the thrombosed right and left portal vein branches both on gray scale and color Doppler. On color Doppler, the tubular channels may be red or blue because of the tortuosity of the venous channels; however, the overall direction of blood flow is toward the liver. Doppler waveforms confirm that the collaterals are venous in nature. Intrahepatic portal to portal collaterals may also develop to shunt blood from a patent portal vein branch to an area of portal vein thrombosis. Despite the presence of periportal collaterals, portal hypertension develops in most patients with cavernous transformation. Pericholecystic collaterals can also develop and are almost always indicative of cavernous transformation; rarely such collaterals can be seen in the presence of a patent main portal vein and portal hypertension.

Treatment

Patients with cavernous transformation have a poorer outcome due to the development of portal hypertension and variceal bleeding. Recently, a few authors have reported successful treatment of cavernous transformation with stent grafts (transjugular intrahepatic portosystemic shunt). Successful placement of a stent graft reduces the risk of variceal bleeding and the risks of anticoagulation therapy.

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Cross-reference

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CASE 99

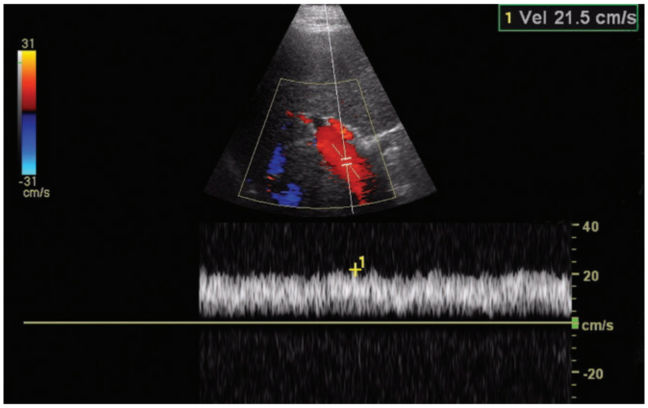

Figure 99-1

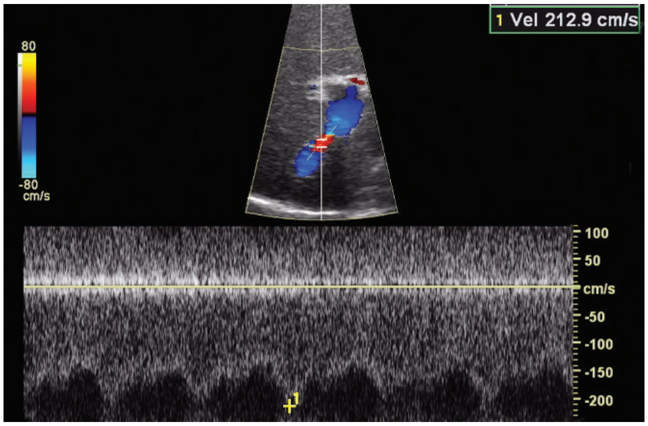

Figure 99-2

HISTORY: A 60-year-old male presents with increasing ascites after placement of a stent graft 1 year ago.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Patent stent graft (transjugular intrahepatic portosystemic shunt, TIPS)
   B. Occluded stent graft
   C. Reversal of flow in the stent graft
   D. Stenosis of the stent graft
2. Which of the following is true regarding TIPS?
   A. Aliasing on color Doppler indicates a stent graft stenosis.
   B. Aliasing can be reduced by using a higher frequency transducer.
   C. Aliasing can be reduced by decreasing the Doppler angle.
   D. Aliasing can be reduced by decreasing the velocity scale.
3. Which of the following is true regarding TIPS?
   A. The ideal screening test for detecting stent graft stenosis should have a high specificity.
   B. On color Doppler, normal right and left portal vein flow direction is away from the stent graft and into the liver.
   C. The lower limit of normal for stent graft velocity is 90 cm/s.
   D. The upper limit of normal for stent graft velocity is 130 cm/s.
4. Which of the following is true regarding TIPS?
   A. A main portal vein velocity of 10 cm/s is at the lower limits of normal.
   B. The normal Doppler waveform in the stent graft is pulsatile.
   C. Flow direction in the hepatic vein into which the stent graft has been placed is normally toward the liver.
   D. Flow reversal in a right or left portal branch is a sensitive indicator of stent graft malfunction.

See Supplemental Figures section for additional figures and legends for this case.

CASE 99

Sonography of TIPS

1. **D.** The portal vein velocity is 22 cm/s (lower limit of normal: 30 cm/s) (Fig. S99-1) and the stent graft velocity is elevated at 213 cm/s (Fig. S99-2). A is correct but D accurately describes the findings.
2. **A.** Aliasing occurs because flow exceeds the velocity range set by the operator. The sampling rate (pulse repetition frequency) must be at least twice the maximum frequency present in the Doppler signal. In other words, time must be allowed to send the Doppler signal out and detect the returning signal before another pulse is sent out. On color Doppler, a wraparound phenomenon occurs in which there is inappropriate color progression from a light color (i.e., yellow) to a light blue. Aliasing can be reduced by increasing the Doppler angle, using a lower frequency transducer, lowering the baseline, and increasing the velocity scale.
3. **C.** The lower and upper limits of normal for stent graft velocities are 90 and 190 cm/s, respectively. At our institution, we found that these values produced an acceptable sensitivity and specificity.
4. **B.** If the waveform is monophasic (i.e., the waveform shows little variation), this suggests a distal (hepatic vein end) stenosis. Pulsatility is due to transmitted cardiac pulsations. This finding has been shown to have a sensitivity of 94% and specificity of 87% in one study.

Comment

Introduction

Ultrasound is an accurate technique for detecting stent graft malfunction. Complications include stent graft stenosis, which usually occurs at the hepatic vein end of the stent in covered stents and is due to fibrosis induced by trauma from stent graft placement.

Sonographic Findings

The entire stent should be evaluated with color Doppler. Velocities should be obtained at any site of focal aliasing as well as within the proximal to mid and distal stent graft. A main portal vein velocity should also be obtained, and flow direction should be determined in the right and left portal vein branches and hepatic vein into which the stent graft was placed. Color Doppler flow is normally retrograde in the right and left portal vein branches and toward the low resistance stent graft. The lower limit of normal for the main portal vein velocity is 30 cm/s. If lower (Fig. S99-1), a downstream stenosis should be suspected. The lower and upper limits of normal for stent graft velocities are 90 and 190 cm/s, respectively. A velocity outside of this range suggests a stenosis (Fig. S99-2). Color Doppler flow in the hepatic vein into which the stent graft was placed should be toward the stent graft. If it reverses, a more distal (hepatic vein end) stenosis should be suspected though this finding has a low sensitivity. We found at our institution that by combining all of the above parameters, we improved our overall sensitivity for detecting stent malfunction.

Treatment

Since the introduction of covered stent grafts, the care of cirrhotic patients who develop complications such as ascites or variceal bleeding has vastly improved. One meta-analysis that compared covered and uncovered stent grafts showed a significant improvement in the patency of covered stent grafts resulting in a decrease in the number of reinterventions. This same study also showed improved clinical outcomes in patients with covered stent grafts, including a decrease in recurrent variceal bleeding and ascites, resulting in an overall decrease in mortality.

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Cross-reference

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CASE 100

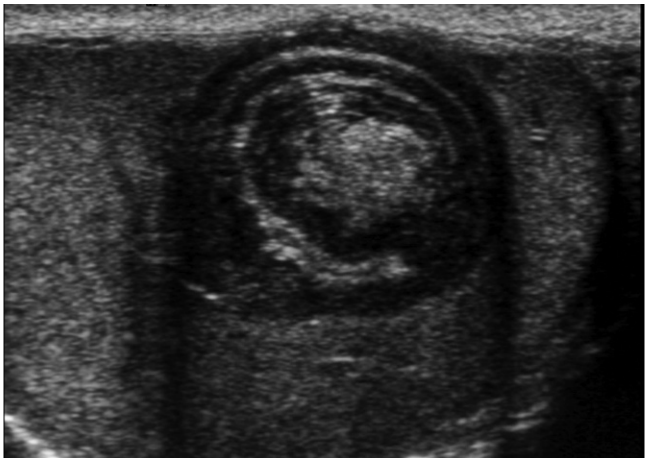

Figure 100-1

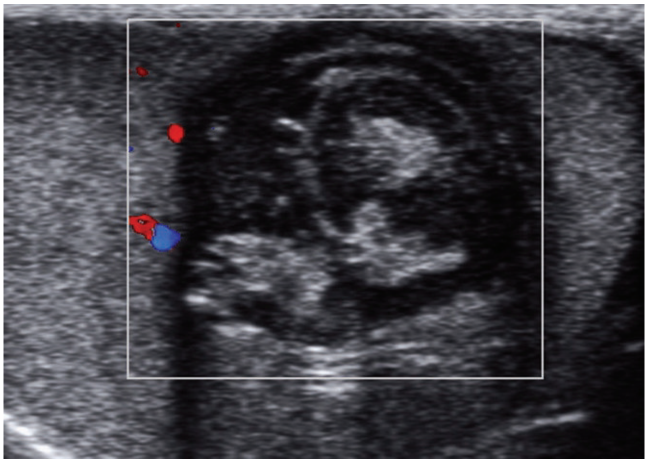

Figure 100-2

HISTORY: A 26-year-old male presents with a nontender palpable testicular mass for 2 months.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Epidermoid cyst
   B. Teratoma
   C. Focal orchitis
   D. Lymphoma
2. Which of the following is true regarding epidermoid cysts?
   A. Epidermoid cysts account for 10% of testicular neoplasms.
   B. Epidermoid cysts are more common in children than adults.
   C. Epidermoid cysts are dysplastic lesions and develop into squamous cell carcinoma.
   D. Epidermoid cysts are composed of keratinizing squamous epithelium and keratin debris.
3. Which of the following is true regarding epididymal tumors?
   A. The majority of extratesticular masses are benign.
   B. The most common extratesticular neoplasm is an adenomatoid tumor, and the second most common is a lipoma.
   C. Adenomatoid tumors are the second most common epididymal neoplasm.
   D. Adenomatoid tumors occur most commonly in the pediatric age group.
4. Which of the following is true regarding epididymal tumors?
   A. Adenomatoid tumors most commonly occur in the epididymal head.
   B. On ultrasound, adenomatoid tumors are usually solid-cystic and hyperechoic.
   C. On ultrasound, adenomatoid tumors have a variable appearance and are solid but may undergo cystic change.
   D. Adenomatoid tumors are composed of myxoid and fibrous tissue.

See Supplemental Figures section for additional figures and legends for this case.

CASE 100

Benign Testicular and Epididymal Masses

1. **A.** Figure S100-1 shows a solid lesion with alternating hyperechoic and hypoechoic concentric rings (arrow). Figure S100-2 shows that the lesion is avascular on color Doppler. The lesion is an epidermoid cyst, but the appearance is not pathognomonic. Teratomas (B) can have an identical appearance to epidermoid cysts.
2. **D.** The keratinizing epithelium accounts for the rings. The keratin debris is echogenic and located in the center of the lesion. Epidermoid cysts are also encapsulated by a fibrous wall that may calcify. They are thought to occur as a result of monodermal development of a teratoma. An alternate theory suggests they are due to metaplasia of the rete testis or seminiferous epithelium.
3. **A.** The most common extratesticular neoplasm is a lipoma, and the second most common is an adenomatoid tumor, which is a benign tumor of mesothelial origin.
4. **C.** Because of their variable appearance, a differential exists that includes focal epididymitis, although acute pain, urinary symptoms, and marked hypervascularity would argue against this. A sperm granuloma caused by a granulomatous reaction to extravasated sperm is also in the differential; it is solid and hypoechoic/heterogeneous and may have color Doppler flow but is often painful. An epididymal leiomyoma should also be considered but is rare. It has a variable sonographic appearance and may be hypoechoic or heterogeneous, with internal vascularity. Finally, papillary cystadenoma, a rare tumor of epithelial origin should be considered; it may be solid or cystic but occurs in the epididymal head and is associated with von Hippel-Lindau.

Comment

Introduction

Epidermoid cysts account for 1% to 2% of testicular neoplasms. They are benign and usually occur between 20 and 40 years of age. Most are small (1 to 3 cm) and nontender. The majority of extratesticular masses are benign. The most common extratesticular neoplasm is a lipoma, and the second most common is an adenomatoid tumor. Adenomatoid tumors are the most common tumor of the epididymis. They are usually located in the tail but can rarely originate in the tunica albuginea, tunica vaginalis, testis, or spermatic cord. Adenomatoid tumors are benign, nontender, and usually occur between 20 and 50 years of age. They are composed of fibrous tissue, smooth muscle, and mesothelial cells.

Sonographic Findings

Epidermoid cysts are well-defined avascular lesions with a characteristic "onion ring" appearance (Figs. S100-1 and S100-2). Epidermoid cysts do not have through transmission because of acoustic impedance by the cyst contents. The sonographic appearance varies depending on the maturation of the lesion and quantity and compactness of the keratin. Epidermoid cysts can have a solid-cystic appearance and mimic teratomas. In one small series, three pathologically proven teratomas had an identical appearance to epidermoid cysts. Epidermoid cysts can also have a nonspecific appearance (heterogeneous) and appear similar to other germ cell tumors. Adenomatoid tumors are usually small and solid, but cystic change can occur. They have a variable sonographic appearance that is nonspecific and may be hypoechoic, isoechoic, or hyperechoic. Vascular flow on color Doppler may also be present.

Treatment

Epidermoid tumors may be enucleated, an approach that has increasingly been used. No recurrence has been reported after long-term follow-up in several series. The presence of the onion ring appearance and negative tumor markers and the absence of vascularity suggest the diagnosis. However, because germ cell tumors can mimic epidermoid cysts, and may not have detectable flow on color Doppler, or elevated tumor markers; enucleation is performed only after frozen section of the tumor. Adenomatoid tumors in the epididymal tail are usually not resected but, if in the tunica or testis, are resected because of their variable appearance and differential that includes germ cell tumors.

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Cross-reference

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CASE 101

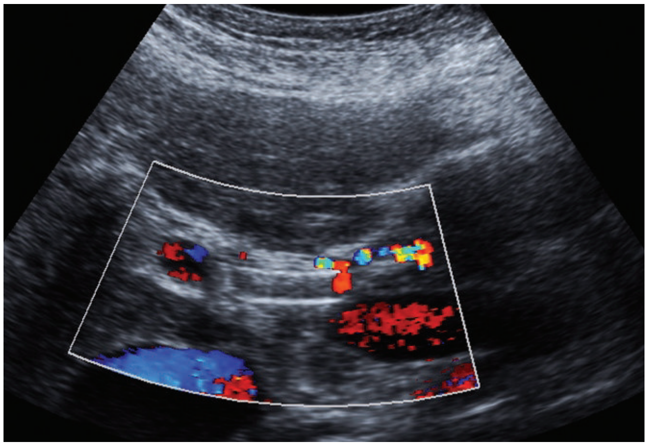

Figure 101-1

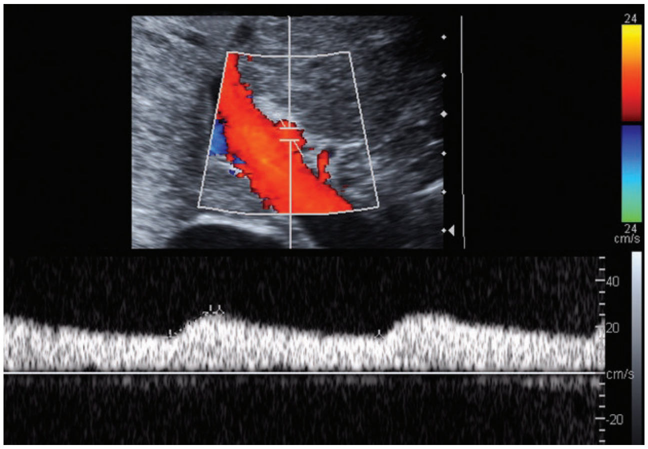

Figure 101-2

HISTORY: A 29-year-old woman who underwent a liver transplant as a child presents with a history of biliary atresia. The patient developed hepatic artery thrombosis and underwent hepatic artery stent placement.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Hepatic artery thrombosis
   B. Portal vein thrombosis
   C. Hepatic vein thrombosis
   D. Hepatic artery collaterals
2. An indirect sign of hepatic artery stenosis is a resistive index (RI) less than which of the following?
   A. 0.8
   B. 0.6
   C. 0.5
   D. 0.3
3. Concerning hepatic artery stenosis, which statement is true?
   A. Hepatic artery stenosis is a late complication of liver transplantation.
   B. Hepatic artery stenosis may be due to faulty surgical technique or allograft rejection.
   C. Hepatic artery stenosis occurs in 15% to 20% of transplant recipients.
   D. Hepatic artery stenosis causes increased resistance in the more distal artery.
4. Which statement is true?
   A. Portal vein stenosis or thrombosis occurs in 10% to 15% of transplant recipients.
   B. A threefold to fourfold increase in the anastomotic to preanastomotic velocity indicates portal vein stenosis.
   C. Hepatic vein stenosis is a sequela of hepatic artery thrombosis.
   D. A triphasic hepatic vein waveform is indicative of hepatic vein stenosis.

See Supplemental Figures section for additional figures and legends for this case.

CASE 101

Duplex and Color Doppler of Liver Transplants

1. **A.** The stent in the main hepatic artery is thrombosed. An arterial waveform obtained from a right hepatic artery branch shows tardus parvus changes (delayed early systolic acceleration [tardus] and diminished amplitude causing a rounding of the systolic peak [parvus]). This indicates that arterial collaterals developed (D) and reconstituted the right and left hepatic arterial branches.
2. **C.** An RI of less than 0.5 is of concern for a hepatic artery stenosis or thrombosis. When combined with a systolic acceleration time (SAT) of 0.08 seconds or greater, the sensitivity and specificity for diagnosing a stenosis greater than 50% or thrombosis were 93% and 64%, respectively. In this study, these parameters did not distinguish between hepatic artery thrombosis and stenosis.
3. **B.** Hepatic artery stenosis occurs in 5% to 11% of hepatic artery recipients and is an early complication. Predisposing factors include faulty surgical technique and rejection but also clamp injury or catheter-induced trauma.
4. **B.** Portal vein stenosis is unusual and occurs in approximately 3% of liver transplants. It typically occurs at the anastomosis and should be suggested when the anastomotic to preanastomotic velocity ratio is 3:1 or greater. However, if there is a size discrepancy between the donor and recipient portal veins, direct portography may be required to determine if there is a pressure gradient indicating a stenosis.

Comment

Introduction

Liver transplantation is now an accepted treatment for end-stage liver disease. Patient survival rates for cadaveric liver transplants are 72% at 5 years. Liver transplant failure can occur due to vascular, biliary, and other complications including infection, recurrent hepatitis or malignancy, and post-transplantation lymphoproliferative disorder.

Sonographic Findings

Ultrasound is an excellent means to detect vascular complications. Complications can involve the hepatic artery, portal vein, hepatic veins, and inferior vena cava (IVC). These vessels can stenose or thrombose, most often at the level of the anastomosis. Hepatic artery stenosis and thrombosis are the most common complications, occurring in 2% to 11% of transplant recipients. Though the two can be difficult to distinguish, an RI less than 0.5 and SAT of 0.08 seconds or greater have an excellent sensitivity for diagnosing stenosis or thrombosis. If findings are questionable, computed tomography angiography should be performed. Portal vein stenosis should be considered when the anastomotic to preanastomotic velocity ratio is greater than 3:1. Portal vein thrombosis is rare and usually occurs in the main portal vein. On color Doppler, no venous flow is detected (Fig. S101-1); the thrombus may also be visible on gray scale images. IVC stenosis and thrombosis are usually early complications and caused by anastomotic narrowing or extrinsic compression from graft swelling or hematoma. IVC stenosis should be considered when the anastomotic to preanastomotic ratio is greater than 3 to 4:1. Visualization of a thrombus and lack of flow in the IVC on color Doppler is indicative of thrombosis (Fig. S101-2). Hepatic vein thrombosis has similar findings. A monophasic waveform suggests hepatic vein stenosis, although in the early transplantation period, loss of phasicity is not necessarily abnormal.

Treatment

Vascular complications of liver transplantation can be treated by a variety of techniques. Hepatic artery thrombosis can be treated with thrombectomy or retransplantation. Hepatic artery stenosis can be treated with angioplasty or surgery if angioplasty fails. Portal vein thrombosis can be treated with thrombectomy, and stenosis with angioplasty, stent placement, or surgical resection. Hepatic or IVC stenosis can be treated with angioplasty; stent placement has also been reported for IVC stenosis.

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Cross-reference

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CASE 102

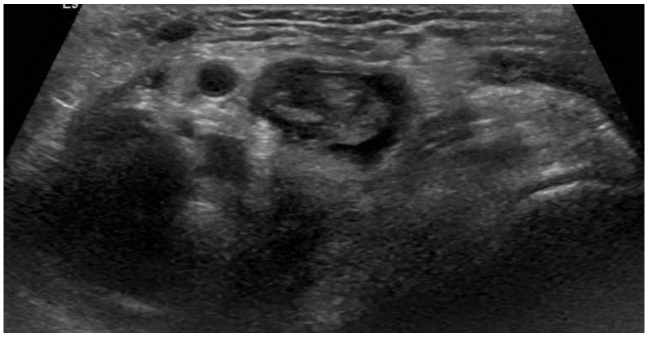

Figure 102-1

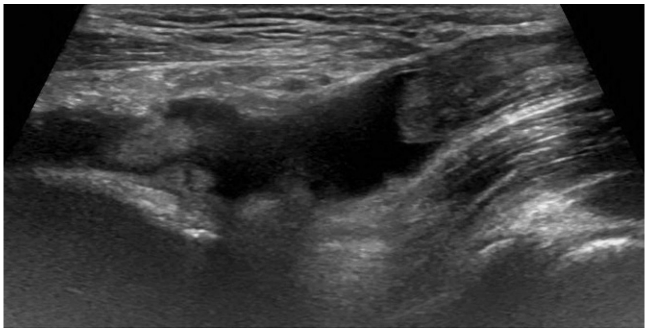

Figure 102-2

HISTORY: A 47-year-old male reported a painful popping sensation in the antecubital fossa during weightlifting.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Distal biceps tendon rupture
   B. Distal triceps tendon rupture
   C. Extensive partial thickness tear of the distal biceps tendon
   D. Proximal biceps tendon rupture

2. Concerning distal biceps tendon tears, which statement is true?
   A. A distal biceps tendon tear usually occurs 1 to 2 cm proximal to where it inserts on the radial tuberosity.
   B. Distal biceps tendon tears usually occur because of a fall on an outstretched arm.
   C. On ultrasound, the forearm is pronated and the elbow in extension or slightly flexed to image the distal biceps tendon.
   D. On ultrasound, a partial thickness tear appears as a focal hyperechoic area within the biceps tendon.

3. Concerning distal triceps tendon tears, which statement is true?
   A. Distal triceps tendon tears usually occur due to direct trauma.
   B. On ultrasound, the torn triceps tendon is retracted proximally for a variable degree and may appear thickened with refractive shadowing. Fluid or hematoma may surround the torn tendon end.
   C. A distal biceps tear causes weakness in extension of the elbow and supination, and a distal triceps tear causes weakness in flexion of the elbow.
   D. Partial thickness tears of the triceps tendon can be managed conservatively.

4. Concerning epicondylitis, which statements are true?
   A. Medial epicondylitis is more common than lateral epicondylitis.
   B. Lateral epicondylitis involves the common extensor tendon; the extensor carpi radialis brevis (ECRB) is the most commonly involved tendon.
   C. On ultrasound, the common extensor tendon is thickened and hyperechoic and may contain defects consistent with partial thickness tears.
   D. Lateral epicondylitis usually occurs in overhead-throwing athletes.

See Supplemental Figures section for additional figures and legends for this case.

CASE 102

Elbow Pathology

1. **A.** Figures S102-1 and S102-2 show that the distal biceps tendon is torn and retracted proximally. The gap between the torn tendon and radial tuberosity contains fluid. There is also refractive shadowing of the thickened, torn tendon end. Extensive partial distal biceps tendon tear (B) might be considered, but the fluid in the gap is indicative of a complete tear.
2. **A.** This area is a zone of relative hypovascularity and predisposed to degeneration and tear. Most distal biceps tendon tears occur in middle-aged men when a large resistive force acts against a flexed elbow (weight lifting). Partial thickness tears are usually due to repetitive microtrauma and degenerative changes. To visualize the distal biceps tendon on ultrasound, the forearm is supinated and the elbow extended.
3. **B.** The sonographic appearance is very similar to a distal biceps tendon tear; occasionally a fragment of bone is avulsed off the olecranon process. On ultrasound, the bone appears echogenic with posterior acoustic shadowing. Distal triceps tendon tears usually occur because of a fall on an outstretched arm. Direct trauma as a cause is much less common. Systemic diseases such as chronic renal failure, rheumatoid arthritis, and anabolic steroid use have also been associated with triceps rupture.
4. **B.** The ECRB is the most commonly involved tendon. Repetitive microtrauma leads to degeneration. There is also a hypovascular zone in the deeper portion of the ECRB that predisposes to degeneration. Lateral epicondylitis is more common than medial epicondylitis.

Comment

Introduction

Distal biceps or triceps tendon ruptures are usually due to a single traumatic event. Distal biceps rupture results in weakness in flexion and supination and, in distal triceps tendon, weakness in extension. A palpable mass (the retracted tendon) or a defect in the course of the tendon may be palpated on exam. Lateral epicondylitis occurs in athletes (tennis players) and nonathletes. Medial epicondylitis usually occurs in overhead-throwing athletes. Patients complain of pain and tenderness over the respective epicondyle.

Sonographic Findings

On ultrasound, rupture of the distal biceps tendon is diagnosed when the tendon is retracted and there is a gap between the torn tendon end and the radial tuberosity. Fluid or hematoma often fills the gap. In a partial thickness tear, the tendon is focally thickened and hypoechoic though it may be thinned. Fluid/hematoma may surround the partially torn tendon. On ultrasound, distal triceps tendon rupture appears very similar to distal biceps tendon rupture; the tendon is avulsed off the olecranon and retracted to a variable degree. In a partial tear, the deeper medial head usually remains attached to the olecranon process. In epicondylitis (medial or lateral), the tendon is thickened and hypoechoic and may have internal vascularity on power or color Doppler. Anechoic defects are indicative of intrasubstance partial thickness tears. Dystrophic calcifications may also develop in the tendon and appear as echogenic foci that may or may not demonstrate posterior acoustic shadowing.

Treatment

Distal triceps and distal biceps ruptures are treated with surgical repair with excellent results. Without operative intervention, loss of strength is significant. While partial thickness tears of the distal biceps tendon can be treated conservatively (high grade partial thickness tears should be repaired), partial thickness tears of the distal triceps tendon are repaired. Epicondylitis can usually be managed nonoperatively with nonsteroidal anti-inflammatory drugs and steroid injections. However, several studies have shown that long-term results are no better than placebo. Newer therapies include percutaneous tenotomy and injection of platelet-rich plasma. One randomized controlled trial comparing platelet-rich plasma injections to steroid injections showed platelet-rich plasma injections to be more beneficial long term.

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CASE 103

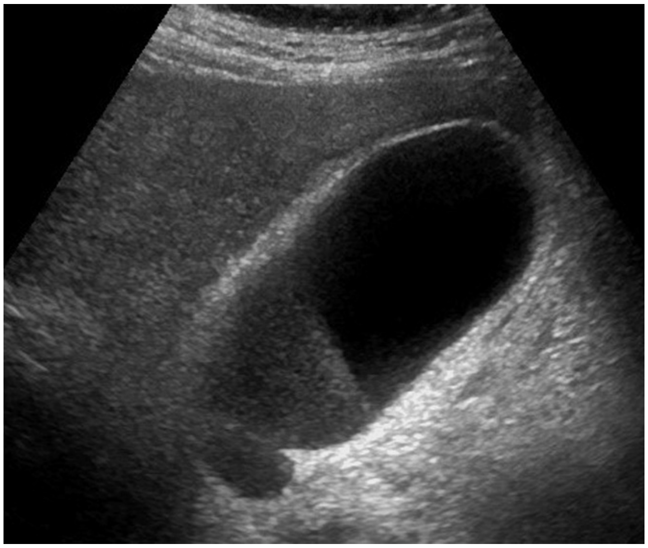

Figure 103-1

Figure 103-2

HISTORY: A 75-year-old male trauma patient in the intensive care unit (ICU) presents with right upper quadrant pain and a positive sonographic Murphy sign.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Emphysematous cholecystitis
   B. Gangrenous cholecystitis
   C. Acute acalculous cholecystitis (AAC)
   D. Chronic cholecystitis
2. Which of the following is true regarding acute AAC?
   A. A sonographic Murphy sign is elicited by having the patient take a deep inspiration and pushing on the sonographically visualized gallbladder with the transducer.
   B. A sonographic Murphy sign must be present to diagnose AAC.
   C. AAC is most common in outpatients who are diabetic or hypertensive.
   D. AAC is more common in older women, with an incidence of 2% to 15%.
3. Which of the following is true regarding acute AAC?
   A. The pathogenesis of AAC is cystic duct obstruction.
   B. Signs and symptoms of AAC are similar to acute calculous cholecystitis.
   C. Prolonged fasting or total parenteral nutrition (TPN) and sepsis can precipitate AAC.
   D. Gangrenous changes are uncommon in AAC.
4. Which of the following is true regarding acute AAC?
   A. On ultrasound, gallbladder wall thickening is a specific finding of AAC.
   B. On ultrasound, gallbladder lumen distention and sludge are specific findings of AAC.
   C. On ultrasound, pericholecystic fluid is a specific finding of AAC.
   D. The best approach for diagnosing AAC is to correlate the sonographic findings with the patient's clinical history.

See Supplemental Figures section for additional figures and legends for this case.

CASE 103

Acute Acalculous Cholecystitis

1. **C.** The gallbladder is distended and filled with layering sludge (arrow, Figs. S103-1 and S103-2); the wall is of normal thickness, and there are no gallstones. The patient had a positive sonographic Murphy sign, very specific for acute cholecystitis. These findings are consistent with acute AAC. Gangrenous cholecystitis (B) is also a consideration because gangrenous changes occur in 40% to 60% of patients with ACC.
2. **A.** If the maneuver elicits maximal reproducible tenderness over the gallbladder, the sign is positive. However, many patients in the ICU are obtunded or sedated, and it is not possible to elicit a sonographic Murphy sign. AAC most commonly occurs in patients in the ICU who have had recent surgery, trauma, or burns; who have had prolonged hypotension; or who have sepsis.
3. **C.** Prolonged fasting or TPN causes biliary stasis, functional cystic duct obstruction, and gallbladder distention. In sepsis, vasoactive mediators and activation of the coagulation pathway by bacterial endotoxins cause blood vessel injury to the gallbladder; the final common pathway is wall ischemia/necrosis and bacterial invasion precipitating AAC. Thus, gangrenous changes are common, resulting in perforation in 7% to 20% of patients and an overall mortality rate of 30%.
4. **D.** Ultrasound should only be performed in patients where there is a high level of suspicion for AAC who have risk factors because of the nonspecificity of the sonographic findings. Gallbladder wall thickening, lumen distention, sludge, and pericholecystic fluid can be present in patients with a low level of suspicion for AAC.

Comment

Introduction

Acute AAC is a difficult clinical diagnosis. It is more common in older men. Its pathogenesis is multifactorial and includes ischemia, biliary stasis, and sepsis. Risk factors include a prolonged ICU stay, major surgery, trauma, burns, severe medical illness, prolonged hypotension or hypovolemia, sepsis, or prolonged fasting or TPN. Presenting signs and symptoms can be very subtle and masked by narcotics, postoperative pain, and an obtunded state. In one study, right upper quadrant pain was present in only 50% of patients, fever in only 37%, and leukocytosis in only 54% to 70%.

Sonographic Findings

It is very difficult to diagnose AAC with ultrasound. Nearly all sonographic findings can be seen in patients with a low suspicion for AAC. Gallbladder wall thickening can be due to right heart failure, hypoalbuminemia, acute hepatitis, chronic liver disease, and acute pancreatitis.

Wall thickness may be normal in AAC. Lumen distention can be due to prolonged fasting or TPN, narcotics, or distal bile duct obstruction and may be absent in AAC. Pericholecystic fluid can be due to ascites, acute pancreatitis, or perforated duodenal ulcer. However, a focal, complex pericholecystic fluid collection is of concern for gangrenous changes and gallbladder wall perforation. Gallbladder sludge (arrow, Fig. S103-1) can develop due to prolonged fasting or TPN. A study evaluating these sonographic findings showed that these gallbladder abnormalities are frequently seen in ICU patients with a low level of suspicion for AAC. The best approach is to perform an ultrasound when a high index of suspicion is present and correlate sonographic findings with clinical history. If the sonographic diagnosis remains uncertain, morphine cholescintigraphy should be considered.

Treatment

ACC can be treated with cholecystostomy or cholecystectomy (laparoscopy or open laparotomy). Percutaneous cholecystostomy is minimally invasive and in the critically ill ICU patient is often the procedure of choice. It is usually performed under ultrasound guidance and when successful, rapid improvement in the patient's clinical status is seen and it can be the definitive treatment. If cholecystectomy is necessary, previous placement of a cholecystostomy tube allows time to stabilize the patient prior to surgery.

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Cross-reference

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CASE 104

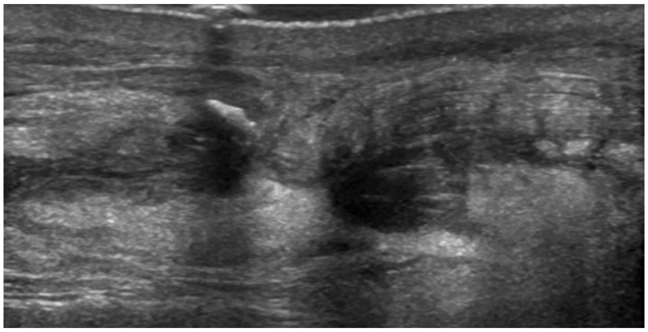

Figure 104-1

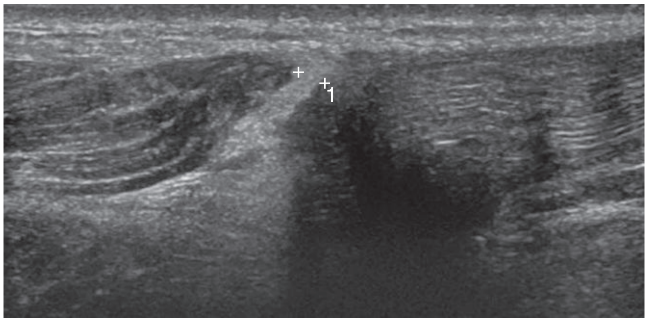

Figure 104-2

HISTORY: A 25-year-old male presents with acute onset of Achilles tendon pain.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Achilles tendinopathy
   B. Extensive partial Achilles tendon tear
   C. Complete Achilles tendon tear
   D. Achilles tendon inflammation
2. Concerning Achilles tendon pathology which statement is true?
   A. The Achilles tendon does not have a synovial lined tendon sheath.
   B. The Achilles tendon is formed by the union of the medial and lateral heads of the gastrocnemius muscles.
   C. Achilles tendinopathy is an inflammatory process.
   D. The gastrocnemius, soleus, and plantaris muscles function together to dorsiflex the foot.
3. Concerning Achilles tendon pathology which statement is true?
   A. Color or power Doppler flow can be detected in the normal Achilles tendon.
   B. Sonographic findings of Achilles tendinopathy include an enlarged, inhomogeneous, hypoechoic tendon.
   C. The paratenon is not a cause of Achilles tendon pain.
   D. Rupture of the Achilles tendon is rare.
4. Concerning Achilles tendon pathology which statement is true?
   A. The Achilles tendon usually ruptures where it inserts on the calcaneus.
   B. Risk factors for primary acute rupture of the Achilles tendon include female sex, fluoroquinolone use, or previous rupture on the contralateral side.
   C. A partial thickness Achilles tendon tear appears as a distinct hyperechoic defect on ultrasound.
   D. A full thickness Achilles tendon tear appears as a gap with a variable degree of retraction between the torn tendon ends on ultrasound.

See Supplemental Figures section for additional figures and legends for this case.

CASE 104

Achilles Tendon Pathologic Condition

1. **C.** The Achilles tendon is completely torn. An extensive partial thickness tear (B) could be considered; an intact plantaris tendon can mimic intact fibers of the Achilles tendon, leading to a mistaken diagnosis of a partial thickness rather than a full thickness tear. It is important to recognize the plantaris muscle tendon unit as a separate structure with a separate insertion on the calcaneus.
2. **A.** The Achilles tendon is surrounded by two membranes (visceral and parietal layers) called the paratenon that permit free movement and gliding of the Achilles tendon. The soleus muscle also contributes to the formation of the Achilles tendon. The gastrocnemius fibers insert more laterally onto the posterior calcaneus and the soleus fibers insert more medially.
3. **B.** The normal Achilles tendon has an echogenic fibrillar pattern and has a mean thickness of approximately 4 to 6 mm. A thick, hypoechoic tendon indicates tendinopathy on ultrasound. Neovascularity may be seen on color or power Doppler imaging. Achilles tendon rupture has been reported to occur in approximately 18/100,000 people, with most injuries occurring in athletes.
4. **D.** The gap between the torn tendon ends of a complete Achilles tendon tear may be filled with hematoma or fat, which can herniate into the gap. The Achilles tendon is predisposed to tear at a zone of relative avascularity between 2 and 6 cm from its insertion. A partial tear appears as a distinct hypoechoic defect in an otherwise normal tendon or tendinotic tendon.

Comment

Introduction

As with other tendons, the Achilles tendon can degenerate or tear. Tendinopathy is thought to be due to repetitive microtrauma and tends to occur in athletes (long distance runners, volleyball, soccer, tennis players). Symptoms include stiffness, pain, and swelling. Tendinopathy is not an inflammatory disorder but a degenerative process with myxoid, hyaline, and fibrinoid degeneration and vascular proliferation (neovascularity). Tendinopathy predisposes to rupture, but rupture can also occur due to trauma or steroid or fluoroquinolone use. Systemic diseases (inflammatory arthropathy, diabetes, gout, systemic lupus erythematosus) also increase the risk for tendon tear.

Sonographic Findings

Achilles tendinopathy appears on ultrasound as a thickened, hypoechoic tendon with increased color Doppler flow. Neovascularity has been reported to correlate with pain but does not bode a poor outcome. Tendon inhomogeneity has been associated with an unfavorable outcome. A partial thickness tear appears as a focal hypoechoic defect. It can be difficult to differentiate a partial thickness tear in the setting of tendinopathy unless a distinct defect is visualized. Achilles paratendinosis cannot be distinguished from tendinosis clinically but can be diagnosed on ultrasound by the presence of a thick, hypoechoic halo that surrounds the tendon. Neovascularity may be present. Tendon rupture is characterized on ultrasound by a gap with a variable distance between the torn tendon ends. The gap may be filled with hematoma or herniated fat (Figs. S104-1 and S104-2).

Treatment

Achilles tendinopathy can be a disabling, chronic condition. There are many different therapies ranging from conservative to surgical. Conservative strategies (rest, orthotics, pharmacologic agents, physical therapy, extracorporeal shock wave therapy) have variable outcomes. Minimally invasive strategies include steroid injection or neovessel obliteration by injecting sclerosing agents into the vessels. The latter treatment was reported to have good short-term results in one small series. Surgery is an established therapy (open tenotomy and debridement of the tendon and paratenon stripping and debridement). The outcomes for tendon debridement are not as good as those for the paratenon. A recent meta-analysis showed that surgical and nonsurgical treatment (using functional rehabilitation) for acute Achilles tendon rupture were equivalent regarding re-rupture rate, range of motion, and functional outcome.

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CASE 105

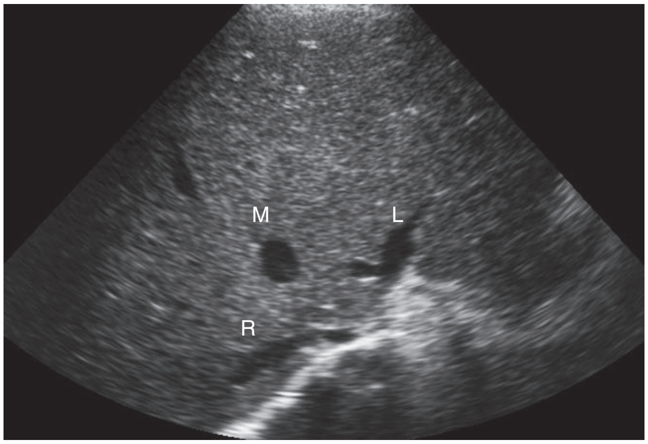

Figure 105-1

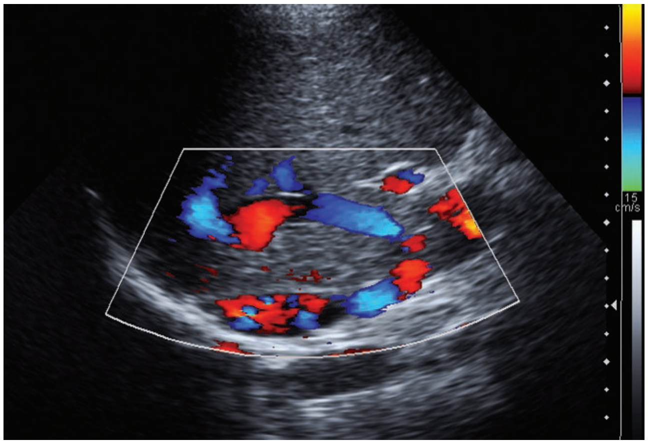

Figure 105-2

HISTORY: A 40-year-old female presents with ascites.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Portal vein thrombosis
   B. Veno-occlusive disease (sinusoidal obstruction syndrome)
   C. Budd-Chiari syndrome (BCS)
   D. Right hepatic vein narrowing
2. Which of the following is true regarding BCS?
   A. Hepatic vein thrombosis has a benign etiology.
   B. Budd-Chiari is classified as primary and secondary.
   C. Primary Budd-Chiari is due to extrinsic compression of one or more of the hepatic veins by a mass.
   D. Intrahepatic hepatic vein thrombosis is idiopathic.
3. Which of the following is true regarding BCS?
   A. BCS has two clinical presentations, acute and chronic.
   B. Ultrasound findings in patients with fulminant BCS include visible thrombus in the hepatic veins and absence of collaterals.
   C. On ultrasound, collaterals are present in patients with acute BCS.
   D. On ultrasound, collateral vessels are not present in patients with chronic BCS.
4. Which of the following is true regarding BCS?
   A. On ultrasound, intrahepatic collateral veins often have the appearance of large, tortuous, comma-shaped vessels.
   B. The waveforms in intrahepatic collateral veins are pulsatile.
   C. On ultrasound, flow is retrograde (towards the inferior vena cava [IVC]) in the patent portion of a more distally occluded hepatic vein.
   D. The waveform in the IVC distal to an IVC obstruction (hepatic portion) is pulsatile.

See Supplemental Figures section for additional figures and legends for this case.

CASE 105

Budd-Chiari Syndrome

1. **C.** The middle and left hepatic veins are obstructed distally and do not communicate with the IVC (yellow arrow, Fig. S105-1); the right hepatic vein is very narrowed (D) (red arrow, Fig. S105-1). Color Doppler shows collaterals that communicate with a caudate vein (yellow arrow, Fig. S105-2) that drains into the IVC (red arrow, Fig. S105-2). Because of hepatic vein occlusion, blood drains from the liver through collaterals to the caudate veins, which directly communicate with the IVC.
2. **B.** Primary BCS is caused by hepatic vein thrombosis or IVC thrombosis. Secondary BCS is due to hepatic vein compression by a mass. The cause of hepatic vein thrombosis is usually a hypercoagulable state. The cause of IVC thrombosis is less clear; IVC endothelial damage from diaphragmatic motion has been suggested. A poor standard of living and infection may also play a role because patients with IVC thrombosis tend to live in poorer countries than patients with hepatic vein thrombosis.
3. **B.** Fulminant BCS develops in a few days and causes severe liver failure. The liver is congested and enlarged, and ascites is present. Collaterals have not had time to develop. Collaterals are present in subacute and chronic BCS because disease onset is slower, allowing time for collaterals to form.
4. **A.** Intrahepatic collaterals do not course in the normal anatomic planes of the hepatic veins. Since blood cannot flow into the IVC, tortuous collaterals develop and drain into caudate veins. Because collaterals are isolated from the right atrium whose contractility contributes to hepatic vein pulsatility, the waveform is monophasic.

Comment

Introduction

BCS is classified as primary (hepatic vein or IVC thrombosis) or secondary (hepatic vein compression by tumor or abscess or hepatic vein invasion by an adrenal, renal, or hepatocellular carcinoma). Hepatic vein thrombosis is usually caused by a hypercoagulable disorder. The cause of IVC thrombosis is less clear, a hypercoagulable state being less common. BCS has four clinical presentations: fulminant, acute, subacute, and chronic. IVC thrombosis usually has a chronic presentation; hepatic vein thrombosis usually has a fulminant, acute or subacute presentation.

Sonographic Findings

Fulminant BCS occurs over a few days and causes severe liver failure. On ultrasound, hepatic vein thrombus, marked hepatomegaly, and ascites are present, but there are no collaterals. Similar findings occur in acute BCS, which develops over a month. With subacute or chronic BCS, portal hypertension predominates; collaterals develop because onset is slower. Ascites occurs less often due to collaterals. Collaterals are large, tortuous, and comma-shaped and do not course in the normal anatomical planes of the hepatic veins. These collaterals communicate with caudate veins (yellow arrow, Fig. S105-2) that drain into the IVC (red arrow, Fig. S105-2). The caudate lobe is often enlarged. The waveforms are monophasic because the collaterals are isolated from the right atrium.

IVC thrombosis causes the waveform distally to be monophasic because the cava is isolated from the right heart whose contractility contributes to its pulsatility. Flow is reversed in the distal IVC and seeks other collateral pathways (azygous system, left renal vein, and superficial abdominal wall vessels) to return blood to the heart.

Treatment

The primary goal in treating BCS is to relieve hepatic congestion, preserve hepatic function, and treat portal hypertension if present. Medical management, including anticoagulants, is used in patients with few symptoms, relatively normal liver function, and controllable ascites. Liver transplantation is lifesaving in fulminant BCS and recommended in end stage liver disease. Angioplasty/stenting is an option for short stenoses, but restenosis is frequent. If intervention fails, a stent graft should be considered. Stent grafts are often used as a bridge to transplantation in fulminant, acute, or subacute BCS.

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CASE 106

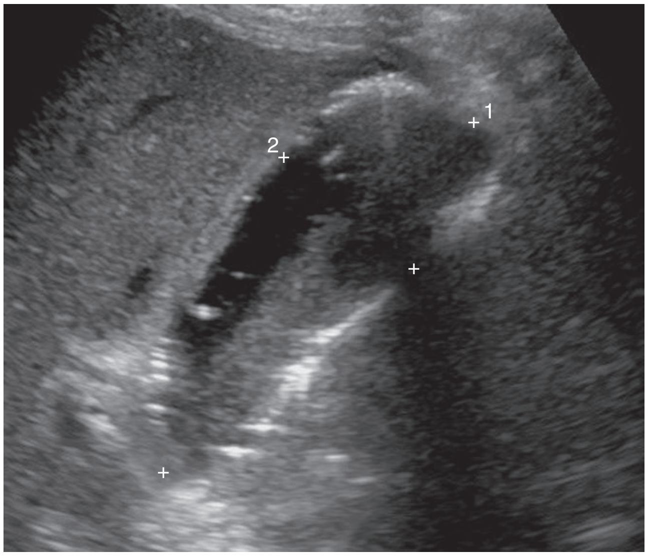

Figure 106-1

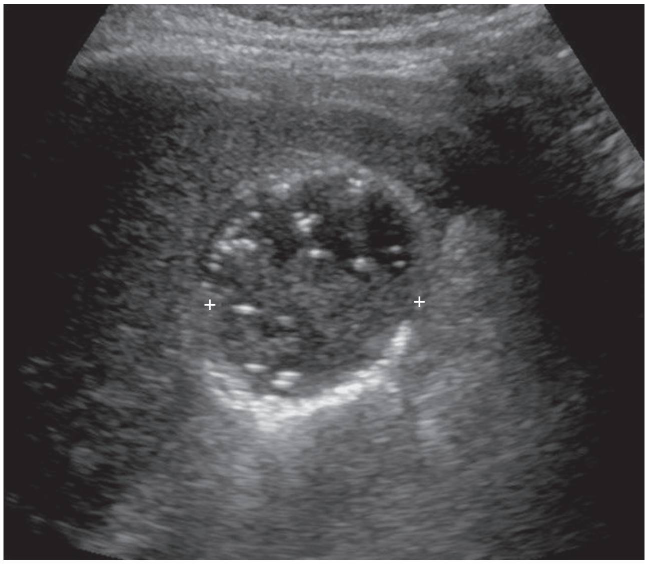

Figure 106-2

HISTORY: A 75-year-old male presents with right upper quadrant pain and a mildly elevated white blood cell count.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Gangrenous cholecystitis
   B. Acalculous cholecystitis
   C. Chronic cholecystitis
   D. Emphysematous cholecystitis
2. Which of the following is true regarding emphysematous cholecystitis?
   A. Intramural or intraluminal gas can produce ringdown artifact.
   B. The presence of air in the gallbladder lumen on ultrasound is diagnostic of emphysematous cholecystitis.
   C. Emphysematous cholecystitis is more common in middle-aged, diabetic women.
   D. Cystic duct obstruction is the cause of emphysematous cholecystitis.
3. Which of the following is true regarding emphysematous cholecystitis?
   A. The pathogenesis of emphysematous cholecystitis is due to ischemia.
   B. The mortality rate of emphysematous cholecystitis is similar to that of acute cholecystitis.
   C. Signs and symptoms of emphysematous cholecystitis are similar to those of acute cholecystitis.
   D. Secondary infection occurs from aerobic organisms in patients with emphysematous cholecystitis.
4. Which of the following is true regarding emphysematous cholecystitis?
   A. Cholesterolosis should be considered as a differential diagnosis of emphysematous cholecystitis.
   B. Adenomyomatosis can be differentiated from emphysematous cholecystitis on ultrasound.
   C. Porcelain gallbladder should be considered as a differential diagnosis of emphysematous cholecystitis.
   D. Emphysematous cholecystitis is a surgical emergency.

See Supplemental Figures section for additional figures and legends for this case.

CASE 106

Emphysematous Cholecystitis

1. **D.** There is dirty shadowing (arrow, Fig. S106-1) behind the echogenic gallbladder wall indicative of mural air and emphysematous cholecystitis. Intramural air causes dirty shadowing because the gas reflects the sound beam and causes multiple reflections between the air in the wall and the transducer. This appears as artifactual noise deep to the wall. Choice A is also correct because gangrenous changes are present in up to 75% of cases of emphysematous cholecystitis.

2. **A.** Ringdown artifact is associated with a collection of gas and appears on ultrasound as a solid streak or vertical band of parallel lines deep to the collection of air. It originates from a bubble tetrahedron that traps a bugle-shaped fluid collection that emits a continuous sound wave back to the transducer when struck with an ultrasound pulse. Air in the gallbladder lumen alone is not diagnostic of emphysematous cholecystitis and can occur from a biliary enteric anastomosis or fistula, sphincterotomy, or patulous sphincter of Oddi.

3. **A.** The pathogenesis of emphysematous cholecystitis is due to thrombosis/occlusion of the cystic artery that causes ischemia/necrosis of the gallbladder wall. Secondary infection occurs from anaerobic organisms (*Clostridium welchii*, *Escherichia coli*, anaerobic streptococcus).

4. **C.** A porcelain gallbladder is a differential consideration. However, the wall, while echogenic, has a "cleaner" shadow deep to the wall. The dependent wall is also echogenic and is often seen on ultrasound. A clean shadow occurs because the calcified wall absorbs most of the incident sound beam, leaving little energy available to produce artifactual noise.

Comment

Introduction

Emphysematous cholecystitis is rare; its incidence is 1%. It is two to three times more common in men than in women. The pathogenesis is not due to cystic duct obstruction but to cystic artery occlusion or obstruction. In one study, pathologic findings showed a high incidence of endarteritis obliterans in emphysematous cholecystitis specimens. This would explain the higher incidence of emphysematous cholecystitis in diabetics. Gallstones are present in only 50% of cases. Gangrenous changes are present in a majority of cases; the risk of perforation is 20%, resulting in a mortality rate of 15% to 25%. Signs and symptoms can be very subtle; patients may be afebrile and have a normal WBC count or nontender abdomen.

Sonographic Findings

Sonographic findings include intramural gas (arrow, Fig. S106-1); the gallbladder wall is echogenic with dirty shadowing or ringdown artifact posteriorly. Gas may also be intraluminal and appears as echogenic foci with comet tail artifact (arrow Fig. S106-2). Gas if intraluminal will change position if the patient is turned and may rise to the nondependent portion of the gallbladder. Adenomyomatosis and porcelain gallbladder are in the differential for mural air. However, the wall of a porcelain gallbladder, while echogenic, has a "cleaner" shadow deep to the wall. Adenomyomatosis is caused by hypertrophy of the gallbladder wall mucosa and muscularis with formation of intramural diverticuli (Rokitansky-Aschoff sinuses) that are filled with bile and cholesterol crystals. These crystals can produce comet tail artifacts that can have an appearance identical to intramural air. Clinical history is very important in differentiating these two entities.

Treatment

Emphysematous cholecystitis can be rapidly progressive with a high mortality and has traditionally been considered a surgical emergency. Prompt cholecystectomy, whether laparoscopic or open, is the suggested definitive treatment. Occasionally in the unstable patient, percutaneous cholecystostomy in combination with antibiotics has been successful. However, it has been shown that there is a spectrum of severity, and those without evidence of sepsis may not require urgent surgical intervention but rather conservative treatment with antibiotics and elective cholecystectomy at a later date.

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Cross-reference

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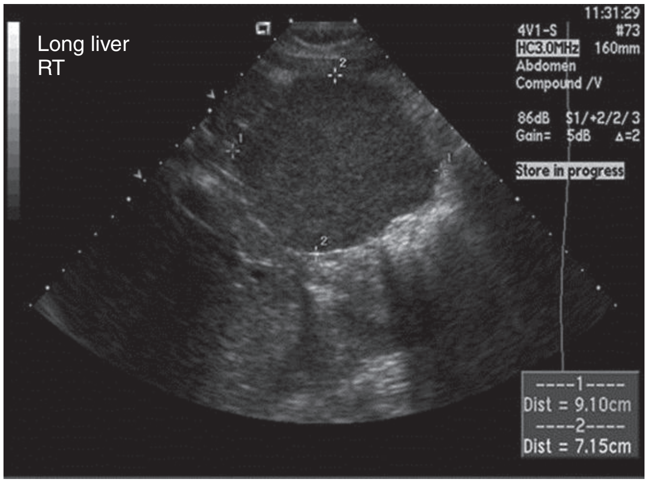

Figure 107-1

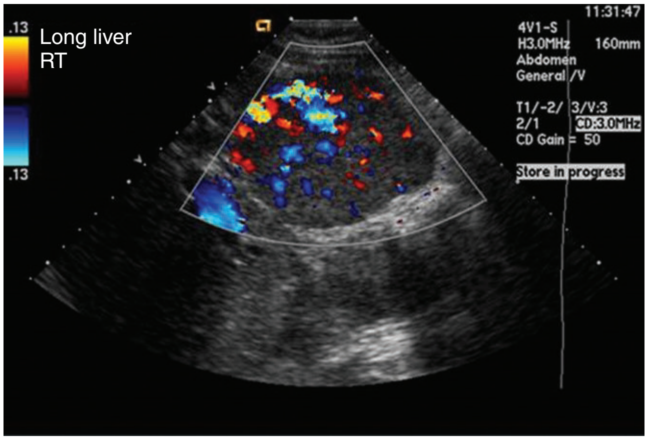

Figure 107-2

HISTORY: A 35-year-old female presents with right upper quadrant pain and no risk factors. Patient does not have hepatitis C.

1. Which one of the following would be the MOST likely diagnosis for the ultrasound images of the liver presented in Figures 107-1 and 107-2?
   A. Cavernous hemangioma
   B. Hepatic adenoma
   C. Hepatocellular carcinoma (HCC)
   D. Hypervascular metastases
   E. Focal nodular hyperplasia (FNH)

2. What is the best NEXT step in management?
   A. Computed tomography (CT) with intravenous (IV) contrast
   B. Magnetic resonance imaging (MRI) with IV contrast
   C. Nuclear medicine study
   D. CT without IV contrast

3. Which is a classic pathologic finding that may be a distinguishing factor on imaging?
   A. Arterial enhancement with delayed washout
   B. Tumor thrombus
   C. Central, stellate scar
   D. Prompt washout with hepatobiliary contrast agent

4. Which nuclear medicine study has classically been used to confirm this diagnosis?
   A. Hepatobiliary scan (hepatobiliary iminodiacetic acid)
   B. Sulfur colloid scan
   C. Tagged red blood cell scan
   D. Hepatic perfusion scintigraphy

See Supplemental Figures section for additional figures and legends for this case.

CASE 107

Focal Nodular Hyperplasia

1. **E.** This is a nonspecific appearance by ultrasound; therefore, the differential is broad and includes all hypervascular hepatic lesions. FNH may be subtle as it consists of parenchymal elements and therefore may blend in with surrounding parenchyma. This is the most likely diagnosis, although answers B, C, and D can be considered. Cavernous hemangioma has slow flow, which is usually not seen on color flow.
2. **B.** MRI with contrast is the next best step in management. FNH demonstrates uptake of contrast on delayed MRI scans with hepatobiliary contrast agents such as gadoxetate disodium. (Eovist) This is due to the fact that FNH has functioning hepatocytes and the other lesions do not.
3. **C.** Typical FNH demonstrates a central, stellate scar. The scar is an area of focal fibrous septa and often contains large vessels which radiate outward. However, other liver lesions may have the appearance of a central scar.
4. **B.** Two-thirds of cases of FNH demonstrate a normal or increased uptake of sulfur colloid due to increased vascularity and higher concentration of Kupffer cells compared to other hepatic masses.

Comment

Differential Diagnosis

The differential diagnosis for this hepatic mass is quite broad. Certainly, in a patient with known cirrhosis and hepatitis C, HCC would be the most likely diagnosis. However, in this young patient without a history of cirrhosis a hepatic adenoma or FNH could have this appearance on ultrasound. In a patient with underlying malignancy, a metastasis could be considered. Cancerous hemangioma would seem less likely as this lesion is nearly isoechoic to the rest of the liver and is fairly vascular.

Imaging Characteristics

FNH is a benign hepatic tumor that most commonly presents in women. FNH is characterized by abnormal arrangement and distribution of hepatocytes, bile ducts, and Kupffer cells. There are two types of FNH—classic and nonclassic. Classic FNH is characterized by malformed vessels, proliferation of bile ducts, and abnormal nodular architecture. Nonclassic FNH will demonstrate bile duct proliferation; however, it lacks either malformation of hepatic vasculature or abnormal architecture.

On ultrasound, FNH classically presents as an isoechoic mass with central vascularity on color Doppler (Figs. S107-1 and S107-2). Sometimes the masses are hard to distinguish from surrounding liver parenchyma. FNH often has a subtle mass effect.

On noncontrast CT, the mass will be subtle and may be slightly hypodense (Fig. S107-3). On contrast-enhanced CT, the mass will demonstrate intense homogeneous enhancement on arterial phase (Fig. S107-4). On portal venous phase and delayed phase equilibrium images the mass will be isodense to liver parenchyma.

Management

Sulfur colloid nuclear medicine scan or MRI, with use of gadoxetate disodium, are used in evaluation of these masses. On MRI, FNH is hyperintense on arterial phase and isointense with venous and delayed phase. FNH distinguishes itself from other hepatic lesions with administration of hepatobiliary-specific contrast agents. With these hepatobiliary-specific contrast agents (gadoxetate disodium), FNH is isointense or slightly hyperintense on delayed phase imaging. Other tumors, such as metastasis and most HCCs, will not take up this agent, and they appear hypointense on delayed MRI. FNH contains Kupffer cells and thus appears most commonly with normal or with increased uptake with nuclear medicine sulfur colloid scan. FNH can appear as a photopenic region in rare cases.

After a diagnosis has been confirmed with MRI, management is conservative. Biopsy is not indicated.

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Cross reference

Ultrasound: *The Requisites*, 3rd ed, 169–170.

Acknowledgment

Special thanks to Ruchir Chaudhari, MD, for preparation in this case.

CASE 108

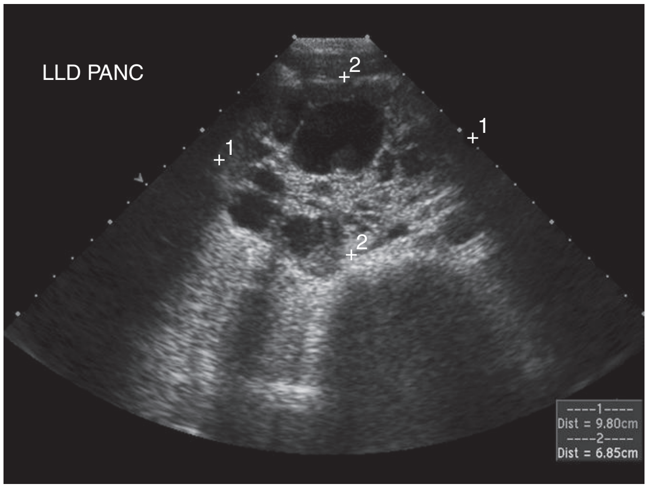

Figure 108-1

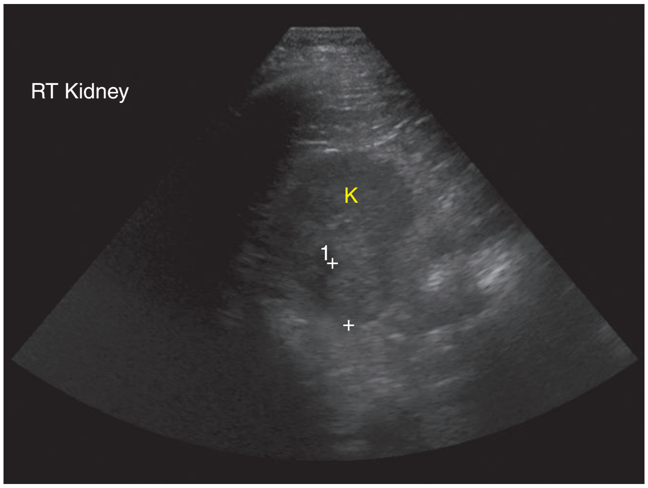

Figure 108-2

HISTORY: A 37-year-old male presents with ultrasound of the pancreas in Figure 108-1.

1. Which of the following would be included in the differential diagnosis for Figure 108-1? (Choose all that apply.)
   A. Autosomal dominant polycystic kidney disease
   B. Von Hippel-Lindau (VHL) disease
   C. Pancreatic pseudocysts
   D. Pancreatic adenocarcinoma
   E. Nonfunctioning neuroendocrine tumor
2. If Figures 108-1 and 108-2 (an ultrasound of the right kidney) are both taken into consideration, what is the most likely diagnosis?
   A. Autosomal dominant polycystic kidney disease
   B. VHL disease
   C. Mucinous tumor of the pancreas
   D. Tuberous sclerosis
3. Concerning the abnormalities within the pancreas in VHL disease, they include all the following EXCEPT:
   A. Serous cyst adenoma
   B. Islet cell tumor
   C. Simple cysts
   D. Intraductal papillary mucinous neoplasm (IPMN)
4. Concerning the abdominal findings of VHL, all may occur EXCEPT:
   A. Adrenal pheochromocytomas
   B. Renal angiomyolipomas
   C. Renal cysts
   D. Liver cysts

See Supplemental Figures section for additional figures and legends for this case.

CASE 108

Von Hippel-Lindau Disease

1. **A, B, and C.** Autosomal dominant polycystic kidney disease may have concomitant pancreatic cysts. VHL disease usually has or is associated with pancreatic cysts. Multiple pancreatic pseudocysts could give this appearance. The other two entities are more likely solid than cystic.
2. **B.** The most correct answer would be VHL disease, which has associated pancreatic cysts and solid masses (renal cell carcinoma [RCC]) of the kidney.
3. **D.** All the tumors listed except for IPMN are associated with VHL disease.
4. **B.** Angiomyolipomas are associated with tuberous sclerosis rather than VHL. All others may be seen with VHL.

Comment

Differential Diagnosis

Differential diagnosis in Figures S108-1 and S108-2 would include any cystic abnormality within the pancreas. Thus, autosomal dominant polycystic kidney disease, with pancreatic cysts, would be considered. Cystic pancreatic tumors such as a mucinous tumor of the pancreas also would be considered. A large IPMN is usually smaller but could be considered. Multiple pancreatic pseudocysts could have this appearance. Solid masses such as adenocarcinoma of the pancreas would not be considered unless there was a secondary pseudocyst from the pancreatic ductal obstruction.

Ultrasound Features

Ultrasound features of VHL disease in this pancreas may vary. Most commonly there are multiple cysts within the pancreas that are well defined and anechoic. However, serous cystadenomas of the pancreas may occur in this entity and appear as a more echogenic mass. Pancreatic islet cell tumors are rare in this entity and appear as a hypoechoic mass. VHL is associated with liver and renal cysts and solid renal masses (RCC).

Management

Management includes directing therapy toward a specific malignancy or life-threatening portions of this entity. For instance, radio frequency ablation is utilized for treatment of RCCs that occur with this entity. Cerebellar and retinal hemangioblastomas may occur with this entity and must be treated. The pheochromocytomas do occur in a small number of patients with VHL. Therapy must be directed at removal of these tumors. Certainly both computed tomography and magnetic resonance imaging may give a more global picture (Fig. S108-3) of this entity.

References

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Cross-reference

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CASE 109

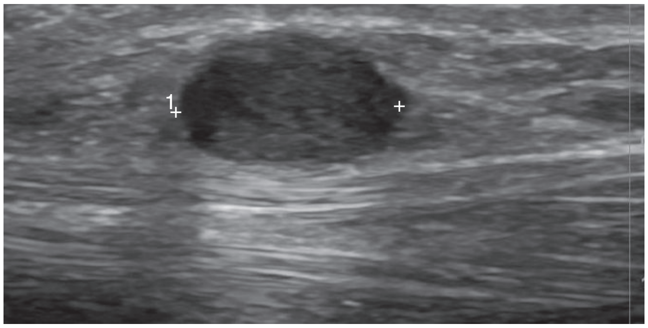

Figure 109-1

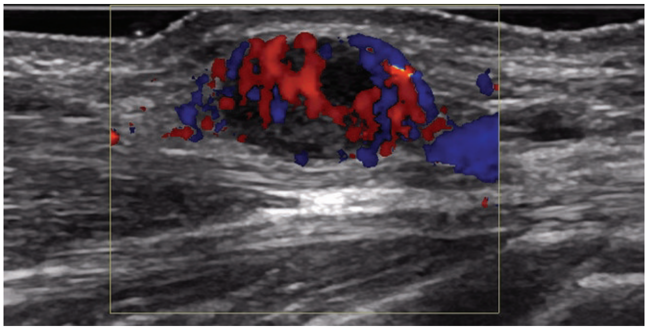

Figure 109-2

HISTORY: A 44-year-old female presents with a rapidly growing tender mass on the volar surface of the distal forearm.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Epidermal inclusion cyst (EIC)
   B. Hemangioma
   C. Sarcoma
   D. Nodular fasciitis

2. Concerning nodular fasciitis of the hand/wrist, which statement is true?
   A. Nodular fasciitis is a reactive proliferative process.
   B. Nodular fasciitis is usually located on the volar aspect of the forearm in the subcutaneous tissues, muscle, or fascia.
   C. Nodular fasciitis is a slow growing malignancy.
   D. Nodular fasciitis is treated with biopsy and observation.

3. Concerning hemangioma, which statement is true?
   A. Hemangiomas are not considered true tumors but reactive lesions.
   B. Hemangiomas are slow growing painful masses.
   C. Hemangiomas cause a bluish discoloration of the skin. On physical exam they are rubbery and compressible.
   D. Hemangiomas are solid, hyperechoic masses with peripheral vascularity.

4. Concerning EICs, which statement is true?
   A. EIC is located most commonly within extremity muscles.
   B. EIC is a painless, rapidly growing mass.
   C. EIC does not undergo malignant transformation.
   D. EIC has been described as having a “pseudotestis appearance” with internal bright reflectors and anechoic clefts on ultrasound.

See Supplemental Figures section for additional figures and legends for this case.

CASE 109

Soft Tissue Masses of the Hand and Wrist

1. **D.** Nodular fasciitis is a rapidly growing tender mass; it is hypoechoic or isoechoic and hypervascular on ultrasound. EIC has no internal blood flow on color Doppler. Sarcomas (C) do grow, are also hypoechoic and vascular, but are not tender and are very rare but nevertheless should be included in the differential. Hemangiomas should also be considered but are not rapidly growing or tender.
2. **B.** Nodular fasciitis is a benign tumor of fibroblastic/myofibroblastic differentiation. It is usually located on the volar surface of the forearm but cases of lower extremity lesions have been reported. Nodular fasciitis is treated with surgical excision; it is important to differentiate it from a soft tissue sarcoma to avoid aggressive surgical resection.
3. **C.** Hemangiomas cause skin discoloration due to their hypervascularity and close proximity to the skin. They are true tumors and consist of small capillary size vessels. On ultrasound, hemangiomas are solid, hypoechoic, and hypervascular on color Doppler.
4. **D.** EIC can simulate the appearance of a testis on ultrasound but may be heterogeneous, echogenic, lobulated, or complex cystic. There is no internal vascularity. EIC occurs in hair-bearing areas and is due to occlusion of pilosebaceous glands or traumatic implantation of viable epidermal cells into the dermis or subcutaneous tissues. EICs are slow growing, firm masses and may cause pain, especially if they rupture or become infected. Malignant transformation into a low grade squamous cell carcinoma is rare and has been reported in 2.2% of patients.

Comment

Introduction

The differential diagnosis of soft tissue masses of the upper extremity is large and includes benign and malignant lesions such as a ganglion, giant cell tumor, hemangioma, glomus tumor, EIC, neurogenic tumor, lipoma, soft tissue sarcoma, nodular fasciitis, abscess, rheumatoid nodule, and tumors of the sweat glands and skin appendages. It is important to obtain an accurate clinical history: length of time the lesion has been present, rapidity of growth, pain/tenderness, history of trauma, arthritis, inflammatory disease, etc. Physical exam findings are also important: is the lesion soft, rubbery or firm? Is skin discoloration present? A high frequency transducer (18 MHz) should be used to denote the lesion's characteristics including size, echogenicity, echotexture, margins, vascularity, calcification, and posterior acoustic enhancement.

Sonographic Findings

Ultrasound findings combined with history can help to narrow the differential diagnosis of a soft tissue lesion of the upper extremity. For example, a pseudotestis appearance and protrusion from the dermis suggests an EIC. A history of a rapidly growing mass that is solid, hypoechoic, and hypervascular suggests nodular fasciitis, as seen in this case (Figs. S109-1 and S109-2). Hemangiomas are also hypoechoic and hypervascular, but are slow growing and painless. Neurogenic tumors are typically hypoechoic and homogeneous with posterior acoustic enhancement (though a target appearance has also been reported) and may be suggested if an entering and exiting nerve can be visualized. A history of carcinoma, lymphoma, gout, or rheumatoid arthritis could also help narrow the differential diagnosis; for example, a hypoechoic mass could represent a metastasis or cutaneous lymphoma in the proper clinical setting. However, there is much overlap in sonographic features, and if it is not possible to make a diagnosis, a biopsy may be necessary.

Treatment

Management of a soft tissue lesion of the upper extremity will depend on the differential diagnosis offered. Some lesions have a characteristic appearance; however, other lesions have a nonspecific sonographic appearance and may require a biopsy or surgical excision. It is the radiologist's responsibility to narrow the differential diagnosis as much as possible to aid the clinician in determining management.

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Cross-reference

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CASE 110

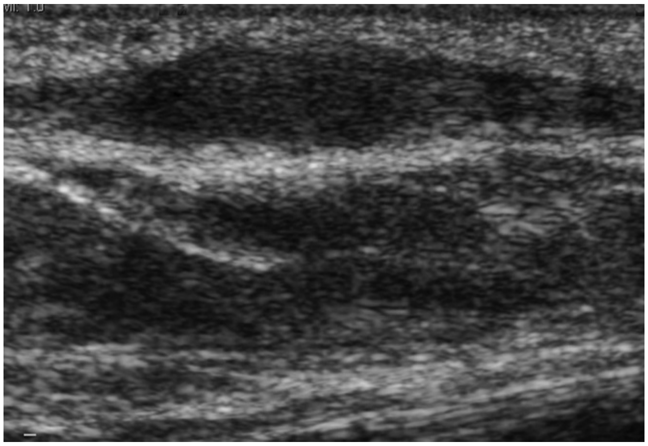

Figure 110-1

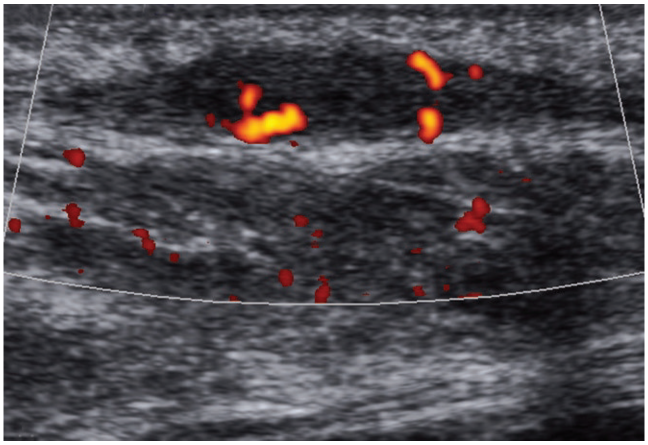

Figure 110-2

HISTORY: A 40-year-old female presents with chronic heel pain.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Partial thickness tear of the plantar fascia
   B. Plantar fasciitis
   C. Plantar fibromatosis
   D. Morton neuroma

2. Concerning plantar fasciitis, which statement is true?
   A. Plantar fasciitis is most commonly due to repetitive microtrauma from sports-related activities such as running, tennis, basketball, and dancing but can be seen in middle-aged or elderly patients from excessive standing or walking.
   B. Typical symptoms include heel pain that gradually decreases with increasing activity.
   C. Plantar fasciitis is due to an inflammatory process.
   D. On ultrasound, the normal plantar fascia is hypoechoic.

3. Concerning plantar fibromatosis, which statement is true?
   A. Plantar fibromatosis occurs primarily in middle-aged women.
   B. Plantar fibromatosis is characterized by fibrous tissue proliferation within the plantar fascia near where it inserts onto the calcaneus.
   C. Plantar fibromatosis is one of the superficial fibroproliferative disorders and is thought to be associated with other fibroproliferative disorders such as Peyronie's disease, and Dupuytren's disease.
   D. On ultrasound, plantar fibromatosis appears as ill-defined, hyperechoic fusiform or nodular thickening of the central or medial aponeurosis.

4. Concerning Morton's neuroma, which statement is true?
   A. Morton's neuroma is a benign tumor.
   B. Morton's neuromas are more common in men than women and cause burning pain and paresthesias that begin at the metatarsal level and radiate to the toes.
   C. On ultrasound, Morton's neuromas are hypoechoic; the nerve has a fusiform shape.
   D. Intermetatarsal bursitis is not associated with Morton's neuroma.

See Supplemental Figures section for additional figures and legends for this case.

CASE 110

Foot Pathology

1. **B.** The plantar fascia is intact but hypoechoic and thickened, measuring more than 4 mm, consistent with plantar fasciitis. Choice A might be considered, but to diagnose a partial thickness tear on ultrasound, a distinct defect should be present. Plantar fasciitis is diagnosed on ultrasound when the fascia measures greater than 4 mm where it inserts on the calcaneus.
2. **A.** If bilateral, a systemic disease should be considered such as rheumatoid arthritis, seronegative spondyloarthropathy (Reiter syndrome, psoriatic arthritis, and ankylosing spondylitis), lupus, or gout. Heel pain, usually described as burning or sharp, is present after rising in the morning, decreases with ordinary walking as the fascia stretches out, but increases with increasing activity.
3. **C.** Plantar fibromatosis is a fibroproliferative disorder; the pathogenesis is multifactorial with a genetic component. It occurs in children and adults, is twice as common in men, and is bilateral in 20% to 50% of patients. It can be symptomatic or asymptomatic. The main differentials include plantar fasciitis and chronic plantar fascial rupture. The containment of the lesion within the fascia excludes most other nonfascial soft tissue lesions, whether benign or malignant.
4. **C.** Morton's neuromas are hypoechoic and can be visualized if at least 5 mm in size. The foot should be scanned on the plantar surface at the metatarsal level with a high frequency linear array transducer. Pressure should be applied from the dorsal surface at the intermetatarsal level to separate the metatarsal heads for better visualization of the interdigital nerve.

Comment

Introduction

Plantar fasciitis is a degenerative process characterized by collagen necrosis, angiofibroblastic hyperplasia, and chondroid metaplasia. The main differential includes plantar fibromatosis and chronic plantar fascial rupture. Plantar fibromatosis, a fibroproliferative disease, can be differentiated from plantar fasciitis by its location. Morton's neuroma is not a tumor but a compression neuropathy caused by entrapment of the plantar interdigital nerve resulting in perineural fibrosis. It is more common in women who wear narrow-toe high heels. Metatarsal pain radiating to the toes is characteristic, but the differential is broad and includes intermetatarsal bursitis, stress fracture, ganglion, or nerve sheath or giant cell tumor.

Sonographic Findings

On ultrasound, plantar fasciitis appears as hypoechoic thickening of the plantar fascia where it inserts on the calcaneus. There may be associated perifascial edema or fluid (Fig. S110-1). Increased color Doppler flow may be present during the acute phase (Fig. S110-2). Plantar fibromatosis appears as hypoechoic fusiform or nodular thickening of the more medial or central plantar aponeurosis on ultrasound. It is usually unilateral but may be bilateral, and there may be multiple nodules. Color or power Doppler flow may also be present. Morton's neuromas most commonly occur in the second or third intermetatarsal space at the level of the metatarsal heads. The neuroma is hypoechoic. If an anechoic lesion with posterior acoustic enhancement is imaged in conjunction with a neuroma, it likely represents the intermetatarsal bursa, which can be inflamed and difficult to distinguish from a neuroma due to their intimate relationship.

Treatment

Plantar fasciitis can be treated with stretching, strengthening, appropriate footwear, taping of the heel, orthotics, physical therapy, nonsteroidal anti-inflammatory drugs, steroid injection, and surgical release if conservative therapy fails. However, most cases resolve within 2 years. Plantar fibromatosis can be treated conservatively with orthotics. The major indication for surgery is pain. A wide excision is necessary, but the nodules may recur. Morton's neuromas can be surgically resected, but new techniques have been reported, including alcohol injection and cryoneurolysis (freezing the nerve by placing a cryotherapy probe into the neuroma), as having been as successful as surgery.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 276.

CASE 111

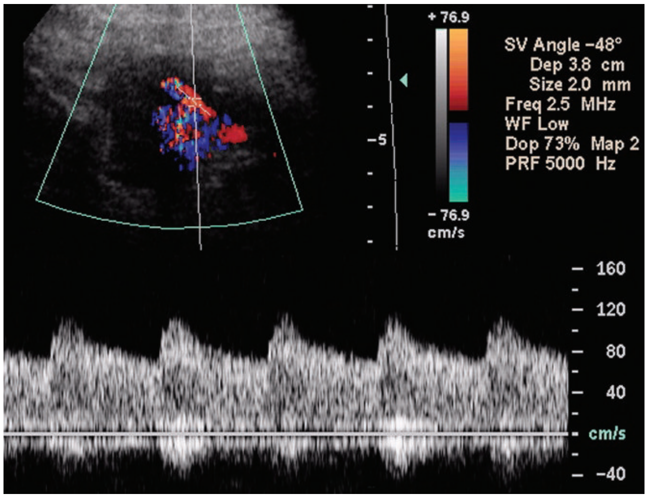

Figure 111-1

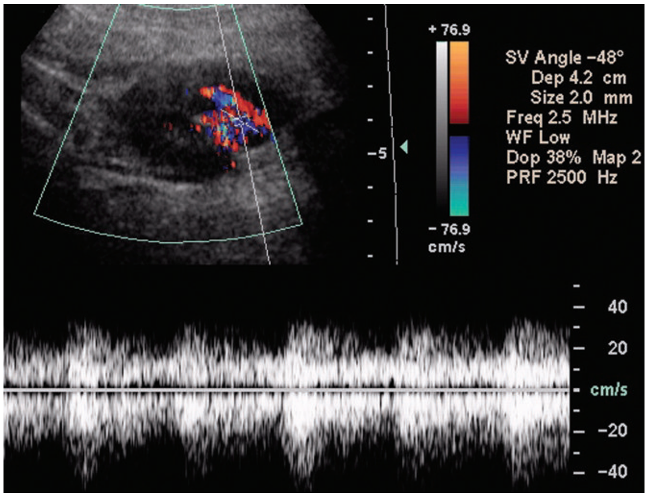

Figure 111-2

HISTORY: A 65-year-old man who underwent a renal biopsy has developed hematuria.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Combined arteriovenous fistula (AVF) and pseudoaneurysm (PSA) of a branch renal artery and vein
   B. Fibromuscular dysplasia (FMD) of the hilar renal artery
   C. AVF of a branch renal artery and vein
   D. PSA of a branch renal artery
2. AVF may be caused by which of the following?
   A. Atherosclerosis
   B. Penetrating trauma to the kidney
   C. Inadvertent needle puncture of a renal artery branch
   D. Dissection of a renal artery
3. What are the sonographic findings of an AVF?
   A. Decreased resistive index in the involved artery
   B. Increased resistive index in the involved artery
   C. Yin-yang appearance in the involved artery
   D. “To and fro” arterial flow in the neck of the AVF
4. What are the sonographic findings of a renal artery PSA?
   A. High peak systolic velocity in the PSA sac
   B. Arterialized venous waveform
   C. High resistive index in the neck
   D. “To and fro” arterial flow in the PSA neck

See Supplemental Figures section for additional figures and legends for this case.

CASE 111

Renal Arteriovenous Fistula and Pseudoaneurysm

1. **C.** The artery of an AVF has increased peak systolic and end diastolic velocities because of the decreased resistance of arterial flow into the low resistance vein. The waveform of the vein appears “arterialized” (simulating the appearance of an artery) because of the rapid flow of blood from the artery into the vein. If a PSA or FMD were present, the vein would have a normal waveform. A combined PSA and AVF should be considered, but the images do not show a PSA with a flow lumen on color Doppler.
2. **B.** Penetrating trauma to the kidney can cause an AVF. Both the artery and vein must be transgressed for an AVF to develop. Trauma may occur due to a stab wound, percutaneous biopsy, placement of a nephrostomy tube, or after a partial nephrectomy, for example.
3. **A.** The artery of an AVF has very high peak systolic and end diastolic velocities because it flows into a low resistance vein; this would cause a decreased resistive index. The resistive index equals the peak systolic velocity minus the end diastolic velocity divided by the peak systolic velocity.
4. **D.** There is arterial inflow into a PSA during systole and outflow during diastole. This causes a “to and fro” appearance to the arterial waveform at the level of the neck. The vein should have a normal appearance. Yin-yang refers to the appearance of the swirling blood in the PSA sac.

Comment

Introduction

Renal artery PSA and AVF have many common etiologies. Both may be caused by penetrating trauma (stab wound, percutaneous biopsy, nephrostomy tube placement), surgery (partial nephrectomy), or inflammation (vasculitis).

PSAs may also occur in angiomyolipomas. Patients with a renal AVF may be asymptomatic or develop hypertension, gross hematuria, increased creatinine, or high output failure although the latter is very rare. Patients with a renal artery PSA may be asymptomatic or present with flank pain, gross hematuria, or hypertension.

Sonographic Findings

AVFs and PSAs have characteristic findings on ultrasound. It is important to obtain a waveform in both the artery and vein when evaluating for either because a combined PSA and AVF may be present. The feeding artery of an AVF has increased peak systolic and end diastolic velocities and a decreased resistive index. The draining vein is arterialized (with apparent systolic and diastolic flow), and the waveform is turbulent because of the rapid pulsatile flow of blood from the artery into the vein. This also causes perivascular tissue vibration (Fig. S111-3). Because of rapid arterial flow into the vein, the vessel wall vibrates and the vibrations are transmitted into the surrounding soft tissues. On color Doppler, these tissues are assigned an artifactual, random red or blue color that is qualitatively much lower in velocity than the AVF. A PSA only involves the artery and at the neck there is forward flow during systole and reversed flow during diastole, creating a “to and fro” waveform. Within the lumen of the PSA, the blood flow is slower and swirls, creating a “yin-yang” appearance. The vein has a normal appearance.

Treatment

Depending on the size and absence or presence of symptoms, a PSA or AVF may be observed with ultrasound as some will spontaneously close. If a PSA or AVF is symptomatic or large, transcatheter intra-arterial coil embolization can be performed and is very successful in most cases.

Reference

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 138–142.

CASE 112

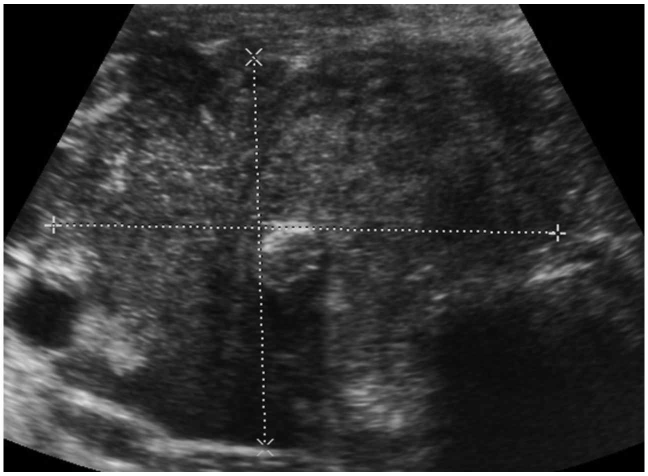

Figure 112-1

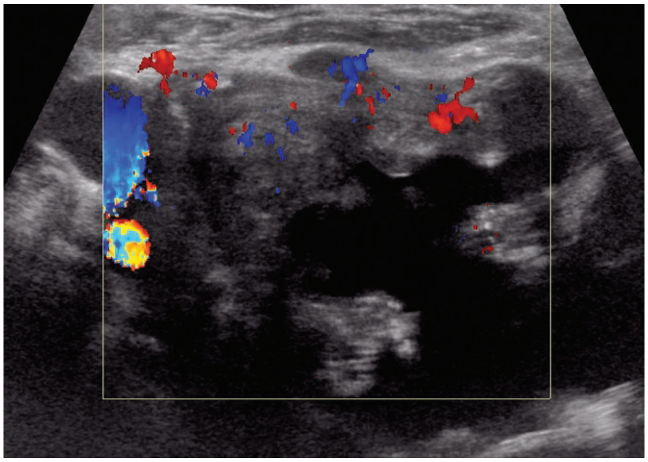

Figure 112-2

HISTORY: A 75-year-old man presents with a large neck mass, dyspnea, stridor, and dysphagia.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Anaplastic carcinoma
   B. Benign appearing nodule
   C. Graves' disease
   D. Thyroid lymphoma
2. Which of the following is true regarding anaplastic carcinoma?
   A. Anaplastic carcinoma is more common in older men.
   B. Anaplastic carcinoma is highly aggressive, with a 5-year survival of 1% to 14%.
   C. Anaplastic carcinoma is a slow-growing mass.
   D. Men less than 65 years of age have a better prognosis.
3. Which of the following is true regarding thyroid lymphoma?
   A. Primary thyroid lymphoma occurs more commonly in men.
   B. Primary thyroid lymphoma is a slow-growing tumor and is usually a Hodgkin's lymphoma.
   C. Hashimoto's thyroiditis is present in more than 90% of patients with primary thyroid lymphoma.
   D. Primary thyroid lymphoma is intrathyroidal and tends not to invade surrounding soft tissue structures.
4. Which of the following is true regarding thyroid metastases?
   A. Thyroid metastases do not affect prognosis.
   B. The most common tumors to metastasize to the thyroid are head and neck squamous cell carcinomas.
   C. Thyroid metastases have a variable appearance on ultrasound.
   D. Thyroid metastases are usually incidentally detected on another imaging study.

See Supplemental Figures section for additional figures and legends for this case.

CASE 112

Non-papillary Thyroid Tumors (Anaplastic Carcinoma, Lymphoma, Metastases)

1. **A.** Figure S112-1 shows a large, solid, hypoechoic/heterogeneous thyroid mass with chunky calcification that abuts the trachea and vascular structures. Figure S112-2 has a similar appearance with cystic change. These appearances can be seen with anaplastic carcinoma. Thyroid lymphoma (D) would also be a consideration as it can be hypoechoic and heterogeneous on ultrasound though cystic change is very unusual.
2. **B.** Anaplastic carcinoma is an undifferentiated, rapidly growing tumor. Extrathyroidal extension and/or distant metastases (liver, lung, bone) are present in 20% to 50% of patients at presentation. However, women less than 65 years with a less than 5 cm or intrathyroidal tumor with no distant metastases have a better prognosis.
3. **C.** In fact, it can be difficult to distinguish between the two on ultrasound. On ultrasound, primary thyroid lymphoma is heterogeneous and hypoechoic with echogenic septae but may appear as a hypoechoic or heterogeneous mass. The presence of a rapidly growing mass is very helpful in differentiating Hashimoto's thyroiditis from primary thyroid lymphoma. Most are non-Hodgkin's B cell lymphomas, but a small percent are mucosa-associated lymphoid tissue (MALT) lymphomas, which have a better prognosis.
4. **C.** Little has been written about the sonographic appearance of thyroid metastases. Their appearance is likely nonspecific, i.e., solid, hypoechoic, or heterogeneous, with varying degrees of cystic change depending on lesion size and necrosis, and have a variable degree of internal vascularity based on the vascularity of the primary tumor. Patients may present with a rapidly growing mass or be asymptomatic.

Comment

Introduction

Anaplastic carcinoma has a dismal prognosis but accounts for only 2% of all thyroid carcinomas. It is three to five times more common in women (mean age, 65 years), and presents as a rapidly enlarging neck mass with neck pain, stridor, dysphagia, and dyspnea due to invasion of the trachea, esophagus, and surrounding soft tissues. Primary thyroid lymphoma is also rare, accounting for less than 2% of thyroid tumors. Primary thyroid lymphomas are four times more common in women (age range, 50 to 80 years). Like anaplastic carcinoma, primary thyroid lymphoma also presents as a rapidly enlarging neck mass. Constitutional symptoms are present in 10% of patients. The most common carcinomas that metastasize to the thyroid include renal cell carcinoma, breast, lung, colon, stomach, and melanoma. Most metastases are solitary.

Sonographic Findings

Anaplastic carcinoma appears as a large, solid, hypoechoic, heterogeneous mass with cystic areas and amorphous calcifications (Figs. S112-1 and S112-2). It is important to examine the neck for invasion/encasement of surrounding structures including the strap muscles, sternocleidomastoid muscle, trachea, esophagus, jugular vein and carotid artery (Fig. S112-2). Primary thyroid lymphoma may appear as a diffuse hypoechoic, heterogeneous process that has an appearance similar to Hashimoto's thyroiditis or as a hypoechoic/heterogeneous mass. Metastases have a nonspecific appearance and can be solid, hypoechoic, or heterogeneous, with cystic change and internal vascularity.

Treatment

Most patients with anaplastic carcinoma have advanced disease and are not candidates for surgery although surgery is the only hope for cure. If surgery is performed, a thyroidectomy and resection of involved lymph nodes is attempted. Combined with chemotherapy and external beam therapy, survival can be prolonged. Referral to a clinical trial is encouraged because standard therapy is usually inadequate for cure. Primary thyroid lymphomas are treated with chemotherapy and radiation although surgery may be required to alleviate symptoms due to tracheal or esophageal compression. The treatment of thyroid metastases is dependent on the histology and biology of the primary tumor. Some studies have reported long-term survival after resection of an isolated renal cell carcinoma metastasis, whereas no survival benefit was noted in lung cancer patients.

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Cross-reference

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CASE 113

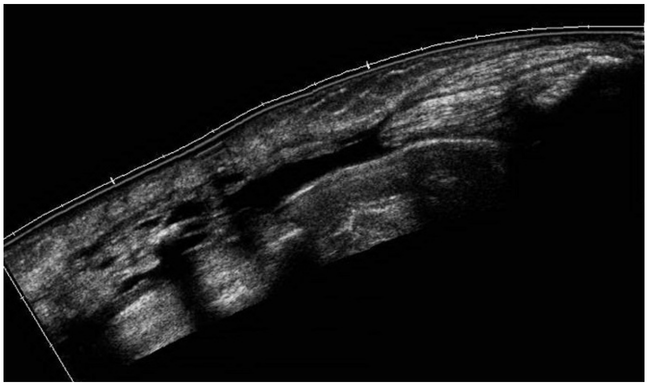

Figure 113-1

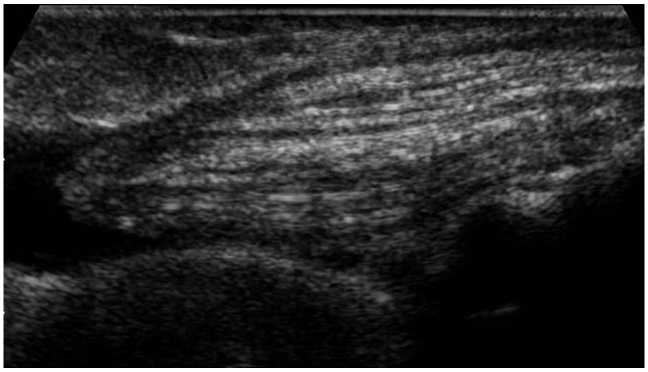

Figure 113-2

HISTORY: A 65-year-old female who fell cannot extend her knee.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Small partial thickness tear of the quadriceps tendon
   B. Rupture of the quadriceps tendon
   C. Extensive partial thickness tear of the quadriceps tendon
   D. Tendinopathy of the quadriceps tendon
2. Concerning the quadriceps tendon, which statement is true?
   A. Certain autoimmune diseases, as well as gout, diabetes, and chronic renal failure increase the risk for quadriceps tendon tear.
   B. The quadriceps tendon consists of the biceps femoris and vastus lateralis, medialis, and intermedius.
   C. It is possible to distinguish quadriceps tendinosis from a partial thickness tear.
   D. Partial thickness quadriceps tendon tears are usually treated surgically.
3. Concerning patellar tendinosis, which statement is true?
   A. Patellar tendinosis is due to repetitive overuse of the knee flexor mechanism.
   B. Patellar tendinosis is a degenerative condition.
   C. The ultrasound finding of patellar tendinosis includes a focal hyperechoic area with disruption of the normal fibrillar pattern in the more distal patellar tendon.
   D. Patellar tendinosis is treated with surgical debridement.
4. Concerning Baker cyst, which statement is true?
   A. A Baker cyst occurs when joint fluid distends a bursa; on ultrasound, the bursa is visualized between the medial head of the gastrocnemius muscle and semitendinosus tendon.
   B. A Baker cyst is an isolated finding and usually not associated with joint abnormalities.
   C. A Baker cyst occurs along the lateral aspect of the popliteal fossa.
   D. On ultrasound, a Baker cyst may appear as a simple or complex fluid collection in the popliteal fossa.

See Supplemental Figures section for additional figures and legends for this case.

CASE 113

Knee Pathology

1. **B.** There is a large gap between the torn quadriceps tendon ends; the gap is filled with fluid (seroma/hemorrhage). The distal end of the torn quadriceps tendon is surrounded by fluid. These findings are indicative of a quadriceps tendon rupture. An extensive partial thickness tear (C) could also be considered as a few attached slips of the tendon could be missed on ultrasound. Inability to actively extend the knee is a physical finding of quadriceps tendon tear.
2. **A.** Certain diseases such as systemic lupus erythematosus, rheumatoid arthritis, gout, diabetes, and chronic renal failure increase the risk for quadriceps tendon tear by weakening the tendon through fatty degeneration, alteration of the collagen structure leading to fibrosis, or microscopic damage to the vascular supply. The rectus femoris, not the biceps femoris, is a part of the quadriceps tendon.
3. **B.** Patellar tendinosis is a degenerative process; histopathologic changes show myxoid degeneration and fibroblastic and vascular proliferation. Patellar tendinosis usually occurs in the proximal tendon, and on ultrasound, a focal hypoechoic area with disruption of the normal fibrillar pattern is seen.
4. **D.** A Baker cyst occurs when joint fluid distends the bursa between the gastrocnemius and semimembranosus tendons. It occurs in the medial popliteal fossa (posterior) and may be simple or complex. If there are septations, internal echoes, or a thick synovium, infection, hemorrhage, or an inflammatory arthritis should be considered. Baker cysts that are bilateral and dissect deep between the gastrocnemius and soleus muscles are more suggestive of an inflammatory arthritis.

Comment

Introduction

There are many different pathologic processes that involve the knee. The quadriceps tendon may rupture or partially tear, the proximal patellar tendon can degenerate, and joint effusions or bursitis can develop due to internal derangements of the knee or systemic diseases. Quadriceps tendon tear can be due to trauma or occur spontaneously. If spontaneous, an underlying systemic disease should be suspected. Tendinosis is caused by repetitive overuse of the knee extension mechanism (volleyball or basketball players). A Baker cyst is most commonly due to osteoarthritis, a meniscal tear, or inflammatory arthropathy of the knee.

Sonographic Findings

Ultrasound is very accurate for diagnosing a complete quadriceps tendon tear. A gap with a variable distance between the torn tendon ends will be visualized (Figs. S113-1 and S113-2). Gentle traction on the patella distracts the torn tendon ends to confirm a complete tear. A partial thickness tear appears as a focal hypoechoic area in the quadriceps tendon. It is not possible to differentiate partial thickness tear from tendinosis unless a distinct defect is noted on ultrasound. Patellar tendinosis usually appears as a focal enlarged, hypoechoic area on ultrasound. A Baker cyst can be simple or complex with septations, debris, and a thick wall. It is very important to visualize the neck of a Baker cyst to confirm the diagnosis because many other cystic lesions can occur around the knee joint and mimic the appearance of a Baker cyst, including meniscal cysts, ganglions, and soft tissue masses such as a myxoid liposarcoma.

Treatment

Partial quadriceps tendon tears are usually managed conservatively. The knee is placed in an extension brace, and gradually, gentle flexion is introduced during physical therapy. Complete quadriceps tendon tears are surgically repaired as soon as possible to achieve optimal functional results. If delayed, the torn tendon ends can retract, making apposition more difficult. Patellar tendinosis can be treated very successfully with physical therapy. In one randomized, controlled trial, no advantage was shown for surgery. A large, painful Baker cyst can be resected, but it is important to determine its cause; magnetic resonance imaging is excellent for diagnosing any underlying derangement in the knee.

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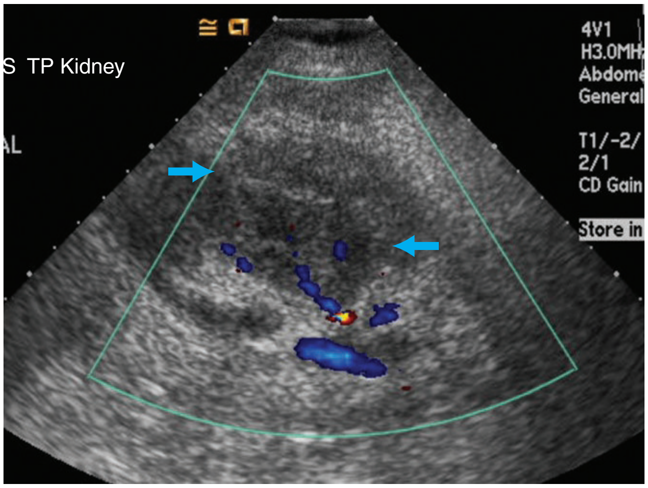

Figure 114-1

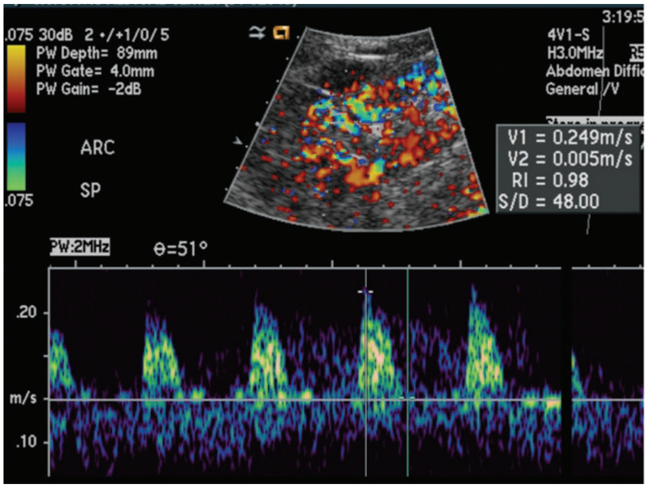

Figure 114-2

HISTORY: A 43-year-old transplant recipient presents with declining urine output and rising serum creatinine after transplant biopsy.

1. Which one of the following would be included in the differential diagnosis for the imaging findings presented in Figures 114-1 and 114-2?
   A. Renal artery stenosis
   B. Renal vein thrombosis
   C. Subcapsular hematoma
   D. Acute tubular necrosis (ATN)

2. In which space is the abnormality located?
   A. Renal cortex
   B. Renal hilum
   C. Perirenal space
   D. Subcapsular space

3. What is the name given to this entity?
   A. Putty kidney
   B. Page kidney
   C. Polycystic kidney
   D. Pancake kidney

4. Characterize the waveform demonstrated in Figure 114-2.
   A. Monophasic venous waveform
   B. High resistance arterial waveform with reversal of diastolic flow
   C. High resistance arterial waveform with absent diastolic flow
   D. High resistance arterial waveform with aliasing

See Supplemental Figures section for additional figures and legends for this case.

CASE 114

Page Kidney

1. **C.** An increased resistive index is nonspecific and can be due to renal vein thrombosis, acute rejection, ATN, or a subcapsular hematoma. Given this fact, there is an echogenic mass surrounding the kidney. These findings are suggestive of renal compression by a subcapsular collection.
2. **D.** The echogenic collection closely follows the renal contour and causes renal compression and is suggestive of a subcapsular location.
3. **B.** Page kidney is the acronym given to renal compression, which occurs with fluid/hematoma accumulation in the contained subcapsular space causing hypertension. Putty kidney is seen with tuberculosis, and pancake kidney is a rare form of horseshoe kidney where the upper poles of the kidneys are fused as well.
4. **C.** A high resistance waveform with sharp upstroke and absent diastolic flow is demonstrated. These findings are suggestive of increased parenchymal pressure and resistance to intrarenal blood flow.

Comment

Differential Diagnosis

Echogenic fluid collections surrounding a kidney may represent a subcapsular or a perirenal/extracapsular hematoma. Collections closely following the renal contour and causing mass effect on the kidney are more likely to be within the contained subcapsular space (Fig. S114-1). These hematomas may be of variable size and appearance over time (Figs. S114-3 and S114-4). Rarely, urinomas may also form in the subcapsular space. Subcapsular hematomas cause compression of the kidney and alter hemodynamics, and as such ischemia develops. Activation of the renin-angiotensin-aldosterone system (RAS) leads to hypertension.

Prior biopsy or other percutaneous interventions, recent lithotripsy, anticoagulation, bleeding from a tumor, and trauma are possible etiologies. Rarely, urinomas may develop in the subcapsular space.

Ultrasound Findings

Subcapsular hematomas tend to follow the same evolution characteristics of hematomas elsewhere. They are echogenic in the acute phase, and differentiation from the distorted renal parenchyma may be difficult. Normal renal architecture may be completely obliterated. Applying color Doppler imaging can help differentiate the vascularized kidney from an avascular hematoma (Fig. S114-1). The hematoma evolves over time to develop cystic areas with echogenic areas secondary to clot lysis and retraction. Late stage hematomas may be entirely liquefied (Figs. S114-3 and S114-4). Spectral Doppler imaging helps depict the sequelae of increased intrarenal pressure. Early compression will show elevated resistive indices and high resistance waveforms with reduced diastolic flow. Continued mass effect will lead to absent flow (Fig. S114-2) and eventually to total reversal of diastolic flow.

Management Options

Management options aim at treating hypertension while preserving renal function. For smaller subcapsular hematomas, medical management with angiotensin-converting enzyme inhibitors and angiotensin receptor blockers may be tried to counter the effects of activation of the RAS system. Surgical treatment options include percutaneous and laparoscopic evacuation of the hematoma. In rare refractory cases, nephrectomy may be required.

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Cross-reference

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Acknowledgment

Special thanks to Pryanka Jha, MD, for preparation of this case.

CASE 115

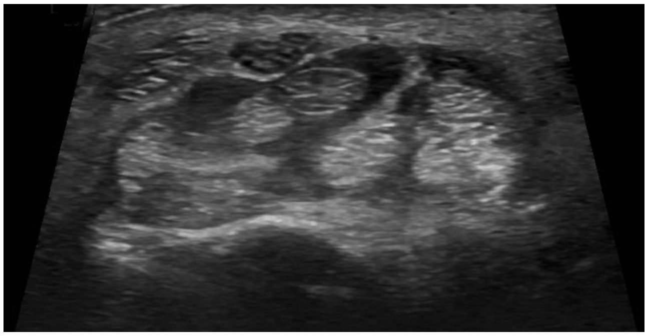

Figure 115-1

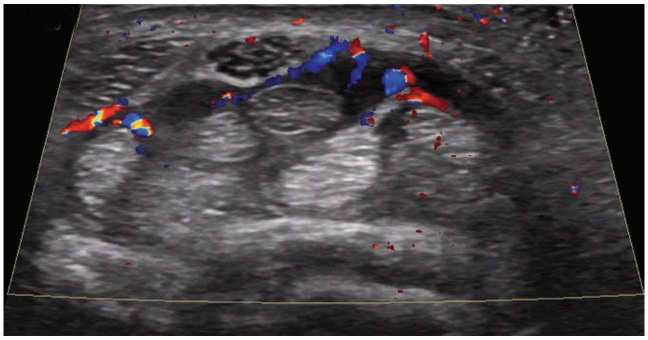

Figure 115-2

HISTORY: A 30-year-old female presents with dorsal wrist pain and swelling.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Ganglion cyst
   B. Giant cell tumor of the tendon sheath
   C. Tenosynovitis
   D. Rheumatoid arthritis

2. Concerning tenosynovitis, which statement is true?
   A. Tenosynovitis is usually caused by an infectious process.
   B. Tenosynovitis is most commonly caused by overuse of the wrist extensor tendons.
   C. Tenosynovitis can be caused by gout or amyloid deposition.
   D. Tenosynovitis is usually post traumatic.

3. Concerning tenosynovitis, which statement is true?
   A. Sonographic findings of tenosynovitis include tendon sheath effusion, thickening, and hypervascularity on color Doppler flow.
   B. Tendon rupture is a common complication of tenosynovitis.
   C. Infectious tenosynovitis is treated conservatively with antibiotics rather than surgery.
   D. There are no sign or symptoms to differentiate idiopathic from infectious tenosynovitis.

4. Concerning tenosynovitis, which statement is true?
   A. De Quervain's disease and trigger digit are types of tendon entrapments.
   B. De Quervain's disease involves the third extensor compartment.
   C. Trigger digit causes catching and popping of the tendon but is not painful.
   D. Trigger digit is best treated surgically.

See Supplemental Figures section for additional figures and legends for this case.

CASE 115

Tenosynovitis

1. **C.** Figures S115-1 and S115-2 show synovial thickening and increased vascularity surrounding the extensor tendons of compartment four consistent with tenosynovitis. Rheumatoid arthritis (D) is a specific cause of tenosynovitis and should be in the differential. A ganglion is complex and cystic on ultrasound, and a giant cell tumor is a solid, focal, hypoechoic lesion that is hypervascular.
2. **C.** Gout and amyloid are two of many causes of tenosynovitis. Though rare, monosodium urate crystals can precipitate in the tendon sheath. Amyloid deposition can occur in the tendon sheath, especially in patients on hemodialysis.
3. **A.** The sonographic findings of tenosynovitis include fluid in the tendon sheath, synovial thickening, and increased flow on color or power Doppler, findings indicative of an inflammatory process. If a patient has fusiform swelling of the digit, marked tenderness along the course of the tendon sheath, and excruciating pain with passive extension of the finger, infectious tenosynovitis should be strongly considered. In addition to these findings, overlying cellulitis and tendon sheath debris (purulent material) may be visualized.
4. **A.** De Quervain's disease and trigger digit are due to mechanical impingement of the tendon as it passes through a narrowed tendon sheath. Pathologic changes are most marked in the pulley and include fibrosis, thickening (rarely nodular), and cyst formation. Both are painful conditions. The abductor pollicis longus and extensor pollicis brevis are affected by De Quervain's disease; these tendons are in the first extensor compartment.

Comment

Introduction

Tenosynovitis is an inflammation of the synovial lining of the tendon sheath. It may be idiopathic (most common), or it may be due to inflammation (i.e., rheumatoid arthritis), crystalline deposition (gout, calcific tenosynovitis, calcium pyrophosphate deposition disease), amyloid deposition (most often in chronic renal failure patients on hemodialysis), or infection. Depending on the etiology, swelling along the involved tendon sheath may be painful (infectious, gout, calcific tenosynovitis) or painless (amyloid deposition). Entrapment syndromes cause pain and locking of the finger as the digit is flexed and extended due to hypertrophy of the pulley.

Sonographic Findings

Sonographic findings of tenosynovitis include tendon sheath effusion, synovial thickening, hypervascularity, and overlying cellulitis if infection is present. If the tendon is inflamed, it has the potential to rupture. Tendinitis appears as tendon thickening and enlargement with loss of the normal fibrillar pattern; tendon rupture appears as a defect between the tendon ends with a variable degree of retraction. It is important to understand the clinical history, physical exam findings, and pertinent laboratory values (uric acid level, for example) to offer the appropriate differential. Sonographic findings of entrapment syndromes include tendon sheath and pulley thickening, effusion, and tendinosis.

Treatment

Depending on the etiology, tenosynovitis may be managed conservatively or surgically. Inflammatory (rheumatoid) arthritis is treated medically; nonsteroidal anti-inflammatory drugs (NSAIDs) and glucocorticoids are used to manage pain and inflammation, and disease-modifying anti-rheumatic drugs (DMARDs) are used as first line therapy for newly diagnosed patients. Biological-response modifiers (tumor necrosis factor–alpha inhibitors) designed to target the inflammatory mediators that cause tissue damage may also be used in combination with DMARDs, making therapy more effective. Gout is treated with NSAIDs and colchicine, but operative intervention may be needed to restore joint and tendon mobility and remove disfiguring, painful tophi. Infectious tenosynovitis is a potential surgical emergency. If symptoms are mild, intravenous antibiotics may be used, but if severe or the patient is unresponsive to antibiotics, surgery is indicated. Trigger finger and De Quervain's disease can be treated successfully with corticosteroid injections, but a small percent of patients may require surgery.

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Cross-reference

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CASE 116

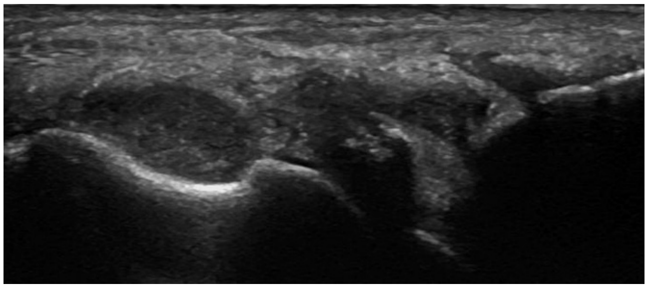

Figure 116-1

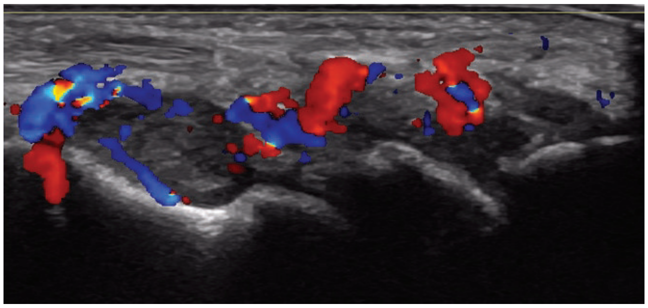

Figure 116-2

HISTORY: A 50-year-old female presents with hand and wrist pain.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Rheumatoid arthritis
   B. Osteoarthritis
   C. Calcium pyrophosphate deposition disease
   D. Seronegative spondyloarthropathy
2. Concerning rheumatoid arthritis, which statement is true?
   A. Rheumatoid arthritis is usually asymmetric in the hands.
   B. Rheumatoid arthritis involves the distal interphalangeal joints.
   C. Bone erosions are marginal and first appear in the "bare areas."
   D. Bony erosions precede synovitis in rheumatoid arthritis.
3. Concerning rheumatoid arthritis, which statement is true?
   A. Rheumatoid arthritis is two to three times more common in men than women and occurs between the third and sixth decades of life.
   B. Rheumatoid arthritis is mediated by the production of various cytokines.
   C. Proliferative synovitis appears as intraarticular hyperechoic tissue on ultrasound.
   D. Color or power Doppler is not sensitive enough to monitor response to treatment.
4. Concerning rheumatoid arthritis, which statement is true?
   A. Radiographs are more sensitive than ultrasound or magnetic resonance imaging (MRI) for detecting bony erosions.
   B. Tenosynovitis is an uncommon finding in rheumatoid arthritis on ultrasound.
   C. Effusions cannot be differentiated from synovitis on ultrasound.
   D. The presence of color or power Doppler flow is indicative of active inflammation and predictive of future erosive bony destruction.

See Supplemental Figures section for additional figures and legends for this case.

CASE 116

Rheumatoid Arthritis

1. **A.** The diagnosis for this case is rheumatoid arthritis, but other seronegative spondyloarthropathies (D) (such as psoriatic arthritis or Reiter syndrome) are also in the differential diagnosis. Distal involvement of the hands and feet, bony proliferation, and entheseal involvement help to differentiate these two diseases.
2. **C.** Rheumatoid arthritis is a symmetric bilateral disease though unilateral carpal involvement may occur. Synovitis precedes bony erosions that first appear in the "bare areas." At these sites there is no protective cartilage and the inflamed synovial tissue destroys the bone. Rheumatoid arthritis involves the radiocarpal, distal radioulnar, mid-carpal, metacarpophalangeal, and proximal intraphalangeal joints. If more distal involvement is observed, a seronegative spondyloarthropathy should be considered.
3. **B.** Tumor necrosis factor–alpha and interleukin 1 are two known inflammatory mediators of rheumatoid arthritis. Biologic agents target these inflammatory mediators and are used to treat patients with rheumatoid arthritis.
4. **D.** The presence of color or power Doppler is an important finding and indicates synovitis, active inflammation, and disease progression. This finding would be used by the rheumatologist to modify drug therapy.

Comment

Introduction

Rheumatoid arthritis is an autoimmune disease that is more common in women than men with an onset between the third and sixth decades. Patients present with hand/wrist swelling and pain. Clinical history, physical examination findings, radiographs, laboratory tests, ultrasound, and MRI are very useful in narrowing the differential diagnosis. Ultrasound and MRI are more sensitive for detecting bony erosions than radiographs. Both also can evaluate for synovitis and effusions, monitor disease activity, and predict relapse and disease progression.

Sonographic Findings

The gray scale ultrasound findings for rheumatoid arthritis include bony erosions around joints, synovitis (hypoechoic thickening of the synovium with increased color Doppler flow), and effusion (Figs. S116-1 and S116-2). It is important to remember that bony erosions only occur when synovitis is present. Most erosions occur on the metacarpal heads but may occur at the phalangeal bases and in the carpal bones. Erosions of the metacarpal head usually occur on the ulnar or radial aspect of the joint, and those involving the interphalangeal joints only occur on the radial or ulnar side. It is also very important to evaluate for synovitis with color or power Doppler, which provides information regarding disease activity and is predictive of future bony erosive destruction. Rheumatoid arthritis can also involve the flexor or extensor tendon sheaths; tenosynovitis appears as hypoechoic thickening and increased color Doppler flow.

Treatment

The key concept in the treatment of rheumatoid arthritis is suppression of the inflammatory process as early as possible in the course of the disease. Treatment of rheumatoid arthritis has evolved over the years with the advent of disease-modifying antirheumatic drugs (DMARDs) such as methotrexate and hydroxychloroquine and biologic agents (tumor necrosis and alpha inhibitors) such as infliximab. While nonsteroidal anti-inflammatory drugs and glucocorticoids have traditionally been first line drugs to decrease pain and swelling, DMARDs slow clinical and radiographic disease progression. Biologic agents target the inflammatory mediators that cause soft tissue and bony destruction and are being used in patients who don't respond to DMARDs. Studies are also being conducted using biologic agents early in the disease course or in combination with DMARDs.

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CASE 117

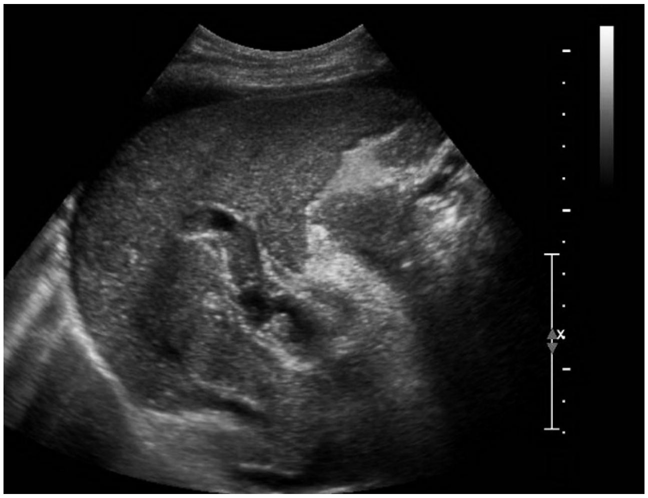

Figure 117-1

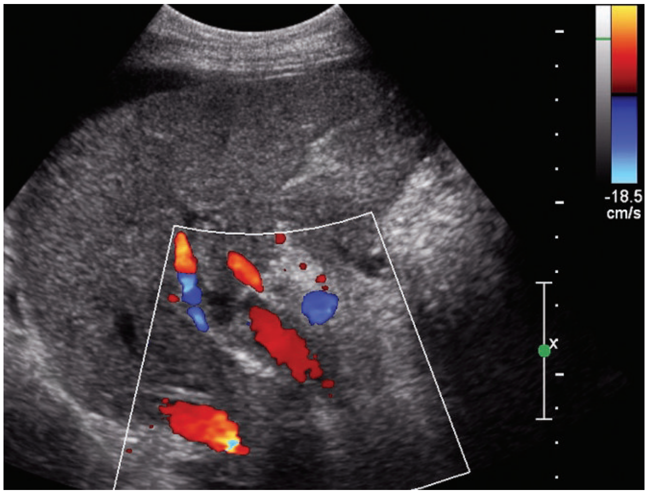

Figure 117-2

HISTORY: A 44-year-old male presents with a history of gastric and prostate carcinoma.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Hepatic vein thrombosis
   B. Cavernous transformation
   C. Occlusive portal vein thrombosis
   D. Non-occlusive portal vein thrombosis

2. Which of the following is true regarding portal vein thrombosis?
   A. Portal vein thrombosis may occur because of a hypercoagulable state.
   B. Portal vein thrombosis is always isoechoic to liver.
   C. Lack of detectable flow on color Doppler indicates portal vein thrombosis.
   D. Portal vein thrombosis occurs in 1% to 2% of patients who develop cirrhosis and portal hypertension.

3. Which of the following is true regarding portal vein thrombosis?
   A. In Figure 117-2, blood flow on color Doppler in the main portal vein and right portal vein branch is hepatofugal.
   B. Very slow flow in the portal vein due to cirrhosis can simulate the appearance of portal vein thrombosis on color Doppler.
   C. Power Doppler is a useful technique to determine direction of flow in the main portal vein.
   D. Cholangiocarcinoma has a tendency to invade the portal vein.

4. Which of the following is true regarding portal vein thrombosis?
   A. It is possible to distinguish benign from malignant tumor thrombus in the portal vein with gray scale ultrasound.
   B. Color Doppler is not useful to distinguish benign from malignant tumor thrombus in the portal vein.
   C. The detection of a venous waveform in portal vein thrombosis indicates malignant tumor thrombus.
   D. The detection of an arterial waveform in portal vein thrombus indicates malignant tumor thrombus.

See Supplemental Figures section for additional figures and legends for this case.

CASE 117

Portal Vein Thrombosis

1. **D.** There is an isoechoic thrombus in the main portal vein and right portal vein branch (arrow, Fig. S117-1) on gray scale. Figure S117-2 demonstrates color Doppler flow around the thrombus (arrow), indicating it is not occlusive. D might be considered except color Doppler flow is detected in the portal vein.
2. **A.** Portal vein thrombosis has several etiologies. It may be due to a hypercoagulable state (antiphospholipid antibody syndrome, myeloproliferative diseases, oral contraceptives, polycythemia vera, protein S/C deficiency, and factor 5 Leiden mutation), an inflammatory process (inflammatory bowel disease, pancreatitis), infection (appendicitis, diverticulitis), as a complication of a procedure or surgical intervention (chemoembolization, partial hepatectomy, liver transplantation, stent graft) or may be due to cirrhosis, trauma, or tumor (most commonly, hepatocellular carcinoma).
3. **B.** Portal vein flow may be too slow to detect on color Doppler although this is unusual. In such cases, color Doppler parameters should be optimized; i.e., a lower frequency transducer in the obese patient and a lower velocity scale may be required to detect slow flow. If flow cannot be demonstrated and no thrombus is visible on the gray scale image, magnetic resonance imaging or computed tomography may be required to exclude thrombosis.
4. **D.** If an arterial signal can be detected, it is diagnostic of malignant portal vein thrombosis. The arterial signal indicates neovascularity; the tumor drags its blood supply with it as it invades the portal vein. When seen, the direction of arterial flow is usually hepatofugal. However, arterial flow cannot always be detected in malignant thrombus.

Comment

Introduction

There are many other causes of portal vein thrombosis. It may be due to a hypercoagulable state, an inflammatory disease, infection, or as a complication of a procedure or surgical intervention. Portal vein thrombosis also occurs in approximately 1% to 25% of the cirrhotics depending on the severity of the disease. It is thought to be due in part to a coagulation defect and slow portal vein flow.

Sonographic Findings

Portal vein thrombus can be echogenic, isoechoic, or anechoic and completely or partially obstruct the portal vein. On color Doppler, no flow will be detected if the portal vein is completely thrombosed but can be detected if the portal vein is only partially thrombosed (arrow, Fig. S117-2). Once thrombus is diagnosed, it is important to determine if it is malignant or benign. On gray scale ultrasound, a dilated, expanded portal vein is suggestive of tumor thrombus because bland thrombus does not expand the portal vein. Color Doppler is also helpful in differentiating benign from malignant thrombus. When hepatocellular carcinoma invades the portal venous system, it drags its arterial supply with it and grows down the portal vein. If color Doppler flow or an arterial signal is detected in the thrombus, it is diagnostic.

Treatment

Portal vein thrombosis negatively affects patient outcome because of the development of portal hypertension that increases the risk for variceal bleeding and also because of the resultant effects of decreased liver perfusion that may contribute to liver decompensation. If the thrombus extends into the superior mesenteric vein, the complexities of performing a liver transplant rise or the patient may lose his or her eligibility for a transplant, depending on the extent of the thrombosis. Treatment of portal vein thrombosis is controversial. Various reported strategies include transjugular intrahepatic portosystemic shunt, thrombectomy, or anticoagulation. In one recent large series, anticoagulation was successful with complete resolution of portal vein thrombus in 39% of patients and partial response in 43%. The thrombus was stable and did not progress in the remainder of patients.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 75–80.

CASE 118

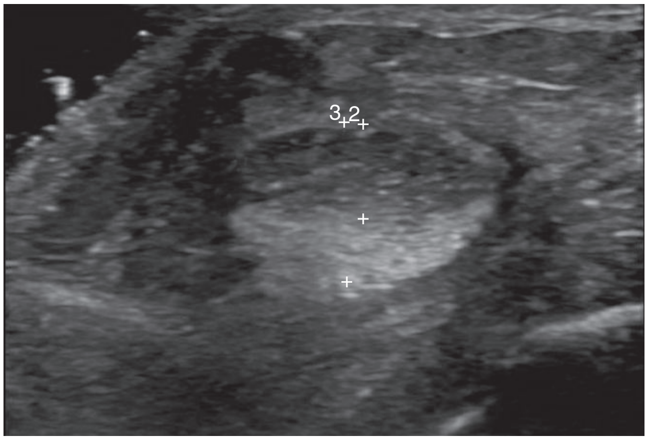

Figure 118-1

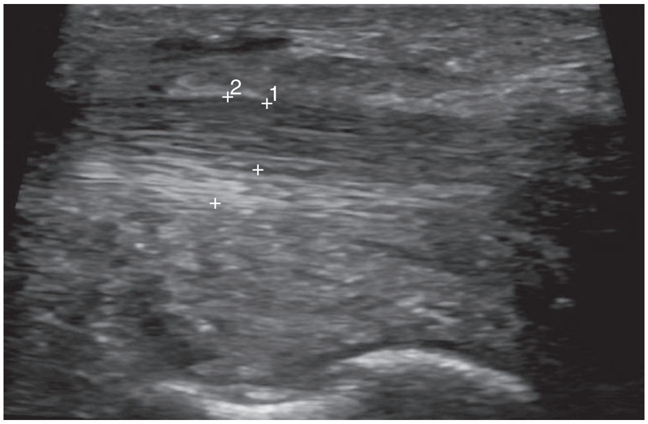

Figure 118-2

HISTORY: A 35-year-old female presents with medial ankle pain.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Tibialis posterior tendon rupture
   B. Intrasubstance tear of the tibialis posterior tendon
   C. Tendinopathy of the tibialis posterior tendon
   D. Calcific tendinopathy of the tibialis posterior tendon

2. Concerning the tibialis posterior tendon, which statement is true?
   A. The tibialis posterior plantar flexes and everts the foot.
   B. There is a zone of hypovascularity within the tibialis posterior tendon that predisposes to degenerative changes in the tendon.
   C. Tibialis posterior tendon dysfunction occurs more commonly in men.
   D. The tibialis posterior tendon dysfunction is inflammatory in nature.

3. Concerning the tibialis posterior or peroneal tendons, which statement is true?
   A. Tibialis posterior rupture usually occurs near the tendon's insertion.
   B. Patients with posterior tibialis or peroneal tendon disease present with pain superior to the medial or lateral malleolus, swelling, and tenderness.
   C. The peroneal muscles plantar flex and invert the foot.
   D. On ultrasound, tenosynovitis of either the tibialis posterior or peroneal tendons appears as a thickened tendon with a hypoechoic appearance.

4. Concerning the peroneal tendons, which statement is true?
   A. Increased flow on color or power Doppler is not present in tendinopathy or tenosynovitis.
   B. Peroneal tendon subluxation is associated with inferior retinacular insufficiency or injury and occurs when one or both tendons are displaced from the retromalleolar groove.
   C. On ultrasound, the split peroneus brevis is seen as two distinct halves with the peroneus longus tendon insinuated in between the split tendon.
   D. The peroneal tendons can sublux and change position within the retromalleolar groove but only when the tendons are intact.

See Supplemental Figures section for additional figures and legends for this case.

CASE 118

Ultrasound of Ankle Disease

1. **B.** The tibialis posterior has a partial thickness, intrasubstance tear; there are longitudinal hypoechoic defects within the tendon. Tendinopathy (C) is also present; a part of the tendon has lost its normal echogenic fibrillar pattern and is enlarged and hypoechoic.
2. **B.** There is a zone of hypovascularity within the tendon, it is immediately distal to the medial malleolus, and it predisposes to tendon degeneration, not inflammation. Tendinopathy can progress to a partial and ultimately a full thickness tear. The tibialis posterior plantar flexes and inverts the foot.
3. **A.** Rupture usually occurs near the tendon's insertion; it cannot be followed to the navicular bone. Instead, a mass-like area of hypoechoic tissue (granulation tissue) with increased color Doppler flow is seen at that level. Swelling and tenderness from ankle tendon disease occurs below the medial or lateral malleolus (i.e., inframalleolar).
4. **D.** The peroneus brevis is located between the peroneus longus and retromalleolar groove and may split (tear) longitudinally due to insufficiency of the superior peroneal retinaculum, crowding of the retromalleolar groove, and ligamentous injuries. The two halves of the tendon are easily seen on ultrasound. Peroneal tendon subluxation is also associated with superior retinacular insufficiency or injury; the intact peroneal tendons can change their anatomic position relative to each other (type A), but in type B, the peroneus longus subluxes through a split (tear) in the peroneus brevis.

Comment

Introduction

The ankle tendons are prone to injury from acute trauma, repetitive microtrauma, sports-related activities (walking, running, dancing), and anatomic variants (low-lying peroneus brevis muscle, accessory peroneus quartus muscle, shallow fibular groove). However, elderly women, the obese, diabetics, and patients with lupus, gout, or inflammatory arthritis are also predisposed to develop ankle tendon disease.

Sonographic Findings

On ultrasound, tibialis posterior tenosynovitis appears as synovial thickening, sheath fluid, and increased flow on color Doppler (Figs. S118-1 and S118-2). Tendinopathy causes the tendon to lose its normal echogenic fibrillar pattern; it becomes thickened and hypoechoic and has increased flow on color Doppler. Most tears are partial and intrasubstance and appear as hypoechoic linear defects within the tendon but may extend to the surface. The peroneal tendons may also become tendinotic or tear. A peroneus brevis tear appears as a longitudinal split; the peroneus longus tendon then insinuates itself in between the torn tendon halves. Isolated peroneus longus tears are unusual; partial tears and ruptures appear similar to the changes described for the tibialis posterior on ultrasound. Peroneal tendon subluxation can best be demonstrated dynamically on ultrasound by placing the transducer over the tendons and having the patient evert and dorsiflex her foot. The tendons may switch locations within the tendon sheath (intrasheath subluxation) or one or both may dislocate from the retromalleolar groove.

Treatment

Traumatic rupture of the tibialis posterior is treated with surgery and primary repair. Tendinopathy is treated conservatively with a boot or cast and nonsteroidal anti-inflammatory drugs (NSAIDs). Physical therapy helps to improve range of motion and muscle strength. If conservative therapy fails, tenosynovectomy and debridement or repair of a tear should be considered. More advanced changes may require tendon transfer. Peroneal tendinopathy is also treated conservatively with NSAIDs, heel wedges, physical therapy, and possibly immobilization. If conservative therapy fails, tenosynovectomy is performed with debridement or repair of a tendon tear. If the tear is large, tenodesis is performed between the peroneal longus and brevis. If tendon subluxation is present, the superior peroneal retinaculum is repaired. If the cause is a shallow fibular groove, the groove is deepened.

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Cross-reference

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CASE 119

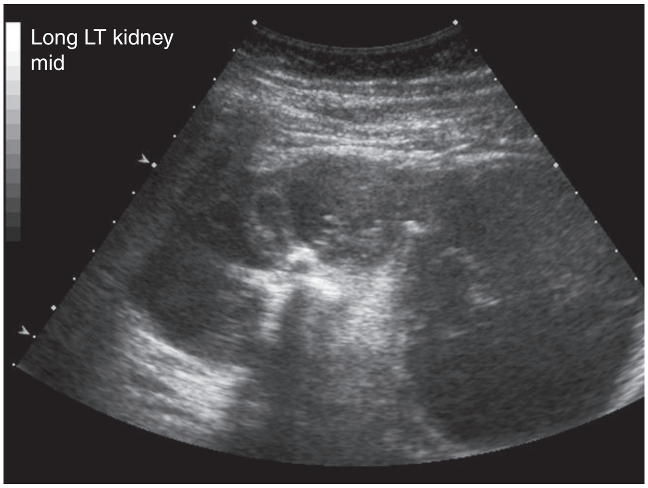

Figure 119-1

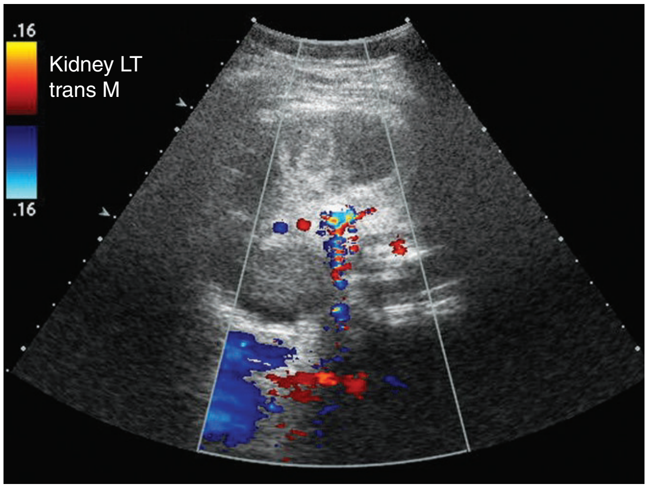

Figure 119-2

HISTORY: A 27-year-old presents with increasing left flank pain.

1. Which one of the following would be included in the differential diagnosis of the left kidney in Figures 119-1 and 119-2? (Choose one.)
   A. Renal abscess
   B. Renal cell carcinoma (RCC)
   C. Xanthogranulomatous pyelonephritis (XGP)
   D. Lymphoma
2. Which one of the following is one of the two most common infectious organisms of XGP?
   A. *Bacteroides*
   B. *Clostridium perfringens*
   C. *Klebsiella*
   D. *Proteus mirabilis*
3. Sonographic features of diffuse XGP include all of the following EXCEPT which one of the listed features?
   A. Multiple hypoechoic areas within the kidney
   B. Renal enlargement
   C. Preservation of the reniform shape
   D. Preservation of the corticomedullary junction
4. Concerning XGP, all of the following are true statements EXCEPT:
   A. XGP is usually associated with nephrolithiasis.
   B. There is usually obstructed uropathy.
   C. XGP only involves the entire kidney and not segments.
   D. For diffuse XGP the treatment of choice is nephrectomy.

See Supplemental Figures section for additional figures and legends for this case.

CASE 119

Xanthogranulomatous Pyelonephritis

1. **C.** There is a central echogenicity with acoustic shadowing consistent with staghorn calculi. There is an abnormal hypoechoic appearance to the rest of the kidney. A renal abscess is considered within the differential and is a variation of this abnormality and could be considered a correct answer. RCC and lymphoma seem less likely.
2. **D.** *P. mirabilis* and *Escherichia coli* are the two most common organisms associated with XGP.
3. **D.** The corticomedullary junction is lost, and usually there is only a remnant of thin parenchyma. There is enlarged hypoechoic kidney.
4. **C.** There are various forms of XGP. There may be either segmental XGP where there is involvement of a single calyx or focal XGP, which mimics an abscess and may be difficult to exclude from a tumor. All other choices are true. For the diffuse form of XGP, nephrectomy is often required.

Comment

Differential Diagnosis

The differential diagnosis for renal enlargement is extensive. Certainly any diffuse infection, diffuse infiltrated mass, or renal vein thrombosis should be considered. However, when there is associated echogenic focus with acoustic shadowing (a central stone), the differential is much smaller. Hydronephrosis, pyelonephrosis, or a more chronic problem such as XGP would be considered most likely.

Ultrasound Findings

Sonographic features of diffuse XGP include renal enlargement with maintenance of the reniform shape. There is lack of the corticomedullary differentiation with a very thin renal cortex. Multiple hypoechoic areas are identified within the kidney. Usually these are fairly uniform. In this case, there is a larger hypoechoic region identified in the lower pole of the left kidney. There is destruction of the renal parenchyma with replacement of lipid-laden macrophages (xanthoma cells). Common sonographic features of XGP are diffuse hydronephrotic appearance with hypoechoic parenchyma and a central stone (Figs. S119-1 and S119-2). There may also be segmental or focal forms of XGP, which are rarer. Computed tomography can be used for further imaging (Fig. S119-3).

Prognosis/Management

If there is focal XGP, this can be treated by partial nephrectomy or focal drainage and nephrolithotomy. However, for more diffuse XGP, nephrectomy is often necessary. XGP is a chronic inflammatory disease associated with indolent bacterial infection. The process begins in the renal pelvis and extends into both the medulla and cortex and results in destruction of the medulla with a thin residual cortex. XGP typically occurs in middle-aged women. In our case, the patient presented with flank pain. This is often associated with malaise, fever, and chills. There may be dysuria. *E. coli* or *P. mirabilis* are the most common organisms associated with XGP. Staghorn calculi are usually present in the majority of cases (Fig. S119-3).

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 126–130.

CASE 120

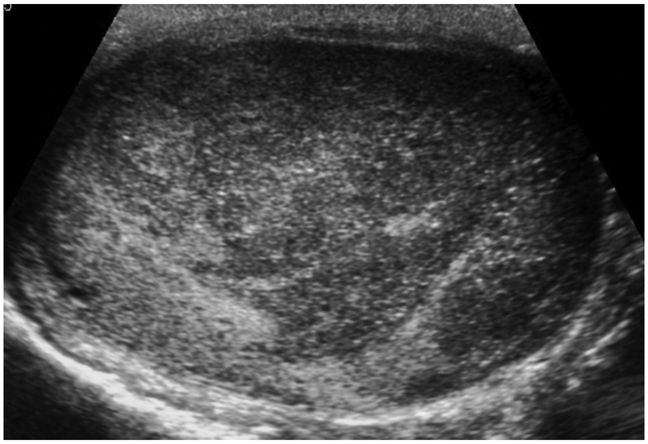

Figure 120-1

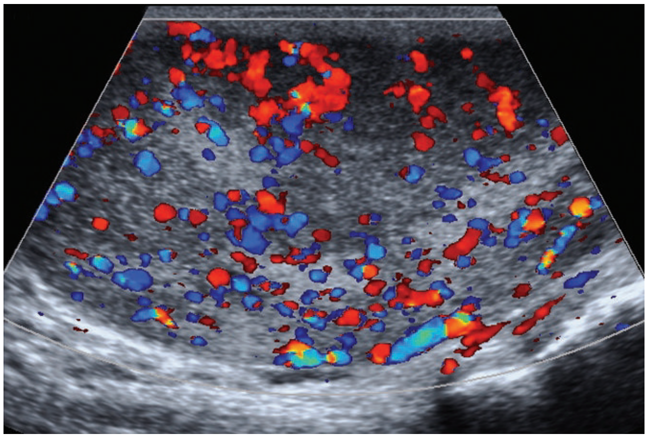

Figure 120-2

HISTORY: A 68-year-old man presents with a painless testicular mass noticed for 1 month.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Orchitis
   B. Germ cell tumor
   C. Lymphoma
   D. Metastasis

2. Which of the following is true regarding testicular lymphoma?
   A. Testicular lymphoma is a Hodgkin lymphoma.
   B. Primary testicular lymphoma is more common than secondary testicular lymphoma.
   C. On ultrasound, testicular lymphoma can appear as one or more solid, hyperechoic masses.
   D. A chronic or granulomatous epididymo-orchitis or vasculitis can appear similar to lymphoma on ultrasound.

3. Which of the following is true regarding gonadal stromal tumors?
   A. Gonadal stromal tumors are benign.
   B. Gonadal stromal tumors are more common in adults than children.
   C. Gonadal stromal tumors are hormonally active in adults.
   D. Gonadal stromal tumors are a subtype of germ cell tumor.

4. Which of the following is true regarding gonadal stromal tumors?
   A. On ultrasound, gonadal stromal tumors are hypoechoic and homogeneous.
   B. Leydig cell tumors are unilateral.
   C. Malignant Leydig cell tumors can be differentiated from benign tumors by their sonographic appearance.
   D. Large-cell calcifying Sertoli cell tumor of the testis is a rare subtype of Sertoli cell tumor that occurs in adults.

See Supplemental Figures section for additional figures and legends for this case.

CASE 120

Nonseminomatous Germ Cell Tumors

1. **C.** There is a large, solid, hypoechoic mass in the testis (arrow, Fig. S120-1) that is hypervascular on color Doppler (Fig. S120-2). Given the patient's age and lack of symptoms, lymphoma is the correct diagnosis. Lymphoma is the most common testicular tumor in men greater than or equal to 60 years. Leukemia, stromal tumor, granulomatous epididymo-orchitis, vasculitis, and metastatic disease (D) (in the proper clinical setting) are in the differential.
2. **D.** Lymphoma is an aggressive tumor that can occur bilaterally, extend into the epididymis, and simulate the appearance of granulomatous epididymo-orchitis (tuberculosis, sarcoidosis). On ultrasound, the testes may be diffusely hypoechoic or hypoechoic nodules may be present; the epididymis may be heterogeneously enlarged or have hypoechoic nodules, similar to lymphoma. However, granulomatous epididymo-orchitis is less vascular, and mild tenderness may be present, unlike in lymphoma. Clinical history is also helpful to differentiate between the two. Focal vasculitis may also appear as a hypoechoic lesion with internal vascularity and simulate a neoplasm.
3. **C.** Leydig cell and Sertoli cell tumors are stromal tumors (nongerm cell). They arise from the sex cords (Sertoli cells) or interstitial stroma (Leydig cells). They account for 1% to 3% of tumors. Leydig cell tumors cause gynecomastia in 20% to 40% of adults due to estrogen secretion. Sertoli cell tumors rarely cause gynecomastia.
4. **A.** These tumors tend to be small, hypoechoic, and homogeneous. However, they can enlarge and undergo hemorrhage and necrosis and become heterogeneous; it is not possible to differentiate it from a germ cell tumor or lymphoma based on sonographic findings alone.

Comment

Introduction

Germ cell tumors usually occur in men under 50 years of age whereas lymphoma is the most common tumor in men greater than or equal to 60 years. Testicular lymphoma is a non-Hodgkin lymphoma (diffuse large B cell) and high grade. It represents 5% of testicular neoplasms. Secondary testicular lymphoma is far more common than primary lymphoma. Gonadal stromal tumors can occur at any age though more occur in the pediatric population. However, they should be considered in the differential of a testicular mass in an adult. Most stromal tumors are unilateral though a small percent are bilateral. Most are asymptomatic. Ten percent are malignant.

Sonographic Findings

Testicular lymphoma appears as one or more solid, hypoechoic, hypervascular masses or as diffuse enlargement of the testes (Figs. S120-1 and S120-2). It can be unilateral or bilateral (40%). Because it is aggressive, it can extend into the epididymis or spermatic cord but this is uncommon. Gonadal stromal tumors tend to be small, hypoechoic, and homogeneous. Peripheral blood flow with little internal flow has been reported as a characteristic finding at color Doppler in one small series. Gonadal stromal tumors can enlarge and undergo hemorrhage and necrosis to become heterogeneous. Malignant Leydig cell tumors tend to be larger, have ill-defined margins, and spread to extratesticular structures. It is not possible to differentiate a benign from a malignant tumor with ultrasound.

Treatment

If testicular lymphoma is suspected, a positron emission tomography–computed tomography (PET-CT), bone marrow biopsy, and chest/abdomen/pelvic computed tomography should be obtained for staging and to identify a biopsy site. Primary testicular lymphoma has a worse prognosis than secondary lymphoma; patients usually develop widespread dissemination including to the central nervous system within the first 2 years. Five-year survival is 12% to 35%, with a median survival of 13 months. After orchiectomy, patients are treated with chemotherapy (CHOP), rituximab, prophylactic intrathecal methotrexate, and radiation to the testes. Although 10% gonadal stromal tumors are malignant, if a lesion is small and a Leydig cell tumor is suspected, an excisional biopsy through an inguinal approach can be performed. If the frozen section is benign, the lesion is locally resected. Such patients have an excellent prognosis.

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 155-158, 162, 164, 165, 172.

CASE 121

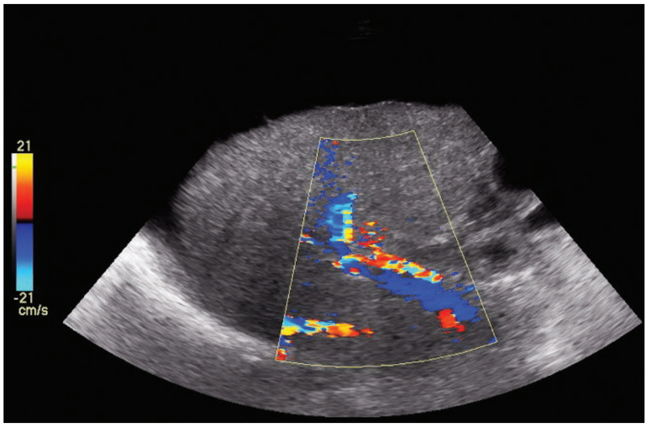

Figure 121-1

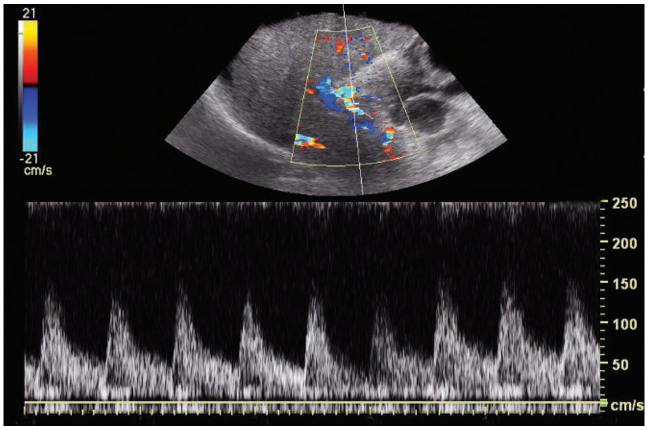

Figure 121-2

HISTORY: A 65-year-old alcoholic male presents with refractory ascites.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Hepatopetal flow in the main portal vein
   B. Hepatofugal flow in the main portal vein
   C. Main portal vein thrombosis
   D. Portal hypertension
2. Which of the following is true regarding portal hypertension?
   A. Cirrhosis is the most important cause of portal hypertension in the Western world.
   B. An arterioportal fistula causes increased resistance to blood flow and subsequent portal hypertension.
   C. Portal or splenic vein thrombosis is an intrahepatic cause of portal hypertension.
   D. Alcoholic cirrhosis is a postsinusoidal cause of portal hypertension.
3. Which of the following is true regarding portal hypertension?
   A. On ultrasound in the setting of portal hypertension, the hepatic artery is diminished in size due to scarring and fibrosis.
   B. Absence of color Doppler flow in a portal vein on ultrasound indicates thrombosis.
   C. On ultrasound, the hepatic vein waveforms lose their normal pulsatility in the setting of cirrhosis.
   D. Portal vein thrombosis is a common finding on ultrasound in the setting of portal hypertension.
4. Which of the following is true regarding portal hypertension?
   A. Portosystemic collaterals are a direct sign of portal hypertension.
   B. Portosystemic collaterals develop only from normally open channels.
   C. A splenorenal shunt develops from a normally open channel.
   D. Ascites and splenomegaly are direct signs of portal hypertension.

See Supplemental Figures section for additional figures and legends for this case.

CASE 121

Portal Hypertension

1. **B.** The ultrasound image shows hepatofugal flow (arrow, Fig. S121-1) in the main portal vein, indicating portal hypertension (D). By convention, hepatofugal flow on color Doppler is blue (flow is away from the transducer), and hepatopetal flow is red (flow is toward the transducer). When portal venous flow reverses, the hepatic artery compensates and increases flow into the liver as noted by the aliasing within the artery (arrow, Fig. S121-2).
2. **A.** The causes of portal hypertension are classified based on whether there is an increase in resistance or increase in flow. Increased resistance is classified as prehepatic, intrahepatic, and posthepatic; the intrahepatic category is further classified as presinusoidal, sinusoidal, and postsinusoidal. Splenic vein thrombosis causes prehepatic portal hypertension, cirrhosis causes intrahepatic portal hypertension, and Budd-Chiari causes postsinusoidal portal hypertension. Primary increased flow is an unusual cause of portal hypertension; one such cause is an arterioportal fistula.
3. **C.** The hepatic vein waveforms are monophasic because scarring/fibrosis from cirrhosis causes hepatic vein stenosis, which isolates the veins from right atrial pressures that normally cause the pulsatility.
4. **A.** Portosystemic collaterals are direct signs of portal hypertension. Collaterals may develop in normally existing veins (gastric (coronary), short gastric, and superior and inferior mesenteric vein branches) or from normally closed channels (paraumbilical vein and splenorenal shunt). Ascites and splenomegaly are indirect signs of portal hypertension.

Comment

Introduction

Portal pressure equals flow × resistance to flow. If flow or resistance to flow increases, portal hypertension develops. Alcoholic cirrhosis is a common cause of portal hypertension and causes architectural distortion from fibrosis and regenerative nodules and sinusoidal compression from hepatocyte enlargement due to alcohol-induced protein and fat deposition, all of which increase resistance.

Sonographic Findings

On color Doppler, hepatofugal flow in the main portal vein or right or left branches is a direct sign of portal hypertension. Occasionally, portal venous flow is temporally hepatopetal and then hepatofugal (bidirectional); hepatofugal flow will develop over time. Portosystemic collaterals are direct evidence of portal hypertension. The left gastric vein normally flows toward the portal vein but reverses flow direction in portal hypertension and drains into esophageal/paraesophageal vessels, producing esophageal varices. This is best seen on color Doppler using a subcostal sagittal approach centered over the left lobe. The short gastric veins normally drain into the splenic vein near the hilum but can reverse flow direction toward the gastric fundus, causing gastric fundal varices. Short gastric collaterals are best seen from the left upper quadrant by orienting the transducer to visualize the spleen and gastric fundus. A recanalized paraumbilical vein is best visualized in the sagittal plane at the level of the umbilical segment of the left portal vein; it runs in the inferior aspect of the ligamentum teres. A splenorenal shunt can be visualized from the left upper quadrant by orienting the transducer in a coronal plane to visualize the splenic and left renal vein.

Treatment

Portal hypertension can lead to variceal bleeding, ascites, and splenomegaly. Therapy for a variceal bleed in a Child class A/B patient includes variceal band ligation and nonselective beta blockers that lower cardiac output and cause splanchnic vasoconstriction, reducing portal and collateral blood flow. Ten to fifteen percent of patients fail therapy and require a stent graft. Recent trials have suggested that stent grafts could be used as first line therapy for active variceal bleeding in Child class B/C patients. A recent study also suggested that stent grafts could be used as first line therapy in patients with refractory ascites.

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Cross-reference

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CASE 122

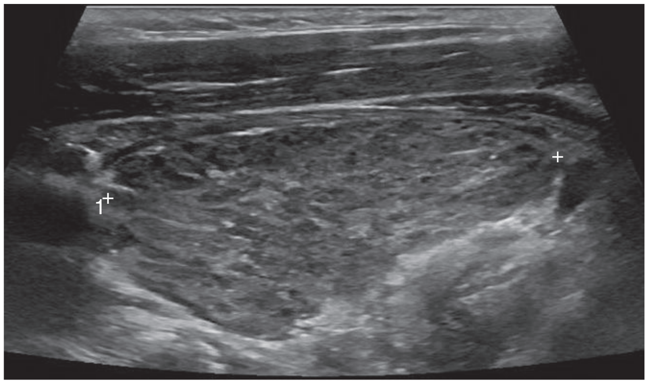

Figure 122-1

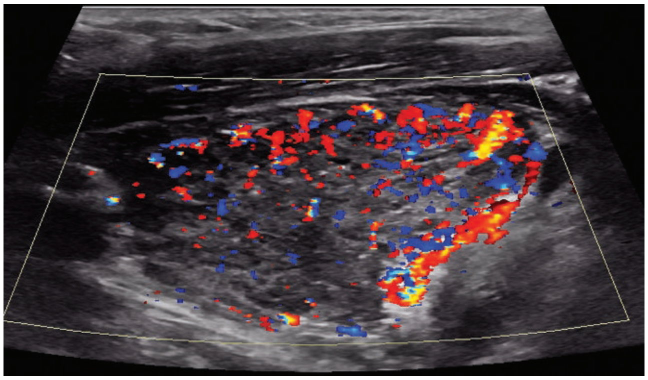

Figure 122-2

HISTORY: A 30-year-old female recently diagnosed with hypothyroidism has a firm thyroid on palpation.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Graves' disease
   B. Hashimoto's thyroiditis
   C. Benign thyroid nodule
   D. Malignant thyroid nodule
2. Which of the following is true regarding Hashimoto's thyroiditis?
   A. Hashimoto's thyroiditis is characterized by lymphoplasmacytic infiltration of the thyroid gland.
   B. Hashimoto's thyroiditis is an autoimmune disease that is common in middle-aged men.
   C. On ultrasound, the thyroid gland is small in Hashimoto's thyroiditis.
   D. Hashimoto's thyroiditis has no association with papillary thyroid carcinoma.
3. Which of the following is true regarding Graves' disease?
   A. Graves' disease is an autoimmune disease and is more common in men.
   B. On ultrasound, the thyroid gland is small, homogeneous.
   C. Lymphocytic infiltration occurs in the thyroid gland due to circulating immunoglobulin G antibodies.
   D. On ultrasound, the thyroid gland is hypovascular.
4. Which of the following is true regarding subacute thyroiditis?
   A. Subacute thyroiditis is an autoimmune disease and more common in middle-aged women.
   B. Patients are usually asymptomatic but have an enlarged thyroid gland on physical examination.
   C. Patients are hyperthyroid initially but become hypothyroid during the course of the disease.
   D. On ultrasound in the acute stage, the thyroid is focally or diffusely enlarged. Areas involved are hypoechoic, heterogeneous, and ill-defined with increased vascularity on color Doppler.

See Supplemental Figures section for additional figures and legends for this case.

CASE 122

Autoimmune Thyroiditis, Subacute Thyroiditis

1. **B.** Figure S122-1 shows innumerable hypoechoic micronodules with echogenic septae throughout both lobes of the thyroid, consistent with Hashimoto's thyroiditis. The thyroid gland is also diffusely hypervascular (Fig. S122-2), an ultrasound finding in both Hashimoto's thyroiditis and Graves' disease (A), but the patient is hypothyroid. In Graves' disease, the thyroid gland is enlarged, heterogeneous, and hypoechoic though changes can be subtle. Intraparenchymal and inferior thyroidal peak systolic velocities have been used to differentiate Graves' disease from Hashimoto's thyroiditis; velocities are very elevated in Graves' disease compared with Hashimoto's thyroiditis.

2. **A.** Lymphocytic infiltration leads to the formation of lymphoid follicles that appear as hypoechoic micronodules on ultrasound. Lymphocytic infiltration causes gland fibrosis, apoptosis (cell death), and hypothyroidism. The prevalence of papillary thyroid cancer is higher in patients with Hashimoto's thyroiditis compared to patients without Hashimoto's thyroiditis.

3. **C.** The antibodies act against the thyroid hormone stimulating receptor, causing increased synthesis and release of thyroid hormone and resulting in hyperthyroidism. On ultrasound, the gland is enlarged, heterogeneous, and hypervascular.

4. **C.** Subacute thyroiditis is a destructive process that causes destruction of thyroid follicles, subsequent release of thyroid hormone, and hyperthyroidism. However, once the follicles are depleted, the patient becomes hypothyroid and, with recovery, gradually becomes euthyroid by 1 year. Patients present with fever, neck pain, fatigue, and an elevated sedimentation rate.

Comment

Introduction

Hashimoto's thyroiditis and Graves' disease have many features in common; both are autoimmune diseases that are much more common in middle-aged women, and both share common auto-antibodies (antithyroid peroxidase and antithyroglobulin), but each has an opposite outcome. Subacute thyroiditis is a post viral inflammatory disorder commonly associated with adenovirus, coxsackie, and Epstein-Barr virus. It too is more common in middle-aged women.

Sonographic Findings

In Hashimoto's thyroiditis, the thyroid gland is usually enlarged but may be normal in size or small. Hypoechoic micronodules and echogenic septae (due to fibrosis) are characteristic ultrasound findings (Fig. S122-1). The gland is usually hypervascular (Fig. S122-2) but may be normal or hypovascular in "burned-out" thyroid glands. In Graves' disease, the gland is enlarged, hypoechoic, and heterogeneous, with diffusely increased vascularity. However, a small percentage of patients will have no gray scale or color Doppler manifestations of Graves' disease on ultrasound. Subacute thyroiditis involves one or both lobes and can be focal or diffuse. Involved areas are hypoechoic, heterogeneous, and ill-defined with decreased color Doppler flow. Adenopathy can occur in up to 60% of patients. With recovery, the thyroid gland becomes isoechoic, and gland vascularity returns to normal.

Treatment

Hashimoto's thyroiditis is treated with hormone replacement. Graves' disease can be treated with antithyroid medications (methimazole), radioactive iodine therapy, or total thyroidectomy. Antithyroid drugs interfere with thyroid hormone synthesis and are often given as initial therapy; however, relapse occurs in more than 50% of patients despite long-term use. Radioiodine therapy is the definitive treatment and commonly used in the United States. Hypothyroidism is induced in approximately 80% of patients. Thyroidectomy is infrequently performed except when a suspicious nodule is present, complications from antithyroid medications develop, a patient refuses radioiodine therapy, or a pregnant patient requires a high dose of antithyroid medication. Subacute thyroiditis can initially be treated with a beta blocker or nonsteroidal anti-inflammatory drugs depending on symptoms. Steroids may be administered in nonresponsive patients. Thyroid hormone replacement should be used if symptomatic hypothyroidism develops but is usually withdrawn within 3 to 6 months as thyroid function recovers.

References

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 237–239.

CASE 123

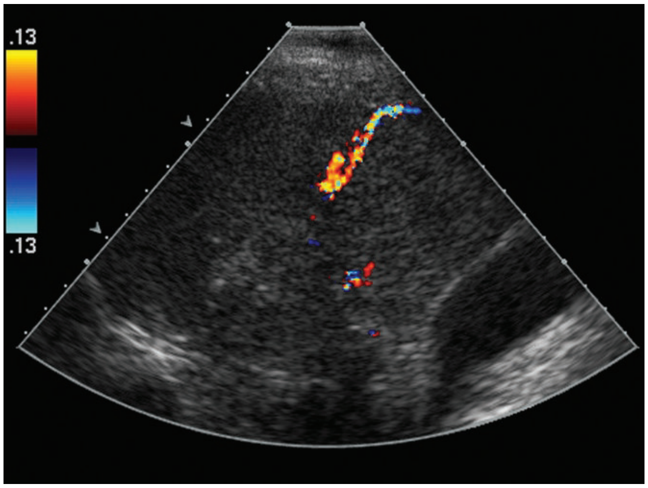

Figure 123-1

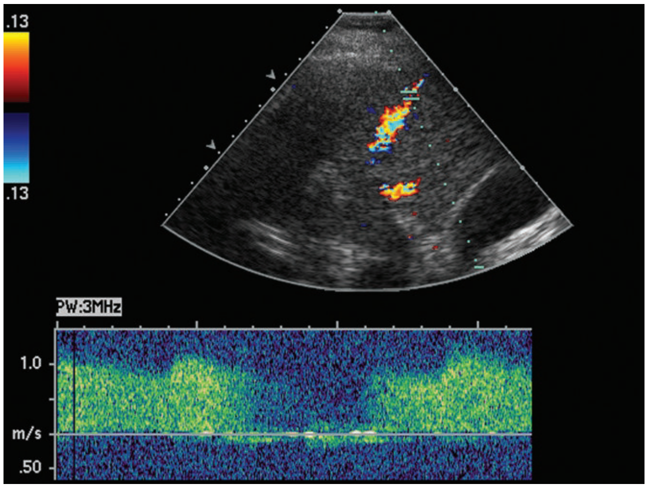

Figure 123-2

HISTORY: A 64-year-old female presents with status post radiofrequency ablation (RFA) of known hepatocellular carcinoma. After ablation the ultrasound was performed as seen in Figures 123-1 and 123-2.

1. Which one of the following would be included in the differential diagnosis for the imaging findings of the liver presented in this case?
   A. Arterial to venous fistula
   B. Venous to venous fistula
   C. Varices in a cirrhotic liver
   D. "Color line sign" or "color track sign"

2. Concerning Figure 123-2, all of the following statements are true EXCEPT:
   A. There is color aliasing.
   B. This appears to represent an arterial waveform.
   C. This color line will usually resolve within 5 minutes.
   D. If this sign persists there is no adverse consequence.

3. Concerning the "color line sign," all of the following statements are true EXCEPT:
   A. The "color line sign" or "color track sign" has been identified in up to 22% of cases after core biopsies of renal transplant.
   B. The "color track" or "line sign" has been identified in up to 12% of cases after core liver biopsies.
   C. The "color track" or "line sign" occurs in up to 20% of cases after cryoablation of the kidney.
   D. "Color line sign" occurs in approximately 5% of patients who had RFA of the liver or kidney.

4. All of the following statements are true EXCEPT:
   A. Color Doppler is helpful before biopsy of liver or renal masses.
   B. When performing biopsy or ablation of the superior pole right renal mass, a transhepatic approach performed under ultrasound guidance may be considered as a possible approach.
   C. Persistence of a "color line sign" for any length of time after a liver or biopsy is correlated with perihepatic or perinephric hematoma.
   D. Computed tomography (CT) should always be chosen over ultrasound guidance, because of the greater ability of CT to identify intervening vasculature structures than ultrasound.

See Supplemental Figures section for additional figures and legends for this case.

CASE 123

"Color Line Sign"

1. **D.** The "color line sign" is one of the names given to the fistula from the site of ablation or biopsy to the surface of the liver and/or kidney. This may be either a venous or arterial fistula. In this case, it appears to be a low resistance arterial waveform.
2. **D.** If this persists greater than 5 minutes, there is often an association with perihepatic or perinephric hematoma. All other statements are true.
3. **C.** The "color line sign" or "color track sign" have been studied after biopsy of the liver, kidney, and RFA but has not been studied after cryoablation.
4. **D.** There are several reasons for performing CT-guided biopsy. However, ultrasound is better in identifying intervening vessels. All other are true statements. Some have advocated transhepatic biopsy of right renal masses.

Comment

Differential Diagnosis

The differential diagnosis in this case is fairly limited. If color Doppler ultrasound has been performed after biopsy or after RFA and this "color line sign" is identified, this indicates either an arterial or venous connection between the deeper hepatic vessels and the liver capsule (Fig. S123-1). In a cirrhotic liver, collateral vessels can be seen on the liver surface. However, these vessels usually do not communicate with vessels deeper in the liver.

Ultrasound Findings

Ultrasound findings are fairly straightforward and include a color signal originating deep within the liver and extending to the liver surface at the site of biopsy or RFA. In this case, there is a color line extending to the liver surface. Post-biopsy ultrasound can identify this signal as either an arterial or a venous waveform. In our case, it was identified as an arterial waveform (Fig. S123-2).

Prognosis/Management

If in fact this "color line sign" on/or "color track sign" stops, there is almost no likelihood of bleeding from the site of biopsy or RFA (Fig. S123-3). However, if the "color line sign" or "color track sign" persists after biopsy, there is a statically significant correlation between persistence of a "color line sign" and hemorrhagic complications such as a hematoma. Pressure should be applied to the site of biopsy if this "color line" is identified. However, there have been no control studies to see if in fact direct ultrasound probe pressure at the site of the "color line" will stop the "color line/bleeding sign" and resolution. As in this case, after 5 minutes, most "color line signs" resolve. However, if this "color line" persists, there is a strong association with hemorrhage communications including hematomas and this patient should be watched closely.

References

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CASE 124

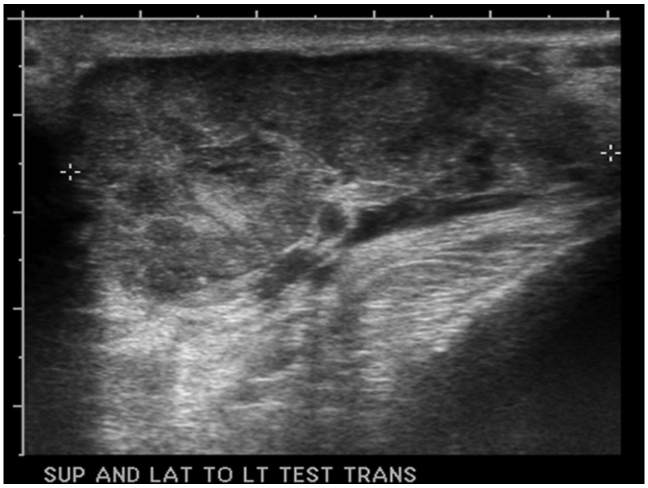

Figure 124-1

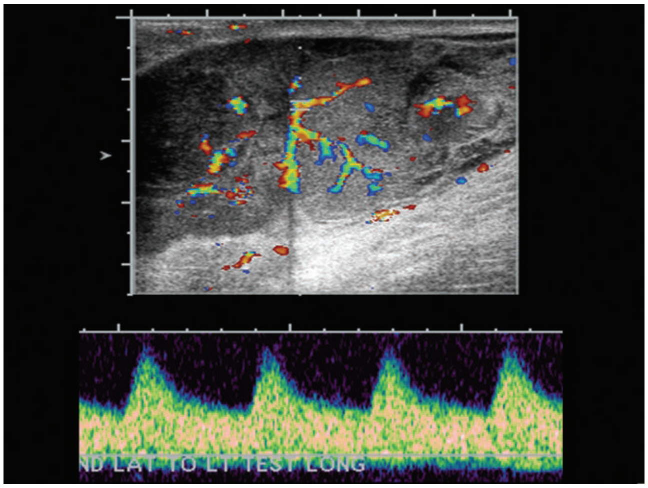

Figure 124-2

HISTORY: A patient presents with complaint of the fullness of the left inguinal canal. These images were obtained in Figures 124-1 and 124-2.

1. Scans of the left testis and epididymis were normal. These images were obtained from the left inguinal canal. Which one of the following would be considered the most likely diagnosis?
   A. Hematoma
   B. Inguinal hernia
   C. Epididymitis
   D. Adenomatoid tumor
   E. Malignant tumor of the spermatic cord
2. Which one of the following is the least useful noninvasive method in helping to narrow the diagnosis?
   A. Examining the other inguinal canal
   B. Examining the left testis and epididymis
   C. Performing color flow Doppler
   D. Having the patient perform the Valsalva maneuver during ultrasound exam
3. What is the most common sarcoma in the inguinal region in adults?
   A. Rhabdomyosarcoma
   B. Liposarcoma
   C. Leiomyosarcoma
   D. Fibrosarcoma
4. What is the one most common extratesticular tumor?
   A. Adenomatoid tumor
   B. Extratesticular lipoma
   C. Fibrous pseudotumor
   D. Sperm granuloma

See Supplemental Figures section for additional figures and legends for this case.

CASE 124

Liposarcoma of the Groin

1. **E.** While uncommon, malignant tumors within the inguinal canal could be considered. The differential is broad and could include a possible hematoma after surgery and an inguinal hernia. However, these do not have increased color flow. Epididymitis and an adenomatoid tumor are within the epididymis.
2. **A.** While examination of the other inguinal canal would be helpful for comparison, this probably will not help establish the diagnosis of this echogenic mass in the left inguinal region. Color flow will establish whether this is a solid mass such as a tumor versus a hernia or hematoma. Performing a Valsalva maneuver is very helpful in excluding a hernia. Examination of the testis/epididymis excludes epididymo-orchitis.
3. **B.** Liposarcomas are the most common scrotal/inguinal sarcomas in adults. Rhabdomyosarcomas are the most common extratesticular sarcomas, occurring most frequently in children. Other sarcomas are much less frequent.
4. **B.** In most series, extratesticular lipomas are slightly more common than adenomatoid tumors. Other choices do occur but are not tumors. Adenomatoid tumors represent approximately 30% of all extratesticular tumors. This is probably the second most common tumor.

Comment

Differential Diagnosis

The differential diagnosis of an extratesticular mass is quite broad. It is important to check if the mass originates from the epididymis or in the inguinal canal. An inguinal hernia should be considered within the differential. Performing Valsalva during ultrasound may help distinguish a hernia from other extratesticular masses. Always considered within the differential would be the sequelae of infection causing epididymo-orchitis. Sperm granulomas occur in more than 1/3 of men who have had vasectomies but only in approximately 2% of the general population. Lipomas and adenomatoid tumors are the two most common primary extratesticular tumors. Metastatic disease to the extratesticular region does occur. Sarcomas of the spermatic cord are the most common primary malignant tumors of the spermatic cord. A sarcoma or metastatic lesion to this inguinal should be considered in the differential of a solid, vascular, inguinal mass with irregular borders.

Ultrasound Findings

Certain maneuvers are helpful to narrow the differential. Lack of movement with Valsalva and lack of peristalsis exclude an inguinal hernia. Lack of intraluminal air or fluid was helpful in excluding a bowel containing hernia. Identifying the testis and epididymis separate from the mass may be important to differentiate an extratesticular sarcoma from an epididymal or testicular lesion. Sarcomas are solid on ultrasound and have increased color flow as identified in this case (Figs. S124-1 and S124-2).

Prognosis/Management

Management usually includes staging computed tomography or magnetic resonance imaging to exclude either local or more distal metastases. Biopsy may be performed for preoperative diagnosis. Surgery would be considered as the treatment of choice. The gross pathological specimen is seen in Figure S124-3.

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Cross-reference

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CASE 125

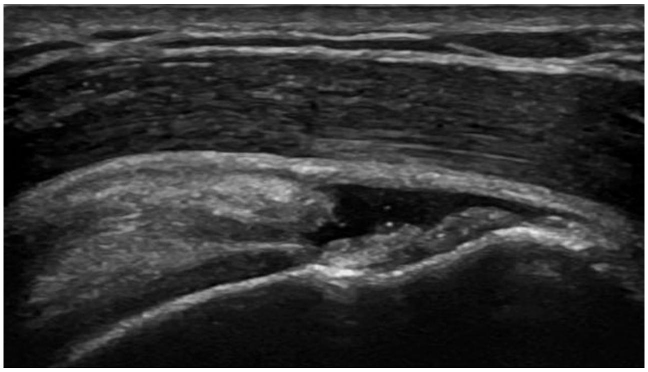

Figure 125-1

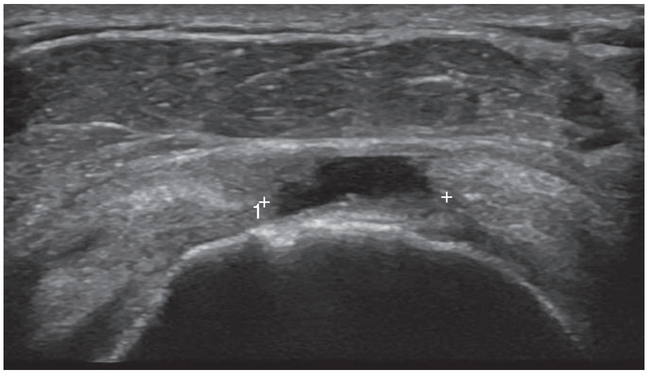

Figure 125-2

HISTORY: A 65-year-old woman presents with right shoulder pain.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Small deep-sided partial thickness tear of the rotator cuff
   B. Full thickness tear of the rotator cuff
   C. Tendinopathy
   D. Extensive partial thickness rotator cuff tear
2. Concerning rotator cuff tears, which statement is true?
   A. Magnetic resonance (MR) is more accurate than ultrasound for diagnosing cuff tears.
   B. Most rotator cuff tears begin in the mid aspect of the cuff.
   C. Most rotator cuff tears occur from trauma to a normal cuff.
   D. Most rotator cuff tears begin in the anterior aspect of the cuff.
3. Concerning rotator cuff tears, which statement is true?
   A. Partial thickness tears occur on the bursal side of the cuff most frequently.
   B. A subdeltoid bursal and joint effusion is a nonspecific finding on ultrasound and is not predictive of a cuff tear.
   C. On ultrasound, a full thickness cuff tear is characterized by a focal defect created by a variable degree of retraction between the torn tendon ends.
   D. On ultrasound, a deep-sided partial thickness tear appears as an ill-defined hyperechoic area on long or short axis views of the cuff.
4. Concerning rotator cuff tears, which statement is true?
   A. Anisotropy can falsely create the impression of a full thickness cuff tear.
   B. Fatty degeneration of the cuff muscles is closely associated with tear size and location.
   C. Fatty degeneration cannot accurately be diagnosed with ultrasound.
   D. Cuff tendinopathy manifests as thinning of the rotator cuff.

See Supplemental Figures section for additional figures and legends for this case.

CASE 125

Rotator Cuff Tear

1. **B.** There is a defect in the rotator cuff in Figures S125-1 and S125-2 and the torn tendon end is retracted on the longitudinal view. The deltoid muscle fills the defect in Figure S125-1. An extensive partial thickness tear (D) might be considered as such tears involve more than 50% of the cuff and can also be compressed by the transducer and mistaken for a full thickness cuff tear. Clinically this is not important as such tears are often repaired.
2. **B.** Most rotator cuff tears begin approximately 15 mm posterior to the intra-articular portion of the biceps tendon. It is theorized that as people age, the rotator cuff in this area (referred to as the crescent) thins due to relative avascularity.
3. **C.** The torn tendon ends are retracted to a variable degree in a full thickness cuff tear. If the torn tendon ends are not retracted, compression with the transducer can separate the torn tendon ends; a focal area of cuff heterogeneity suggests a nonretracted tear may be present.
4. **B.** The greater the tear size and the closer it begins to the intra-articular portion of the biceps tendon, the greater the risk for fatty degeneration. This is thought to be due to anterior disruption of the rotator cable insertion resulting in a greater degree of retraction of the torn tendon and subsequent fatty degeneration over time. Ultrasound has been shown to be comparable to MR for diagnosing fatty degeneration of the cuff musculature.

Comment

Introduction

Rotator cuff disease is the most common cause of shoulder pain, occurring in 65% to 70% of patients. Ultrasound is very accurate for diagnosing cuff tears and comparable to but less expensive than magnetic resonance imaging. It also is better tolerated and preferred by most patients. It is important to diagnose cuff tears prior to the development of irreversible changes such as fatty degeneration of the cuff musculature, fixed retraction, loss of tendon quality, and increase in tear size.

Sonographic Findings

Full thickness cuff tears vary in size. If fluid surrounds the torn tendon, the tear is easier to visualize. In the absence of fluid, the deltoid muscle and inflamed peribursal fat occupy the space created by the tear and abut the humeral head cartilage. If a massive tear is present, no cuff will be visualized because it is retracted beneath the acromion. It is important not to mistake the overlying deltoid muscle for the cuff. These massive tears often occur in elderly patients and are usually chronic. Partial thickness tears can be more difficult to diagnose and should be visualized on both short and long axis views. Partial thickness tears appear as distinct hypoechoic or mixed hypoechoic/hyperechoic defects that usually occur along the deeper side of the cuff.

Treatment

The decision as to how to manage a rotator cuff tear should be made based on the risks and benefits of operative versus nonoperative management. Tear acuity, tear size, the risk of irreversible changes, fatty degeneration of the cuff muscles, fixed retraction, loss of tendon quality, and the patient's age should be taken into account. Initial nonoperative management should be considered in a patient older than 70 years with a chronic tear, with a cuff tear that cannot be repaired, and with an intact cuff or a partial thickness tear. Conservative treatment for a partial thickness tear would include nonsteroidal anti-inflammatory drugs and physical therapy to strengthen the cuff muscles and improve range of motion. Patients with an acute or small to large full thickness cuff tear benefit from surgery with the goal of preventing irreversible changes to the cuff.

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Cross-reference

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CASE 126

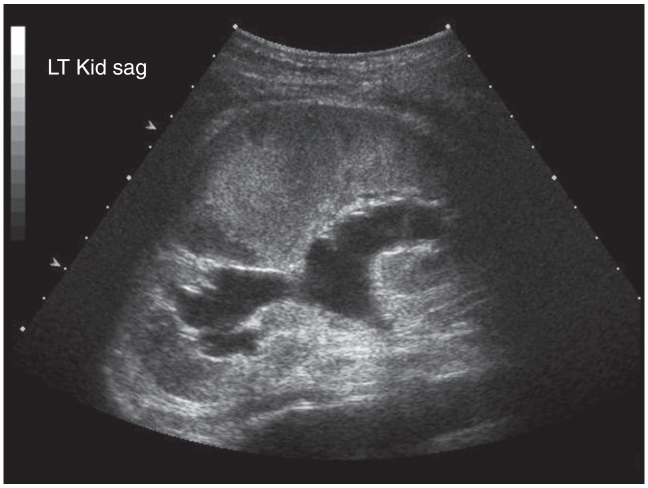

Figure 126-1

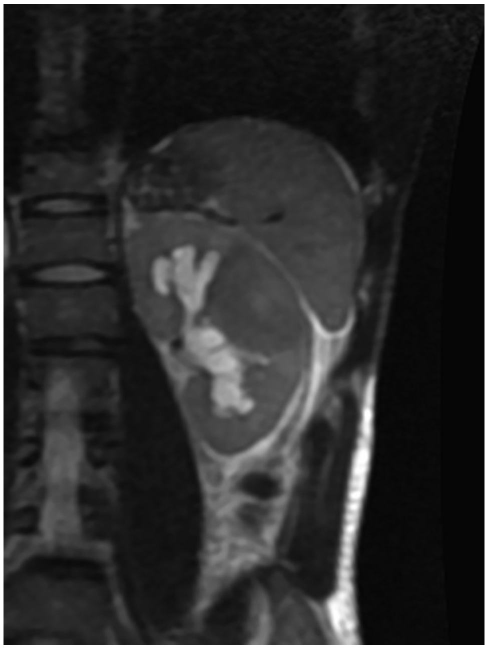

Figure 126-2

HISTORY: A 25-year-old male presented with this ultrasound of the kidney.

1. Ignoring the mild hydronephrosis, which one of the following would be most likely included in the differential diagnosis for the isoechoic region in the left kidney in Figure 126-1? (Choose all that apply.)
   A. Renal abscess
   B. Renal lymphoma
   C. Renal cell carcinoma (RCC)
   D. Renal infarct
   E. Renal oncocytoma

2. Of the following lesions listed, which lesion presented is usually hyperechoic rather than a hypoechoic mass?
   A. Oncocytoma
   B. Xanthogranulomatous pyelonephritis
   C. Hemorrhagic cyst
   D. Angiomyolipoma

3. Typical appearances of renal lymphoma include all of the following EXCEPT:
   A. Solitary, multiple hypoechoic or anechoic masses
   B. Diffuse infiltration of the kidney causing enlargement, but with preservation of the renal shape
   C. Direct invasion of the mass into the renal vein
   D. Direct invasion of the kidney from a large retroperitoneal nodal mass

4. Which one of the following statements concerning lymphoma is NOT true?
   A. Hodgkin's lymphoma more commonly affects the kidney than non-Hodgkin's lymphoma.
   B. Poor prognostic factors with lymphoma include advanced patient age and a poor daily performance status.
   C. Treatment in a patient with lymphoma can include chemotherapy.
   D. Image-guided percutaneous biopsy may be helpful in establishing a diagnosis of lymphoma.

See Supplemental Figures section for additional figures and legends for this case.

CASE 126

Renal Lymphoma

1. **A, B, C, and E.** Renal lymphoma and a renal abscess may have a variety of appearances. All could be considered within the differential diagnosis. RCC and renal oncocytoma are usually well demarcated, but could be considered.
2. **D.** This is the entity that is most typically more echogenic because of the fat contain within the lesion. However, a pitfall is approximately 10% of RCCs may appear hyperechoic. Other masses listed are usually not hyperechoic.
3. **C.** While this has rarely been reported, it is an uncommon feature of the renal lymphoma and more common in RCC. All other choices occur with renal lymphoma.
4. **A.** This is a false statement as non-Hodgkin's lymphoma more commonly involved the kidneys compared to Hodgkin's lymphomas. All other choices are true.

Comment

Differential Diagnosis

Differential for an isoechoic or hypoechoic renal mass would include renal lymphoma and an infection such as a renal abscess could be considered. Renal tumors, including an oncocytoma or RCC, may appear hypoechoic. RCCs may also be hyperechoic or isoechoic. Some cysts with hemorrhage may appear hypoechoic/isoechoic. Also, certain anatomical variants such as a splenic hump or a so-called dromedary hump may appear as a hypoechoic mass in the mid pole of the left kidney. This is discussed elsewhere within this case series.

Ultrasound Findings

Renal lymphoma may be either a bilateral or unilateral process. Renal lymphoma may cause nephromegaly as in this situation. There is preservation of the renal shape but marked enlargement of the kidneys due to infiltrated process by lymphoma. Hypoechoic masses scattered throughout the kidneys are a typical feature of renal lymphoma. This is often a bilateral process. These masses are hypoechoic, in some cases; they almost appear cystic (Fig. S126-1). Perirenal lymphoma could also be confused as a hematoma. Bulky lymphoma from the para-aortic region may be extended to involve the kidneys. Usually, these masses are not extremely vascular as with other renal tumors such as RCC. Renal lymphoma usually does not invade the renal vein as does RCC. Rarely renal lymphoma may be associated with hydronephrosis from the extra-renal extent of the lymphoma. Magnetic resonance imaging and computed tomography are helpful for staging (Fig. S126-2).

Prognosis/Management

Prognosis and treatment are dependent on a number of factors. The younger the age of the patient, the better the prognosis. Certainly, lymphoma isolated to one region has an improved prognosis. When there is nodal involvement and involvement of the solid organs, the prognosis is usually worse. Serum level of lactate dehydrogenase increases with the amount of lymphoma tissues within the body. Thus, a higher level carries a poorer prognosis.

Treatment typically includes chemotherapy. In some cases radiation therapy is used. More recently monoclonal antibody therapy was used to attack and destroy cancer cells. After treatment, the kidney may appear normal or small (Fig. S126-3).

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Cross-reference

Ultrasound: The Requisites, 3rd ed, 121–122.

CASE 127

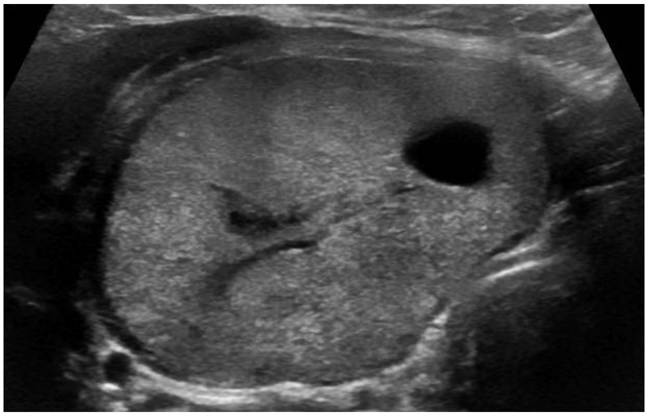


Figure 127-1

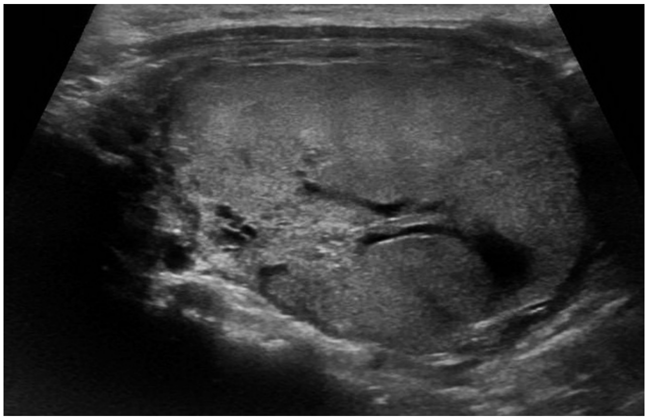


Figure 127-2

HISTORY: A 55-year-old man presents with a large thyroid nodule.

1. Which of the following would be included in the differential diagnosis for the imaging findings presented? (Choose all that apply.)
   A. Papillary thyroid carcinoma
   B. Follicular adenoma
   C. Follicular carcinoma
   D. Medullary carcinoma
2. Which of the following is true regarding follicular neoplasm?
   A. It is possible to differentiate a follicular adenoma from carcinoma with ultrasound-guided fine needle aspiration (FNA).
   B. A follicular carcinoma tends to be hyperechoic and large and does not have a halo on ultrasound.
   C. The prognosis of a follicular carcinoma depends on the presence of vascular invasion and distant metastases.
   D. Eighty percent of follicular neoplasms are carcinomas.
3. Which of the following is true regarding medullary carcinoma?
   A. Medullary thyroid carcinoma is associated with MEN I and slightly more common in men.
   B. Medullary thyroid carcinoma spreads more commonly to cervical lymph nodes than to distant sites.
   C. Metastases from medullary thyroid carcinoma commonly spread to the liver, lung, and bone.
   D. Medullary thyroid carcinoma is radiosensitive.
4. Which of the following is true regarding medullary thyroid carcinoma?
   A. Medullary carcinoma is derived from the follicular cells in the thyroid.
   B. Calcitonin is a marker for papillary thyroid carcinoma.
   C. Medullary carcinoma is hereditary in 75% of cases.
   D. On ultrasound, medullary carcinoma can be difficult to distinguish from papillary carcinoma.

See Supplemental Figures section for additional figures and legends for this case.

CASE 127

Non-papillary Thyroid Tumors

1. **A,B,C.** The ultrasound shows a large solid, isoechoic nodule with an anechoic (cystic) center and a thin hypoechoic rim (Figs. S127-1 and S127-2). This is a characteristic appearance for follicular adenoma. However, a follicular carcinoma (C), follicular variant of papillary carcinoma, and nodular hyperplasia could have an identical appearance. This nodule was benign. It is not possible to differentiate a follicular adenoma from a follicular carcinoma with FNA; it must be determined at surgical pathology by the presence of capsular or vascular invasion or distant metastases.
2. **C.** Follicular carcinoma spreads hematogenously to bones and lung and occasionally liver and brain. If the insular variant is present, prognosis is very poor. Follicular carcinoma tends to be hypoechoic and large and usually does not have a halo or cystic spaces on ultrasound.
3. **C.** Distant metastases are present in 13% of patients with medullary thyroid carcinoma at initial presentation. Elevated calcitonin is an excellent marker. The liver and bones are most commonly involved followed by the lungs and mediastinum. Metastases are frequently multiple and involve multiple sites. On ultrasound, liver metastases tend to be hyperechoic but can be hypoechoic or heterogeneous.
4. **D.** On ultrasound, medullary carcinoma tends to be larger, more homogeneous, and with greater cystic change compared to papillary carcinoma. However, there are overlapping features with papillary thyroid carcinoma. Papillary thyroid carcinomas can be large and are typically very hypoechoic, and both may have cystic changes and microcalcifications that in medullary carcinoma are caused by calcium deposits around amyloid.

Comment

Introduction

Eighty to ninety percent of follicular neoplasms are benign, and only 10% to 20% are malignant. Follicular carcinoma tends to occur in older males as opposed to adenomas. Medullary thyroid carcinoma originates from the calcitonin-producing parafollicular (C cells) in the thyroid and is considered a neuroendocrine tumor. It can be multifocal and bilateral, especially if familial. Seventy-five percent of cases are sporadic and 25% are familial (MEN IIA and B, familial medullary thyroid carcinoma). It is slightly more common in women. Ten-year survival is 75% to 88%.

Sonographic Findings

Follicular neoplasms have a characteristic appearance on ultrasound; they tend to be isoechoic or hyperechoic with a thin hypoechoic halo and central cystic spaces. It is not possible to determine if a follicular neoplasm is benign or malignant based on ultrasound features, and a differential diagnosis for this appearance exists. Sonographic features have been reported that favor a follicular carcinoma, including larger size, absence of a hypoechoic halo, hypoechoic appearance, and absence of cystic change. Medullary thyroid carcinoma has overlapping features with papillary carcinoma but tends to be larger and homogeneous and have greater cystic change. Both tend to be hypoechoic with microcalcifications.

Treatment

Follicular carcinoma has an excellent survival rate: 10-year survival is 92%. However, if there is extensive vascular invasion and distant metastases, survival is decreased. Medullary thyroid carcinoma has a lower survival rate; if the nodule is palpable, lymph node metastases will be present in 50% of patients. Thyroidectomy is the definitive therapy for the above mentioned tumors, with lymph node dissection when indicated. In particular, for medullary thyroid carcinoma, thyroidectomy is the mainstay of treatment because the tumor does not concentrate iodine. If the familial type of medullary thyroid carcinoma is present with germline RET mutations, a total thyroidectomy is recommended by age 5 or 6 or earlier. Targeted therapies (tyrosine kinase inhibitors) are also being used in clinical trials in patients with advanced or metastatic disease. Preoperative ultrasound is standard prior to surgery to identify and mark metastatic nodes. Ultrasound is also used to survey for disease recurrence.

References

Ganeshan D, Paulson E, Duran C, Cabanillas ME, Busaidy NL, Charnsangavej C. Current update on medullary thyroid carcinoma. *AJR Am J Roentgenol*. 2013;201:W867–W876.

Lee S, Shin JH, Han BK, Ko EY. Medullary thyroid carcinoma: comparison with papillary thyroid carcinoma and application of current thyroid criteria. *AJR Am J Roentgenol*. 2010;194:1090–1094.

Pitt SC, Moley JF. Medullary, anaplastic, and metastatic cancers of the thyroid. *Semin Oncol*. 2010;37:567–579.

Sillery JC, Reading CC, Charboneau JW, Henrichsen TL, Mandrekar JN. Thyroid follicular carcinoma: sonographic features of 50 cases. *AJR Am J Roentgenol*. 2010;194(1):44–54.

Cross-reference

Ultrasound: The Requisites, 3rd ed, 235–236, 243.

Supplemental Figures

CASE 1

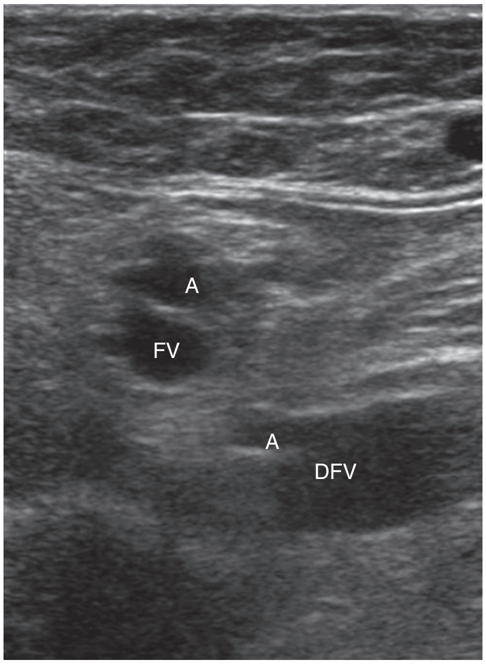


Figure S1-1. The femoral vein (FV) and superficial femoral artery (A) are in the near field and the deep femoral vein (DFV) and deep femoral artery are in the far field. The DFV is dilated.

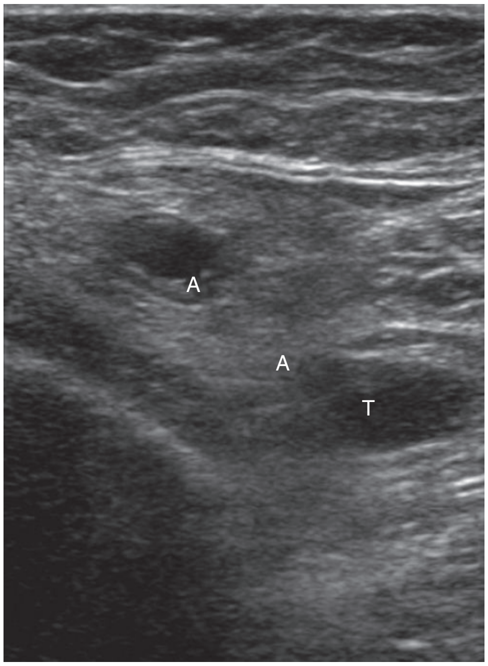


Figure S1-2. With compression, the femoral vein compresses but the deep femoral vein does not and contains DVT (T). Note the intraluminal thrombus is oval with compression indicating it is soft and deformable. The DVT is poorly echogenic but acute DVT echogenicity is variable.

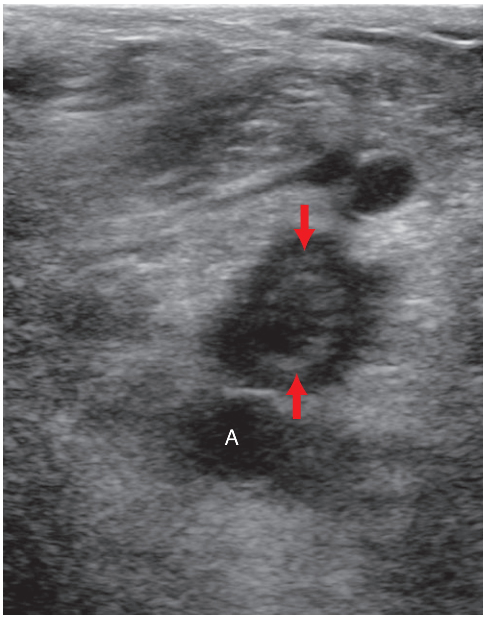


Figure S1-3. Without compression image of acute popliteal DVT in another patient. Transverse image of the popliteal fossa demonstrates a markedly dilated popliteal vein superficial to the popliteal artery (A). The acute DVT in the vein (arrows) is heterogeneous. There are poorly echogenic and more echogenic regions.

Figure S1-4. With compression image of acute popliteal DVT in same patient as Figure S1-3. With compression, the vein is noncompressible and dilated indicating an acute DVT.

CASE 2

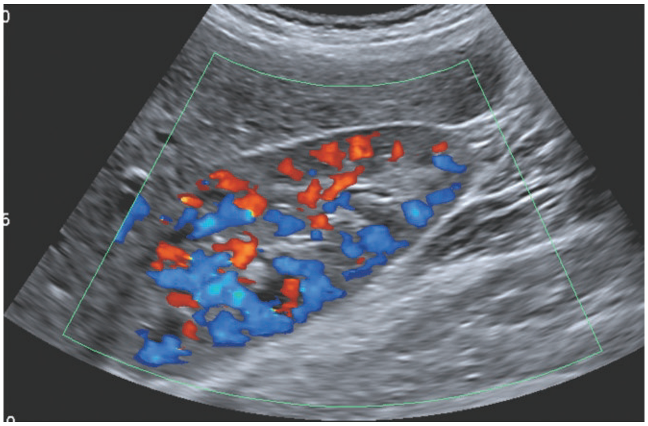


Figure S2-1. Color Doppler of the kidney shows red and blue signals. There is a paucity of color at the cortex and the upper and lower poles due to low flow and poor Doppler angle.

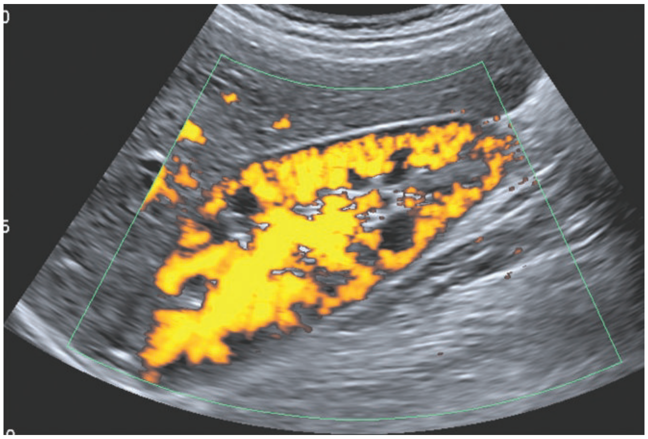


Figure S2-2. Power Doppler of the kidney with single color indicating power Doppler. There is no difference between arteries and veins. There is better filling of the slower flow in the cortex and at the poles. Power Doppler is not angle dependent like color Doppler. Slower flow can be detected because of better signal to noise compared with color Doppler.

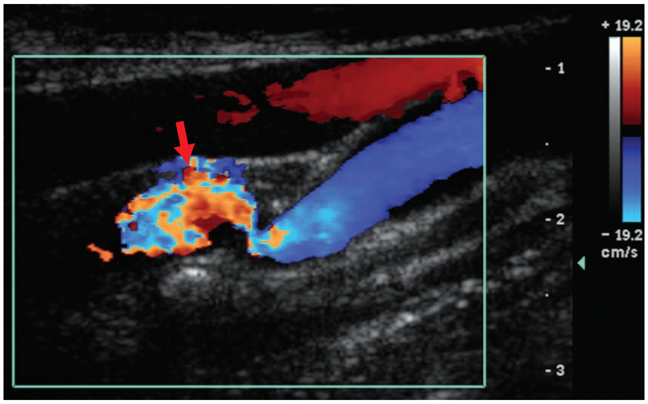


Figure S2-3. Color Doppler of the mid internal carotid artery in a patient with carotid fibromuscular dysplasia demonstrates angulation of the vessel and aliasing after the narrowing (arrow).

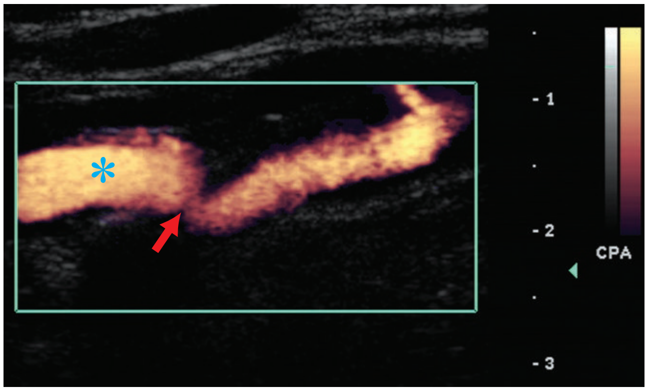


Figure S2-4. Power Doppler of the mid internal carotid artery shows the area of narrowing (arrow) and poststenotic dilatation (*). Power Doppler does not alias. The contour of the vessel is shown better without the aliasing artifact.

CASE 3

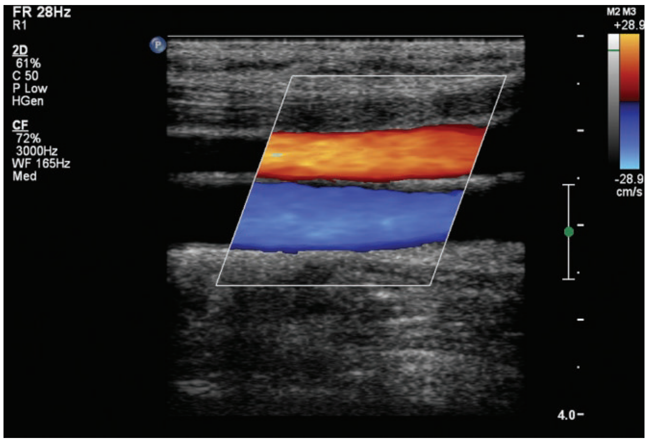


Figure S3-1. The color box is oriented toward the head. Red is assigned blood flow toward the transducer (toward the feet) and blue is assigned flow away from the transducer (toward the head). The color is unrelated to if the vessel is an artery or vein. The more superficial jugular vein is red and the deeper common carotid artery is blue.

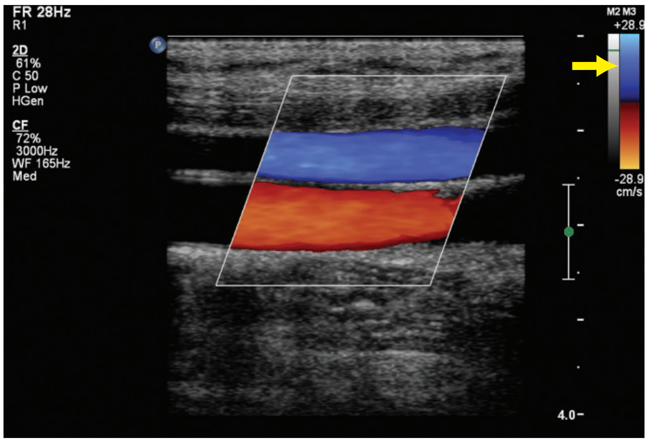


Figure S3-2. Color map inverted. The color box is still oriented toward the head but the color assignment has been inverted. Blue is assigned blood flow toward the transducer (toward the feet) (arrow) and red is assigned flow away from the transducer (toward the head). The more superficial jugular vein is blue and the deeper common carotid artery is red.

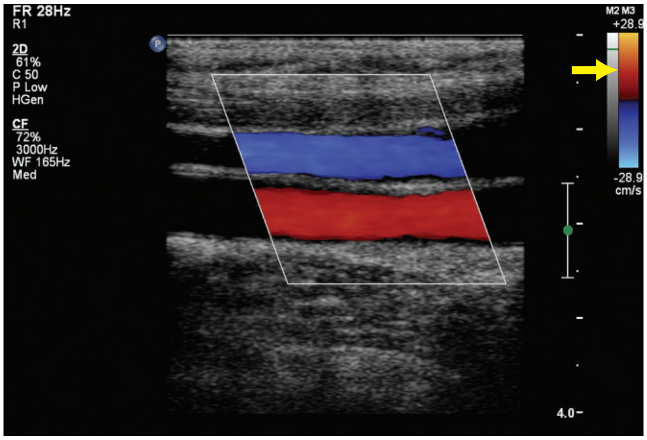


Figure S3-3. Color box direction is changed. The color box is oriented toward the feet. Red is assigned blood flow toward the transducer (toward the head) (arrow) and blue is assigned flow away from the transducer (toward the feet). The more superficial jugular vein is blue and the deeper common carotid artery is red.

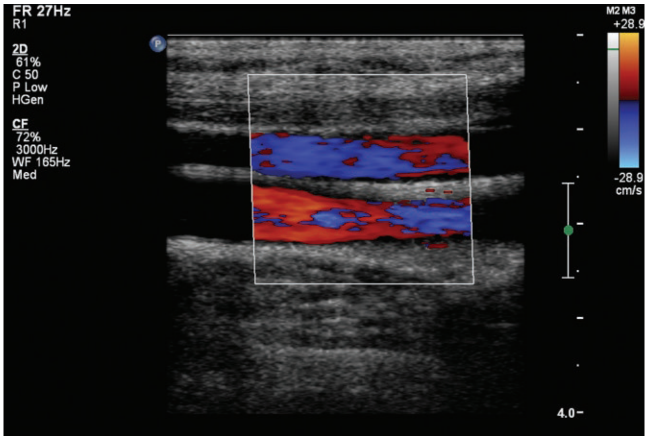


Figure S3-4. Color box set to straight down, perpendicular to blood flow. At 90 degrees there is no Doppler shift but some off axis flow does create a weak color signal. The direction of flow cannot be assigned since both colors are present in the vessels.

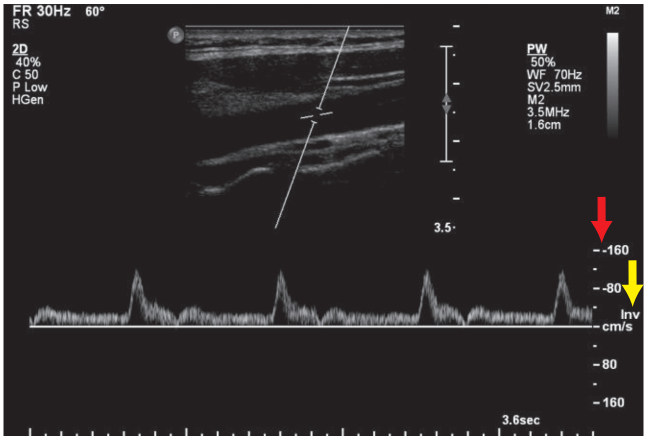


Figure S3-5. Spectral Doppler of common carotid artery has flow away from the transducer. The spectrum is ABOVE the baseline because the spectrum has been inverted. Note the Doppler shifts are in the negative range above the baseline (red arrow) and the spectral is labeled Inv for inverted (yellow arrow).

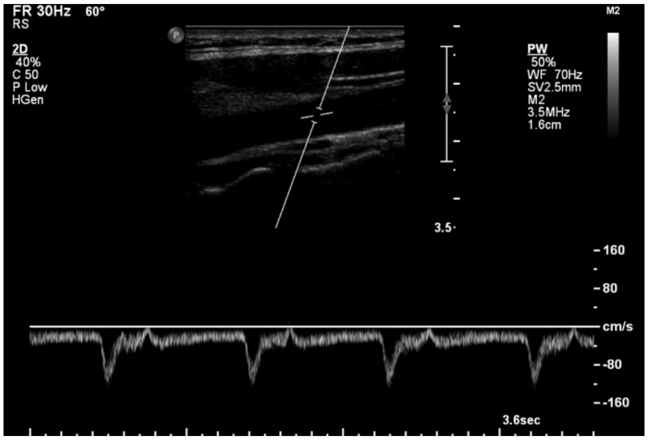


Figure S3-6. Spectral Doppler of common carotid artery with flow below the baseline indicating flow away from the transducer (not inverted as in Fig. S3-5) with flow toward the head.

CASE 4

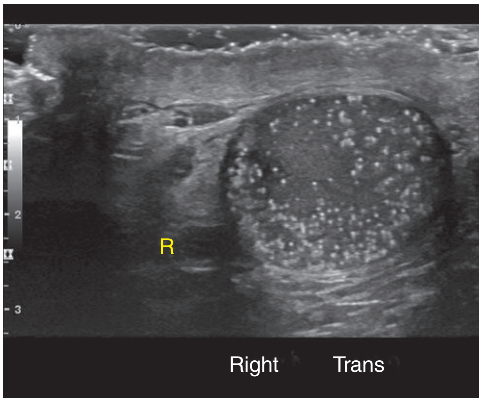


Figure S4-1. Ultrasound of the right (R) testis shows multiple echogenic foci scattered throughout the testis.

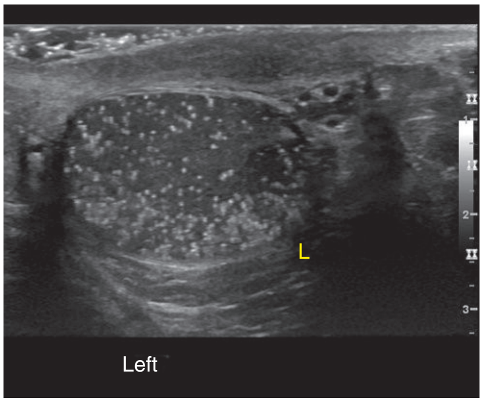


Figure S4-2. Ultrasound of the left (L) testis shows multiple echogenic foci scattered throughout the testis.

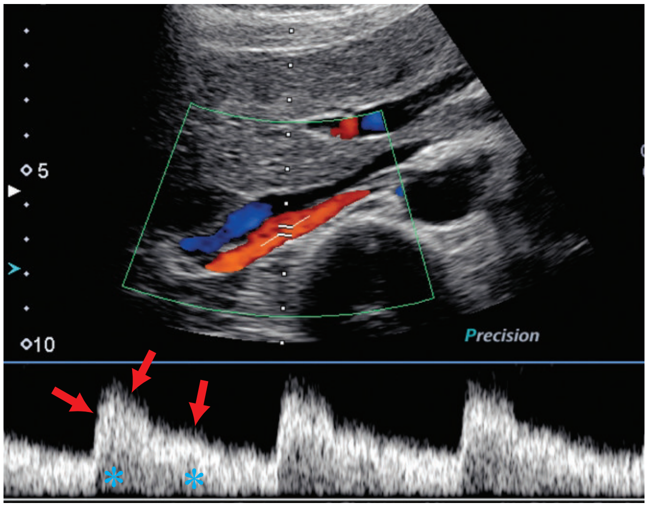


Figure S5-1. Main renal artery spectral Doppler shows normal spectral broadening. There is spectral broadening in the renal artery because the flow profile is parabolic. If one looks up and down at each time point there are signals at all velocities. In parabolic flow, the fastest velocity is in the center of the vessel and slows down gradually in the layers of flow that are closer to the vessel wall. Note the envelope (arrows) is whiter than the window but there are signals (filling in) of the spectral window in systole and diastole (*).

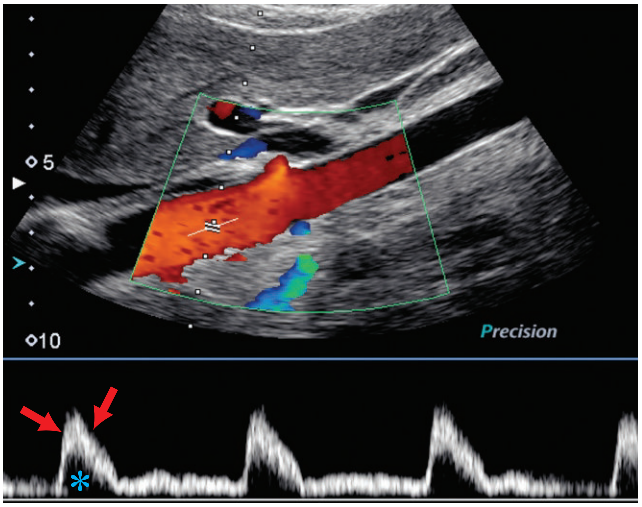


Figure S5-2. Spectral Doppler of the abdominal aorta shows normal absent spectral broadening. There is no spectral broadening in the aorta because the flow profile is plug. In plug flow, the fastest velocity is present in most of the width of the vessel and blood slows down abruptly only near to the vessel wall. The envelope is well defined and there is not filling of the spectral window in systole (*) since all of the blood in the sample volume is flowing at the same velocity and direction. Velocity does slow down near the vessel wall but this is not in the sample volume.

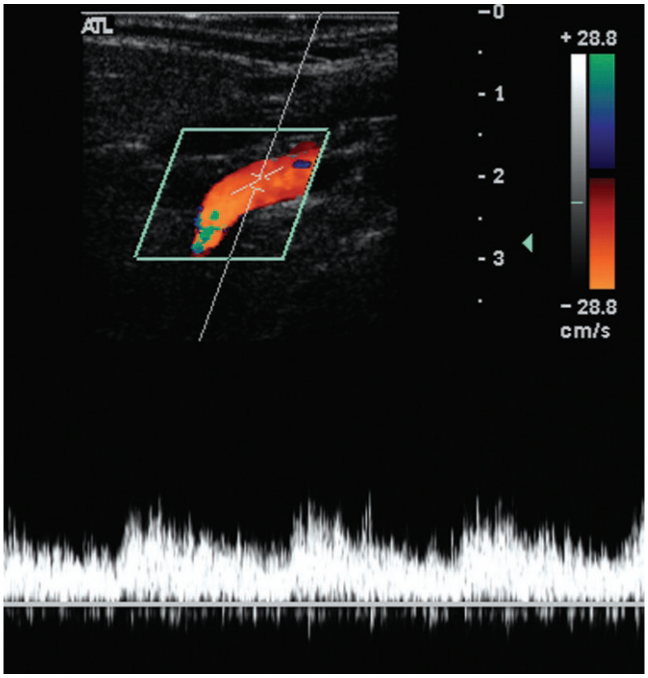


Figure S5-3. Abnormal spectral broadening. Spectral Doppler of the internal carotid artery downstream from a stenosis (not shown) has poststenotic turbulence and abnormal spectral broadening. The envelope is poorly defined and there are transient high velocity lines in the spectrum. All velocities are represented and there is filling in of the window. The velocities at the edge are less white and more gray than the lower velocities below peak, which are more white. This indicates slower, rather than faster, flow is more common. Fewer red blood cells are moving at the highest velocities There is also simultaneous forward and reverse flow with signals above and below the baseline.

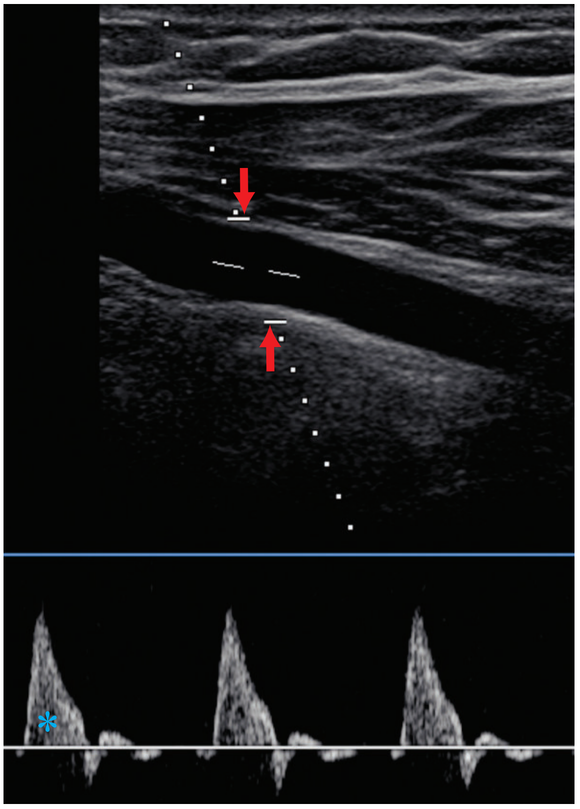


Figure S5-4. Spectral Doppler of the subclavian carotid artery demonstrates spectral broadening due to an overly large sample volume (between arrows). There is filling in of the window (*).The artery has plug flow but the lower velocities at the wall are now detected because the sample volume includes the blood flowing near the vessel wall. Sample volume sizes are generally not larger than half of the vessel diameter.

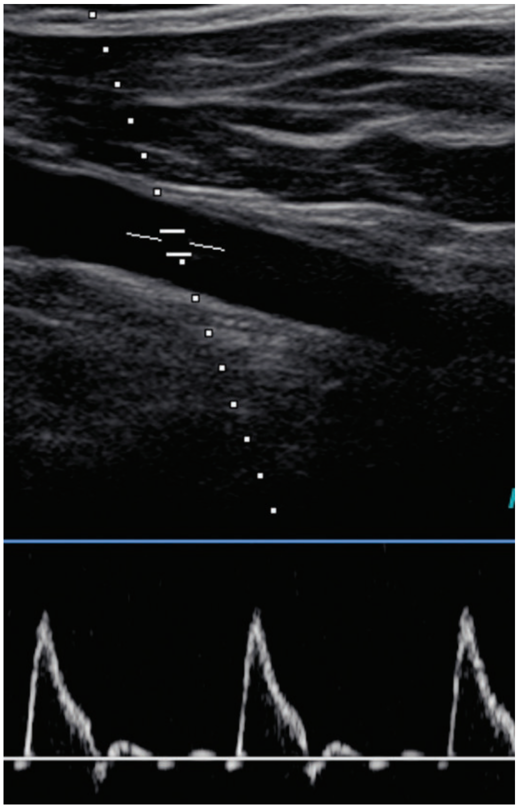


Figure S5-5. Spectral Doppler of the subclavian artery demonstrates normal waveform shape without spectral broadening when the sample volume size is set to the correct size.

CASE 6

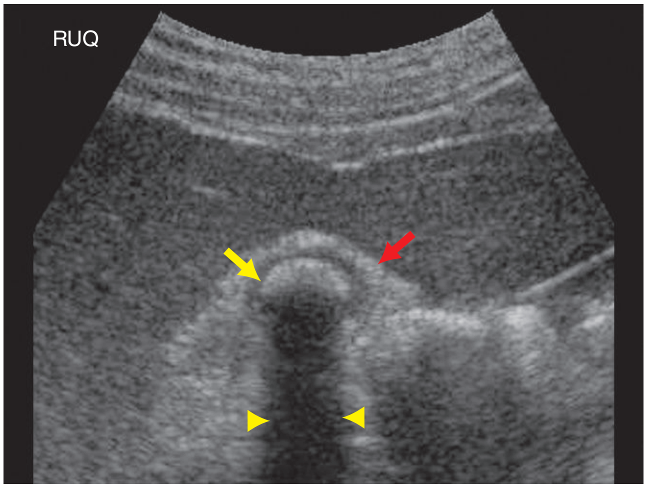


Figure S6-1. Real-time ultrasound of right upper quadrant of the abdomen demonstrates slight gallbladder wall thickening (arrow) noted anteriorly. Next there is an echogenicity (arrow), then an acoustic shadow (arrowheads). These three are the components of wall (W), echo (E), and shadow (S).

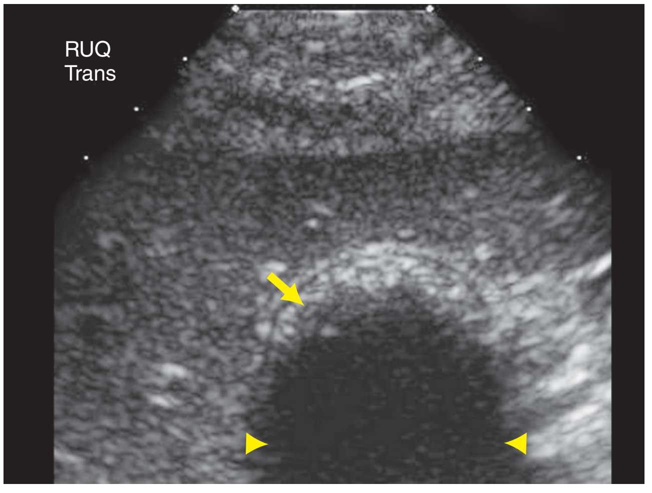


Figure S6-2. Similar findings in another patient in which the gallbladder wall is not thickened but there is increased echogenicity (arrow) and distal acoustic shadowing (arrowheads).

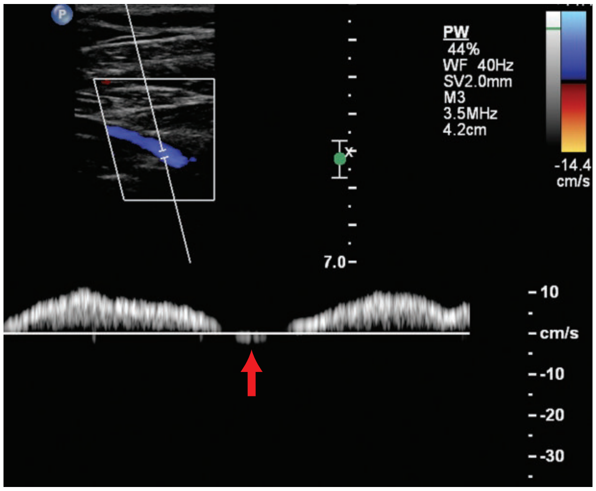


Figure S7-1. The common femoral vein is patent by color and demonstrates normal phasic variation on the spectral Doppler waveform. There is transient flow reversal (arrow) during breathing, which may be present normally, as it was in this case.

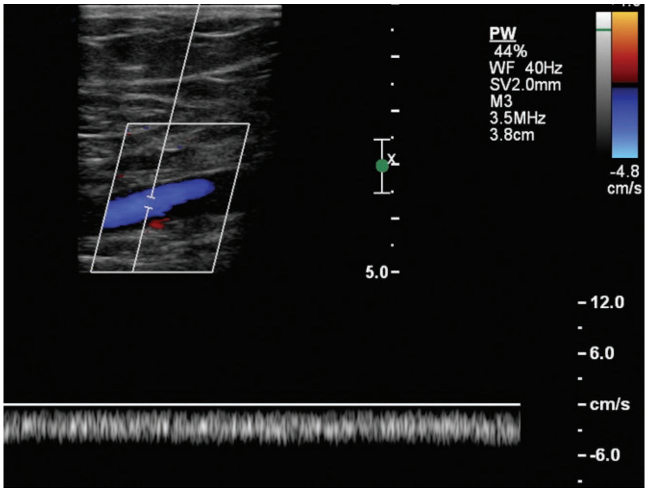


Figure S7-2. The contralateral common femoral vein is patent by color but there is an asymmetric continuous right spectral Doppler waveform. This indicates obstruction between the site of the sample and the heart. Since the other side is normal, the obstruction is in the common femoral vein above this, the iliac vein, or the left pelvis. Inferior vena caval involvement is ruled out when there is a unilateral blunt common femoral vein waveform.

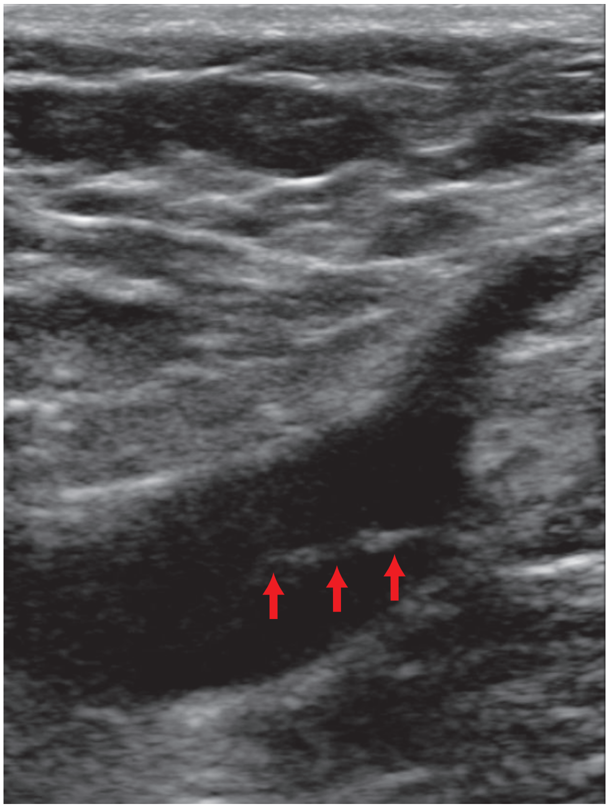


Figure S7-3. A gray scale image of the right common femoral vein above the sample in Figure S7-2 demonstrates a thin synechia in the vein (arrow). This weblike change is the sequel of prior DVT and can be the source of the obstruction.

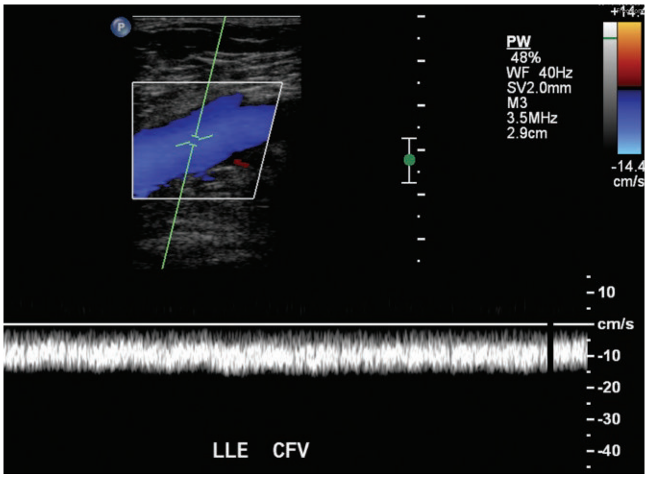


Figure S7-4. In different patient with bilateral leg swelling, spectral Doppler of the common femoral vein is blunted and nearly continuous.

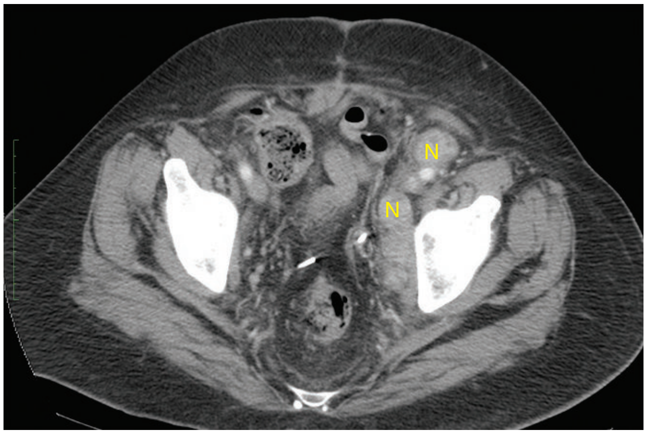


Figure S7-5. In the CT of the patient in Figure S7-4, there is extrinsic compression on the iliac vein by metastatic adenopathy (N).

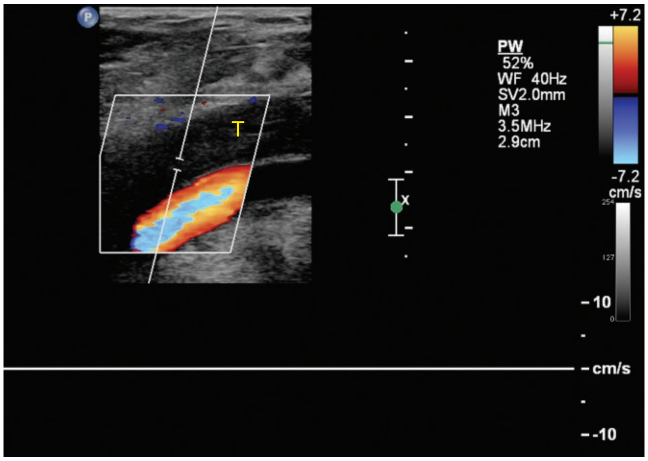


Figure S7-6. In a different patient who presents with acute swelling of the leg, acute deep venous thrombosis was present (T). The thrombus is completely occluding the vein and there is no flow by color or spectral Doppler.

CASE 8

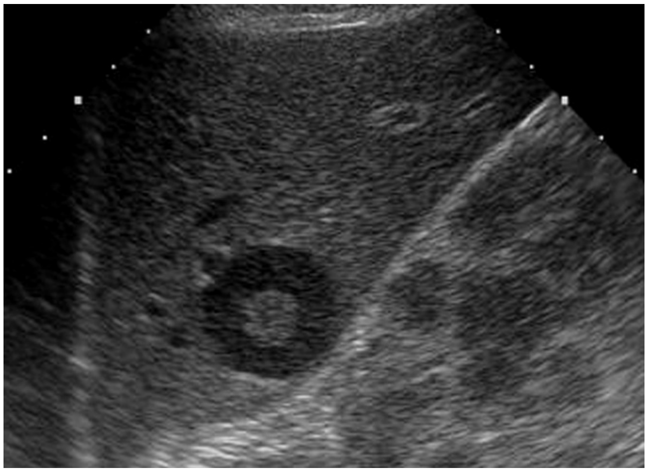


Figure S8-1. Gray scale sonographic image through the liver demonstrates a round hepatic lesion with isoechoic center and hypoechoic rim.

Figure S8-2. Axial CT image through the upper abdomen demonstrates innumerable hepatic masses, compatible with metastatic disease.

CASE 9

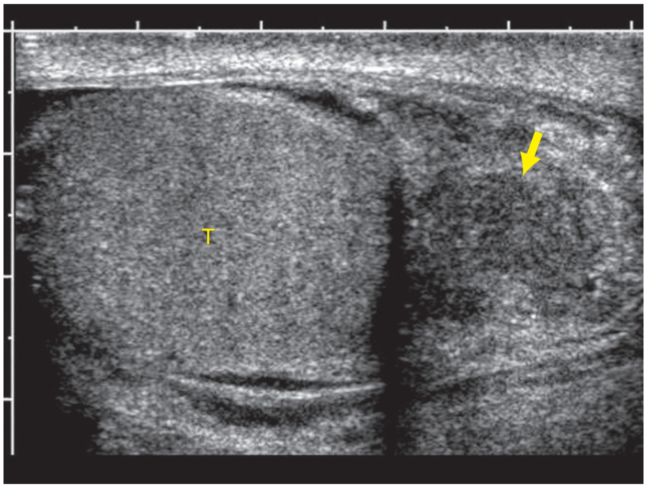


Figure S9-1. Enlarged epididymis (arrow) adjacent to the testis (T).

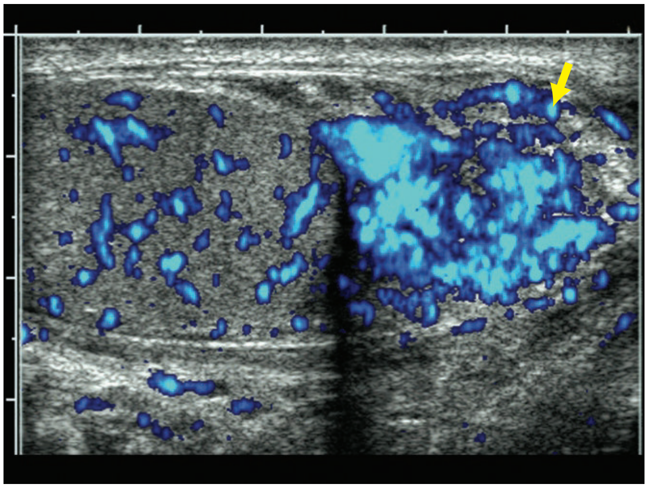


Figure S9-2. Increased color flow due to hyperemia of the epididymis (arrow).

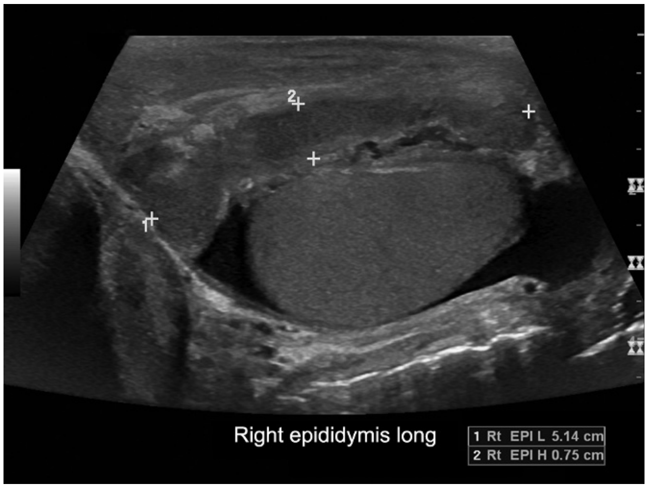


Figure S9-3. In another case, there is an enlarged epididymis (calipers).

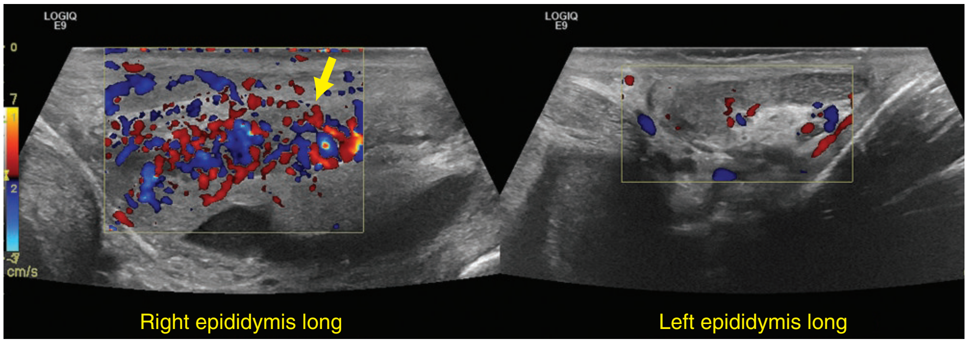


Figure S9-4. Color Doppler shows increased flow in the affected epididymis (arrow) as compared to the other side.

CASE 10

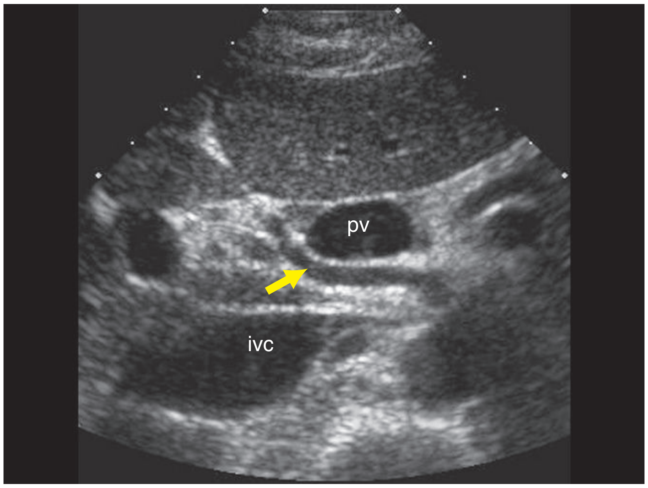


Figure S10-1. Transverse ultrasound of upper abdomen showing a tubular structure (arrow) posterior to portal vein (pv) that corresponds to replaced right hepatic artery. (Inferior vena cava = ivc).

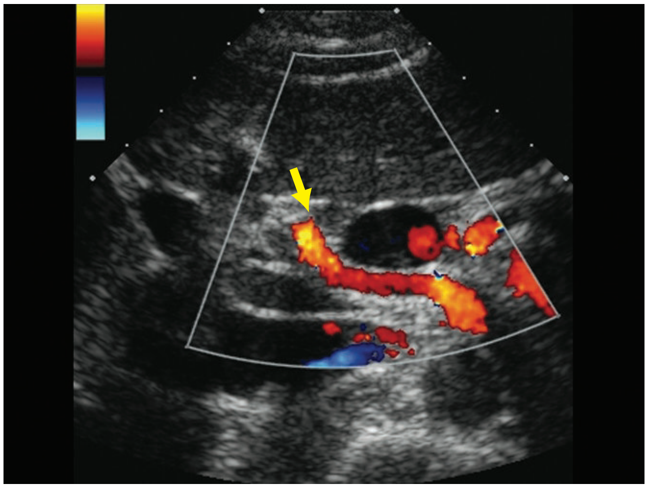


Figure S10-2. Color Doppler of the same image showing color flow in the replaced RT hepatic artery (arrow).

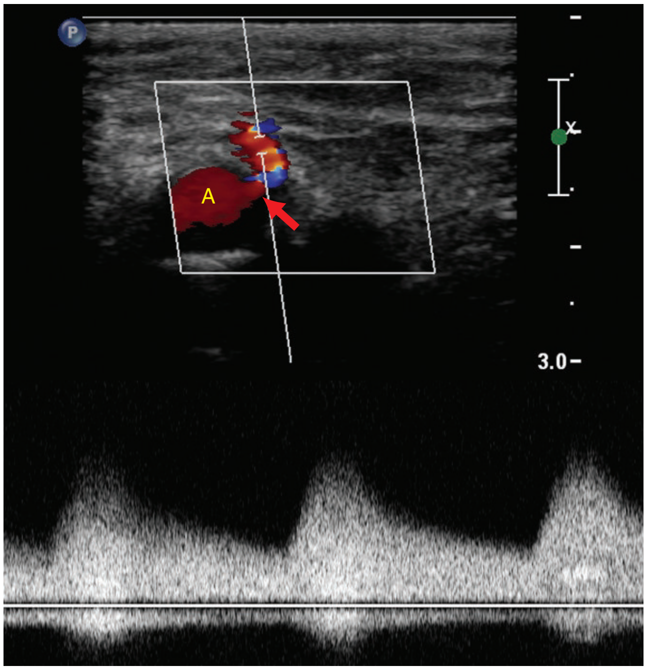


Figure S11-1. The common femoral artery (A) demonstrates a tract anteriorly at 3 o'clock (arrow). There is color aliasing in the tract. Spectral Doppler in the tract shows a low pulsatile waveform with high systolic and diastolic flow. The continuous forward flow is typical of an arteriovenous fistula and does not demonstrate the "to and fro" of a pseudoaneurysm neck nor the normal forward and reverse flow of a normal arterial branch.

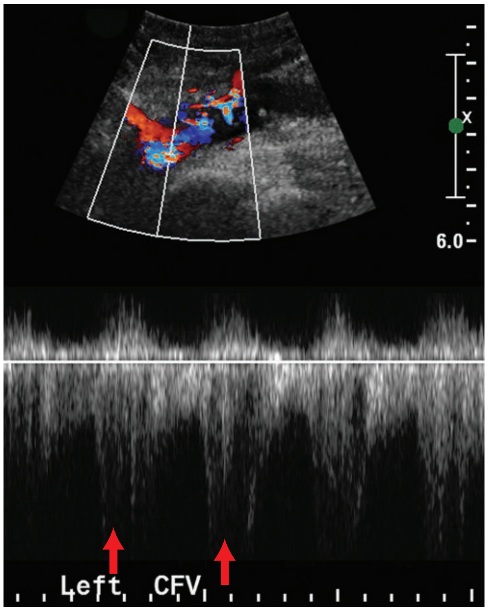


Figure S11-2. Color and spectral Doppler of the common femoral vein do not show the normal phasic variation. There is spectral broadening as well as forward and reverse flow. In addition there are periodic increases in the Doppler velocity (arrows) corresponding to systole. This is due to an inrush of arterial flow through the fistula in systole creating an "arterialized" venous waveform.

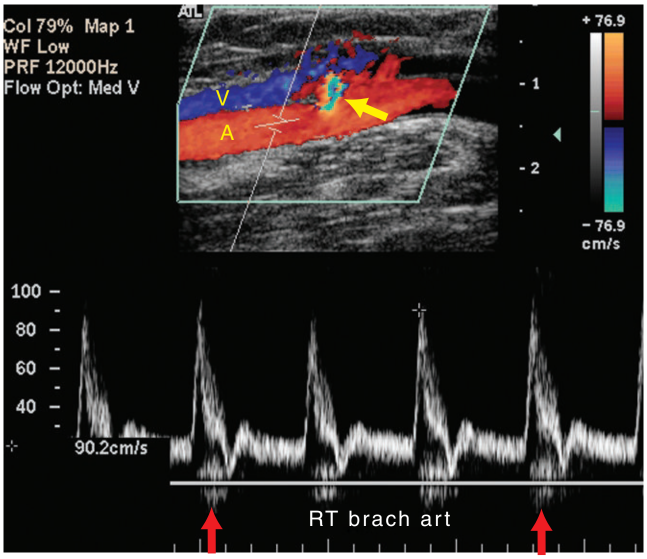


Figure S11-3. In a different case, the hemodynamic changes in the arterial waveform proximal to the fistula are shown. The site of the fistula is the region of high velocity aliasing (yellow arrow) with flow from brachial artery (A) to vein (V). Proximal to the fistula, the common brachial artery waveform shows increased diastolic flow without flow reversal. A systolic bruit in the spectrum is also noted (red arrows).

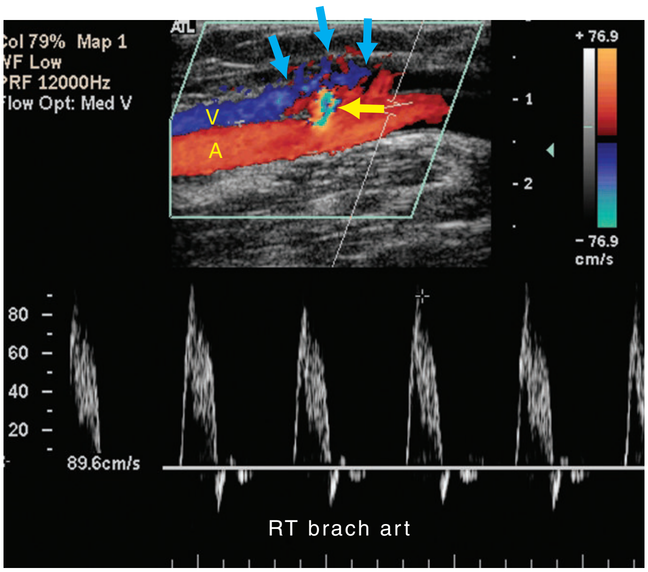


Figure S11-4. The brachial artery waveform (blue arrows) distal to the arteriovenous fistula (yellow arrow) returns to a normal multiphasic waveform with back and forth flow in diastolic and little forward diastolic flow.

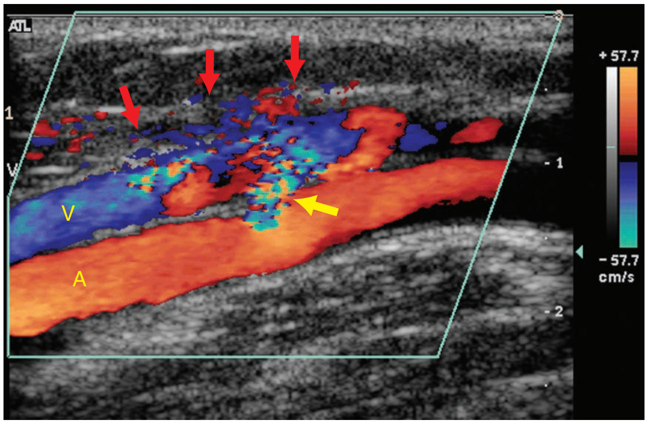


Figure S11-5. The turbulence in the arteriovenous fistula creates perivascular tissue vibrations (color bruit) outside the vessels (red arrows). The site of the fistula is seen as an area of color aliasing (yellow arrow) between the brachial artery (A) and vein (V).

CASE 12

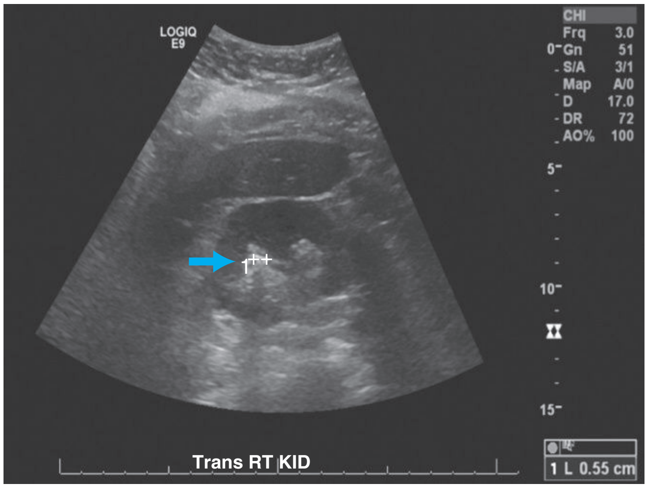


Figure S12-1. Gray scale ultrasound image demonstrates an echogenic focus with posterior acoustic shadowing (arrow).

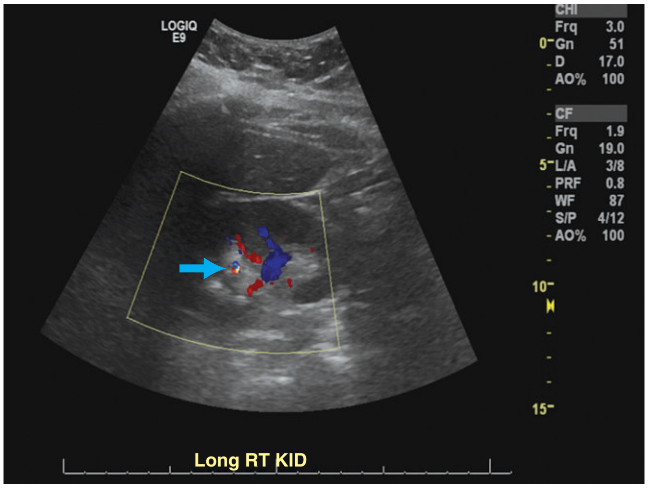


Figure S12-2. Color Doppler imaging of the same echogenic focus demonstrates the “twinkle artifact” posteriorly (arrow), most consistent with a renal stone.

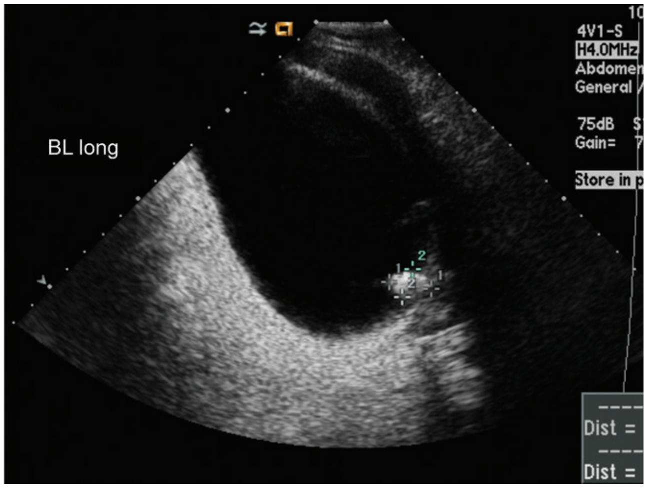


Figure S12-3. Gray scale ultrasound image demonstrates an echogenic focus (calipers) in the bladder with posterior acoustic shadowing.

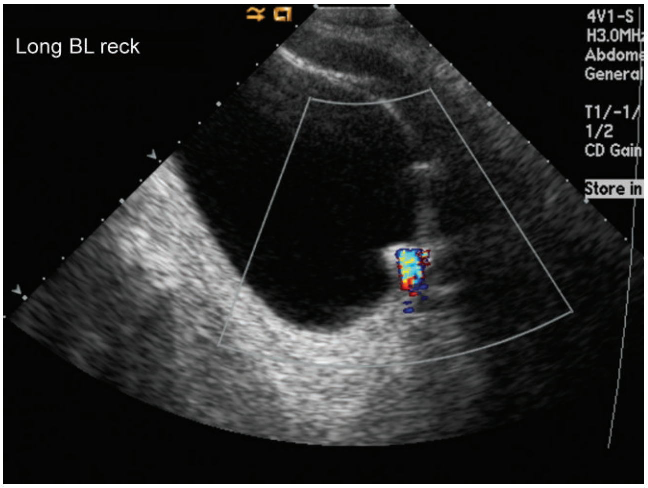


Figure S12-4. Color Doppler image of the same stone demonstrates “twinkle” artifact posterior to the stone.

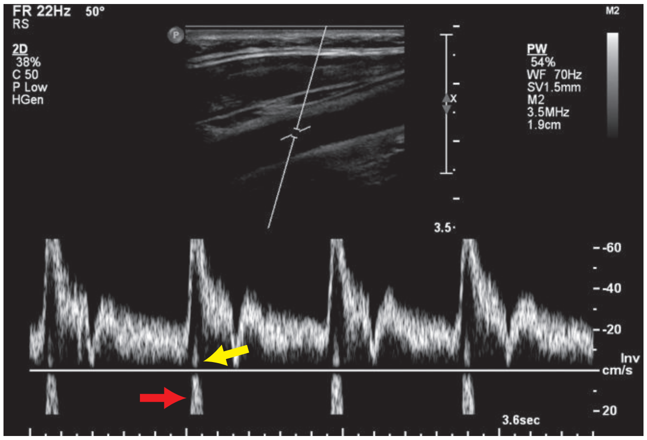


Figure S13-1. The common carotid artery waveform demonstrates spectral aliasing. The fastest moving, aliased, flow wraps around to below the baseline (red arrow) and continues into the correct direction (yellow arrow).

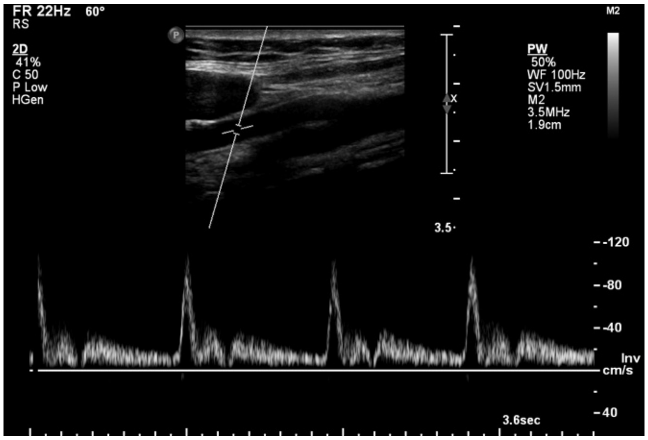


Figure S13-2. The external carotid artery (ECA) waveform is not aliased. Peak systolic velocity is 100 cm/s. The scale peak of 120 cm/s in the direction of the ECA flow is adequate to record its peak velocity without aliasing.

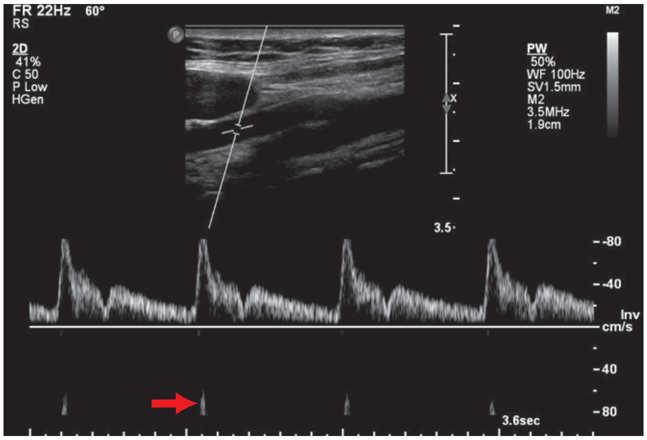


Figure S13-3. The ECA demonstrates a small amount of aliasing, just at the lower aspect of the spectrum below the baseline (arrow). The scale is incorrectly set to a peak of 80 cm/s.

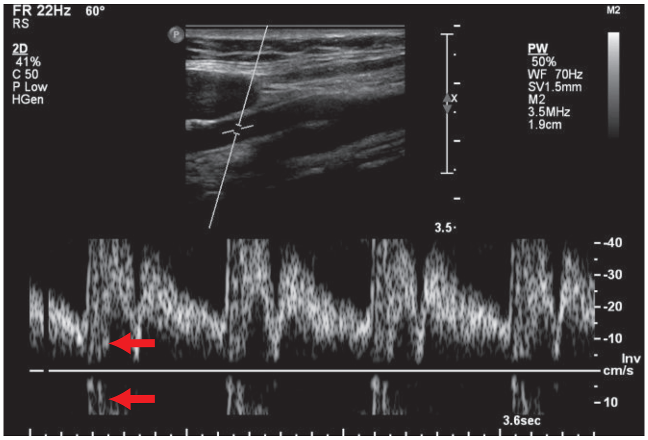


Figure S13-4. The ECA demonstrates more aliasing than Figure S13-3 since the scale is incorrectly set to a peak of 40 cm/s. In systole, the signal goes all the way through the proper direction above the baseline, all the way through the improper direction below the baseline, and back above the baseline (arrows). This could be mistaken for spectral broadening if aliasing is not recognized.

CASE 14

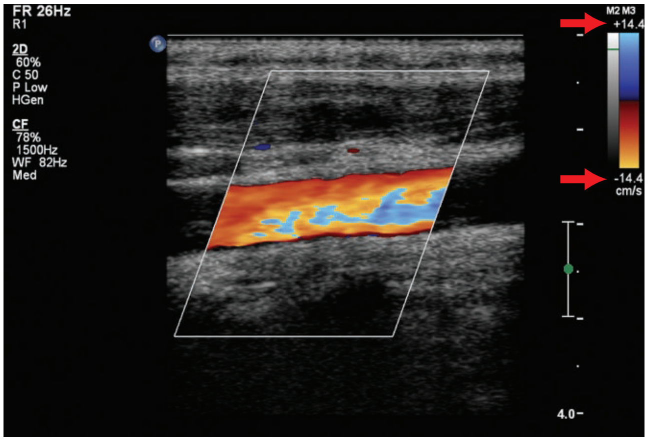


Figure S14-1. Color Doppler of the common carotid shows the vessel to be widely patent. The vessel is moving toward the head and should be red (away from the transducer). There is blue and yellow in the center of the vessel due to aliasing. Note the low color scale (arrows). A low scale improves color filling but can lead to the aliasing artifact.

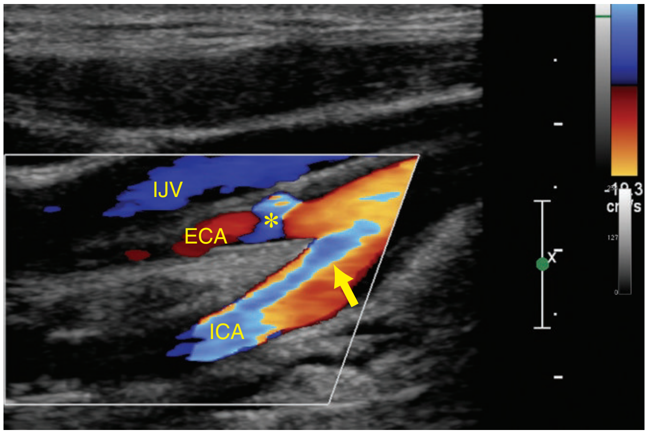


Figure S14-2. Color Doppler of the bifurcation demonstrates aliasing as the cause of the color in the internal carotid artery (ICA). The aliasing (arrow) changes from red and yellow (correct direction) and wraps around to light and dark blue (aliased direction). This is not due to stenosis but rather to the low Doppler scale, which demonstrates the faster moving blood in the center of the vessel. The internal jugular vein (IJV) is blue and demonstrates the correct direction of blood back to the heart (toward the feet). The external carotid artery (ECA) also has an area of blue (*). This is not due to aliasing but rather to flow reversal created by the bifurcation. Note the color changes but has a black line around it indicating true reversal.

CASE 15

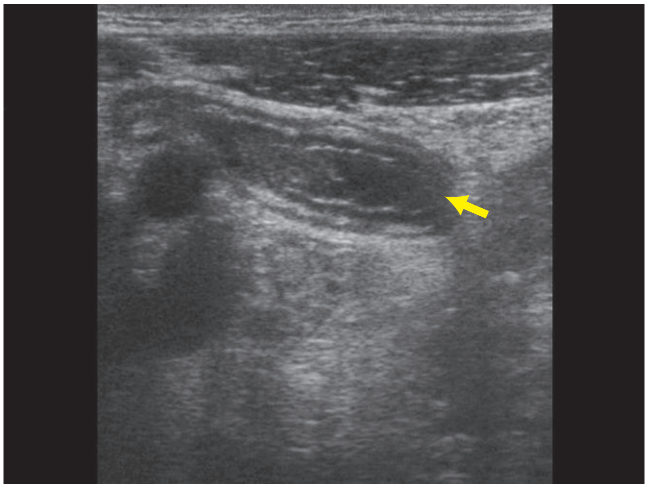


Figure S15-1. Ultrasound showing fluid-filled blind ending tubular structure (arrow) with surrounding echogenic mesentery fat.

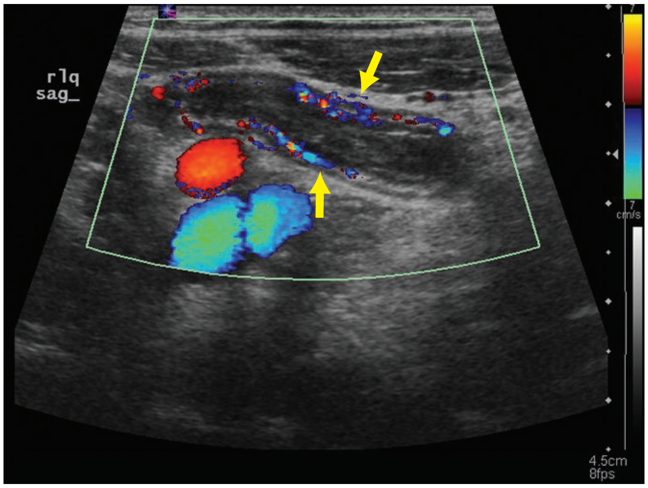


Figure S15-2. Increased color flow of the acutely inflamed appendix (arrows).

CASE 16

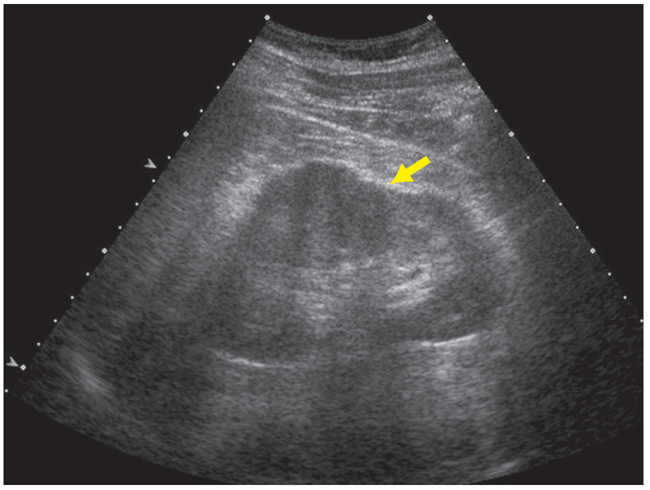


Figure S16-1. Ultrasound of the left kidney demonstrates the appearance of a hypoechoic mass within the mid pole of the left kidney causing bulging of the kidney (arrow).

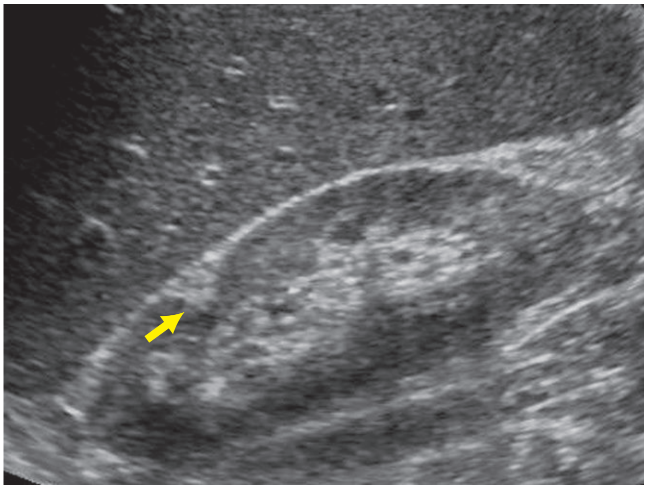


Figure S16-2. Longitudinal view of the right kidney demonstrates echogenic focus in the anterior portion of the upper right pole of the kidney (arrow).

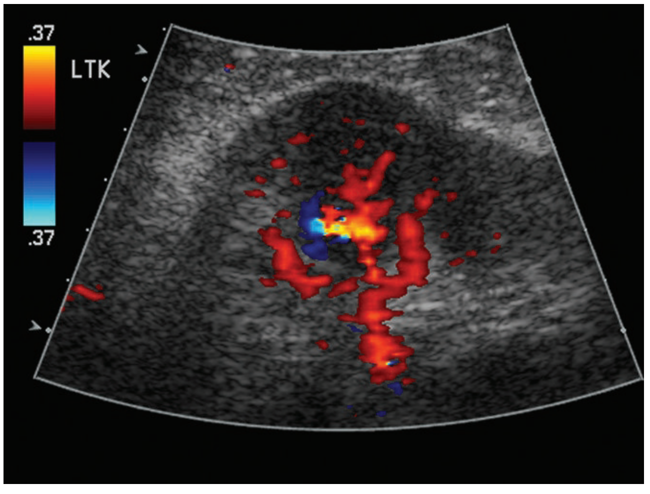


Figure S16-3. Color Doppler through that region demonstrating similar Doppler appearance between that region and the rest of the kidney. There is no displacement of vessels.

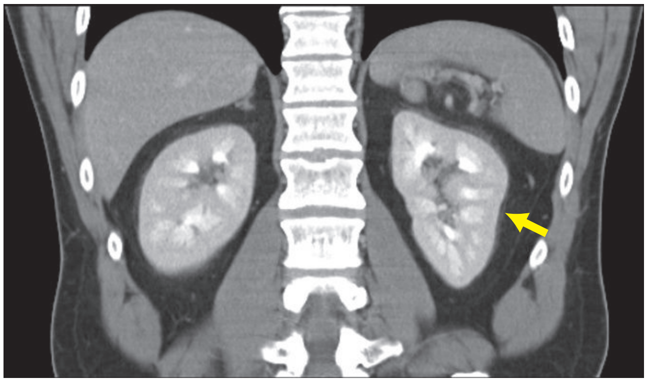


Figure S16-4. Coronal reconstructed CT demonstrates a normal variation of “dromedary hump” (arrow).

CASE 17

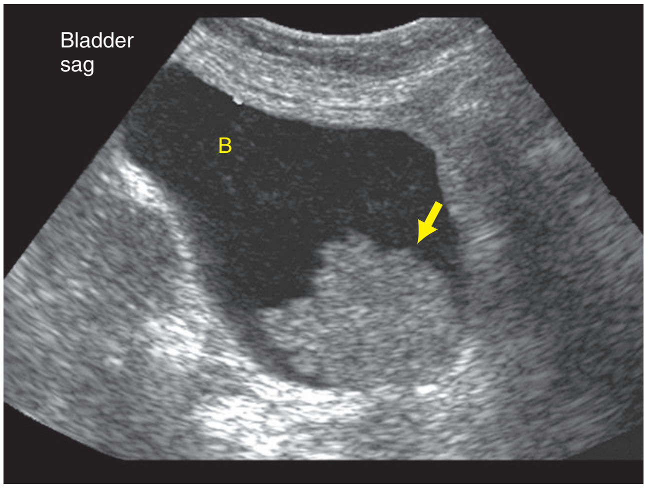


Figure S17-1. Longitudinal ultrasound of the bladder (B) demonstrating echogenic mass (arrow).

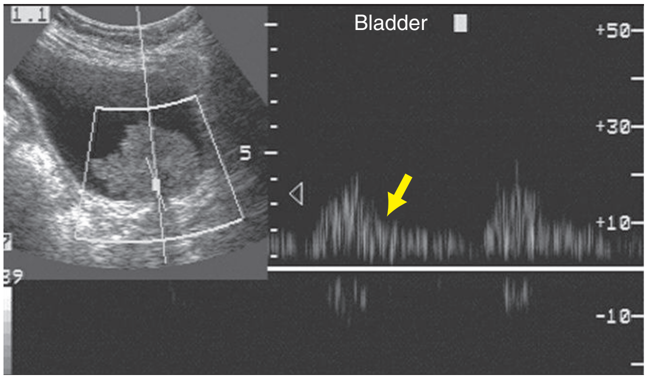


Figure S17-2. Pulse Doppler waveform through the mass demonstrating arterial flow (arrow).

CASE 18

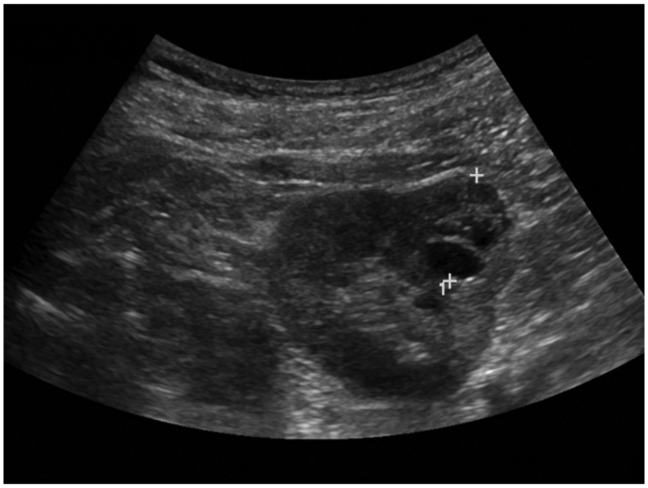


Figure S18-1. Real time ultrasound exam of the left kidney demonstrates a multi-septated mass with cystic and solid components noted within the left kidney

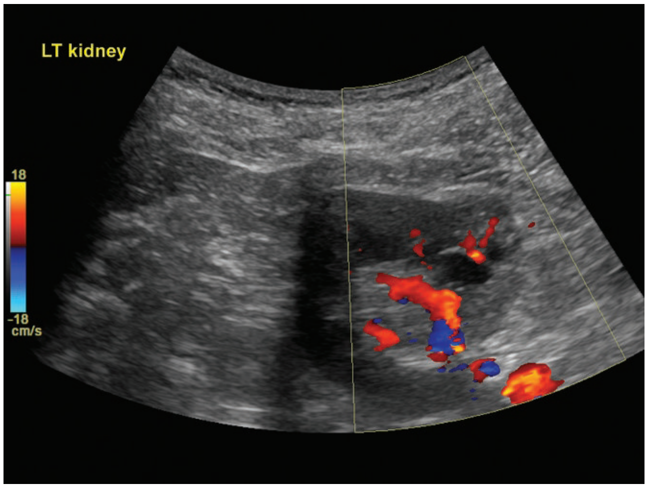


Figure S18-2. Color Doppler ultrasound demonstrates much of the mass as internal vascularity with thick septa and solid components.

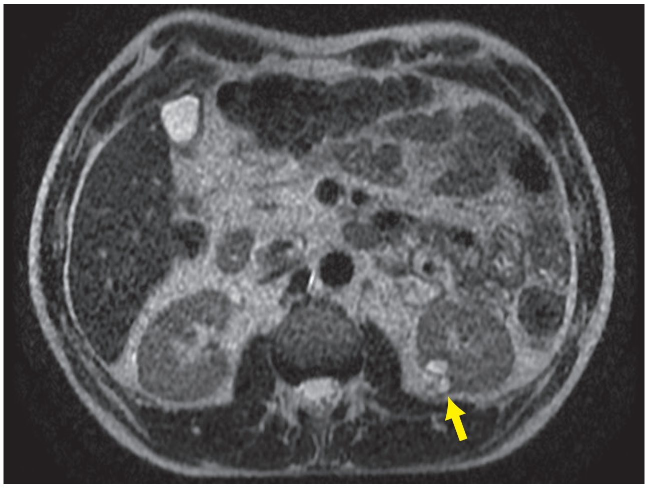


Figure S18-3. Attenuated MRI showing this multi-septated mass in the left kidney (arrow).

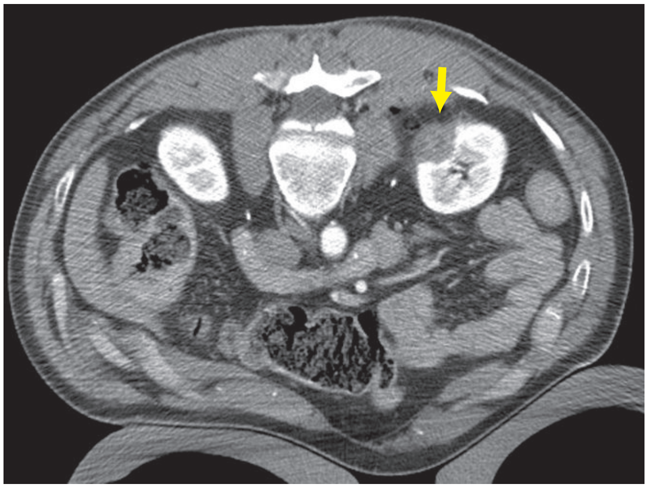


Figure S18-4. A contrast-enhanced CT scan performed immediately after radiofrequency ablation of the mass demonstrates the mass has been completely ablated and there is no evidence of any enhancement (arrow).

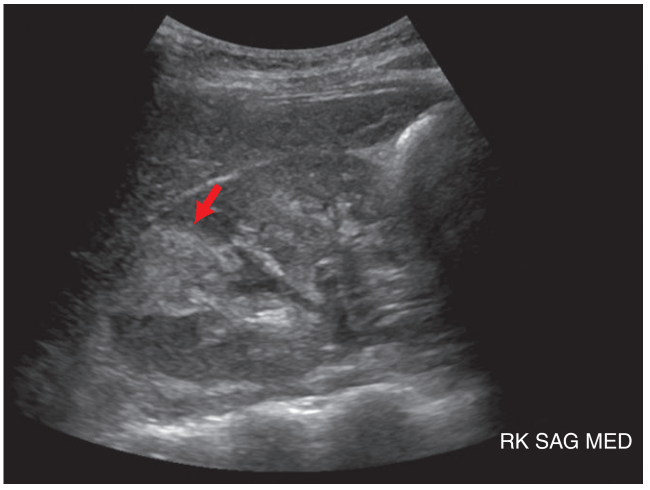


Figure S19-1. Sagittal ultrasound without color demonstrates well-demarcated echogenic region seen within this superior pole of the right kidney (arrow).

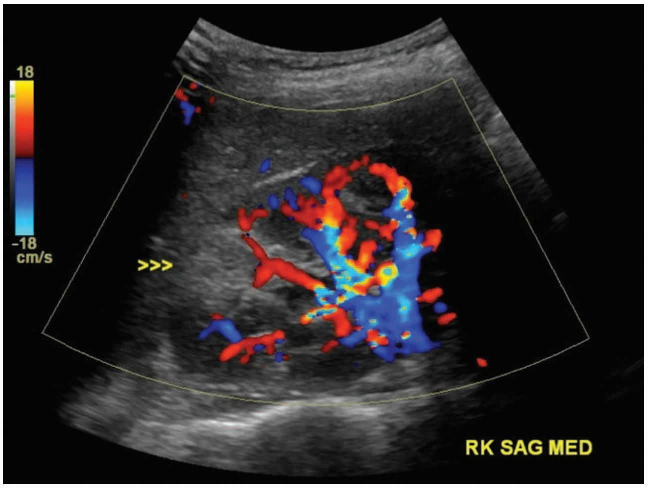


Figure S19-2. Color Doppler ultrasound of the right kidney demonstrates the echogenic region without color flow seen in the superior pole (arrowheads).

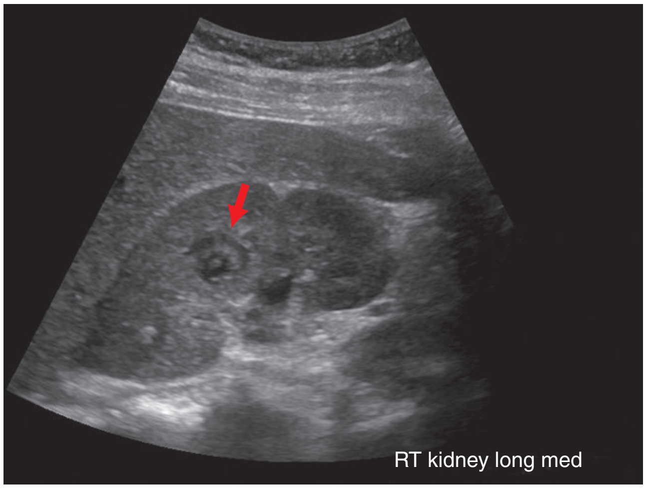


Figure S19-3. Longitudinal ultrasound in another patient demonstrating hypoechoic region noted within the right kidney corresponding to a small renal abscess (arrow).

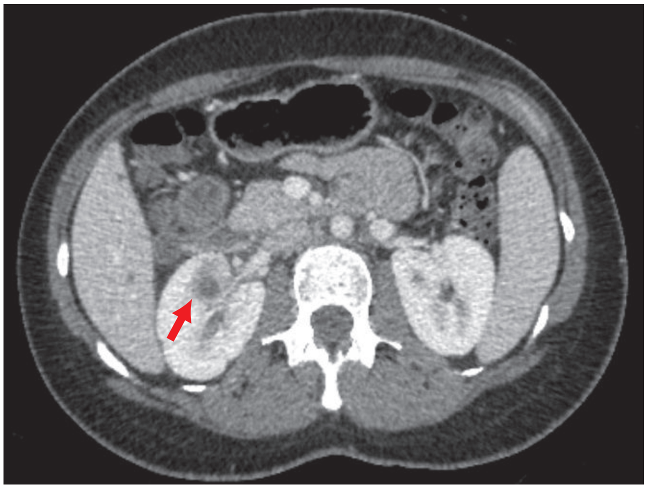


Figure S19-4. Contrast-enhanced CT demonstrating an area of decreased density noted within the right kidney (arrow).

CASE 20

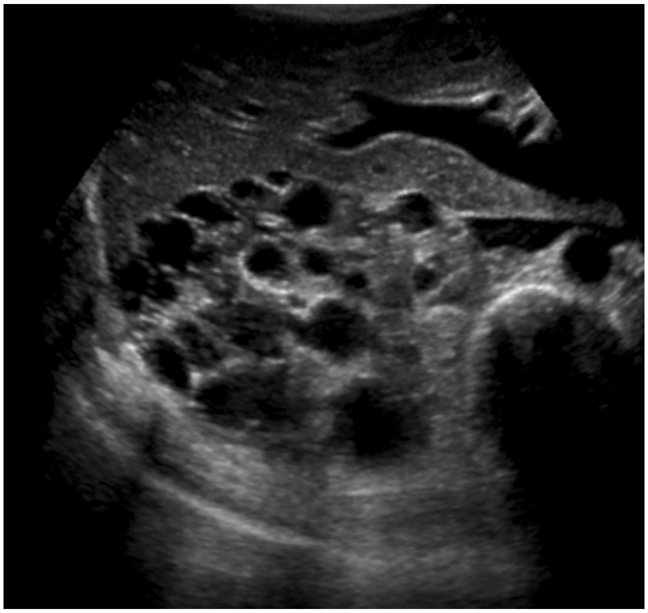


Figure S20-1. Image of the right kidney demonstrates multiple unilocular, anechoic lesions.

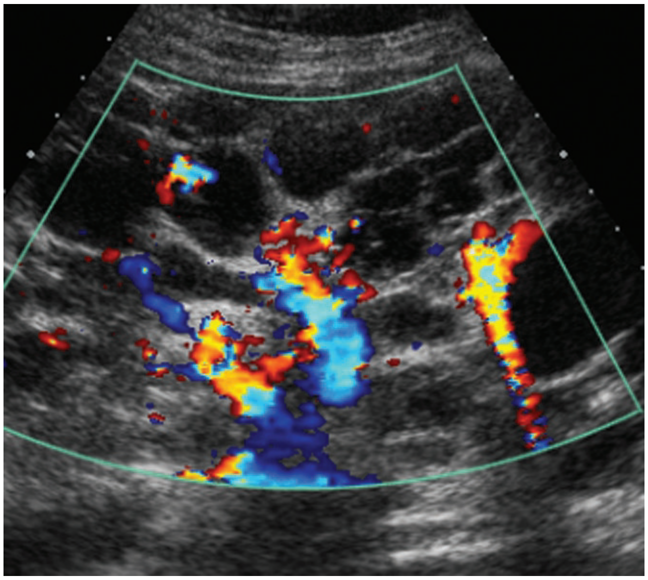


Figure S20-2. Doppler evaluation of the left kidney does not demonstrate internal vascularity.

Figure S20-3. CT demonstrates multiple bilateral renal cysts.

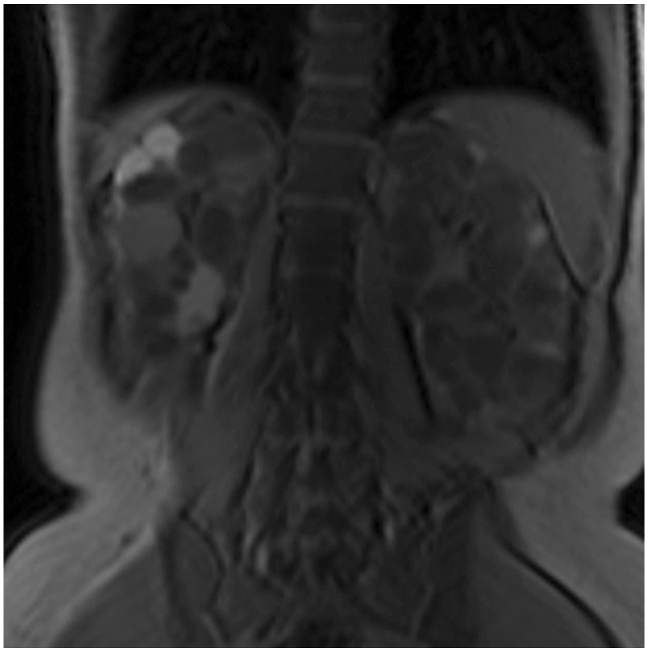


Figure S20-4. MRI demonstrates multiple bilateral cysts.

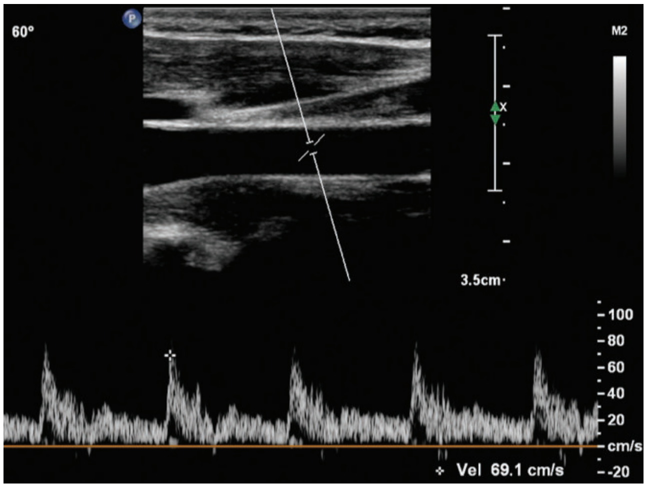


Figure S21-1. Spectral Doppler angle correction is incorrect. The angle is set at 60 degrees but it is not aligned to the walls of the vessel.

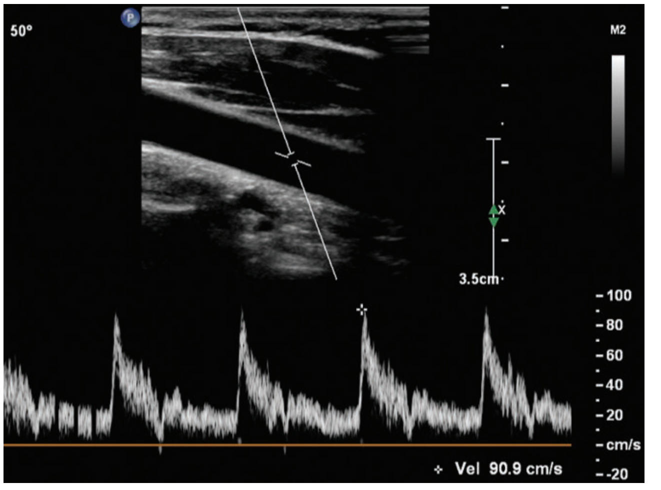


Figure S21-2. Spectral Doppler angle correction is correct. The angle is set parallel to the vessel walls. The Doppler angle is 50 degrees. A Doppler angle at or less than 60 degrees is acceptable. Note the difference in peak systolic velocity between Figures S21-1 and S21-2; 69 and 90 cm/s is a significant difference.

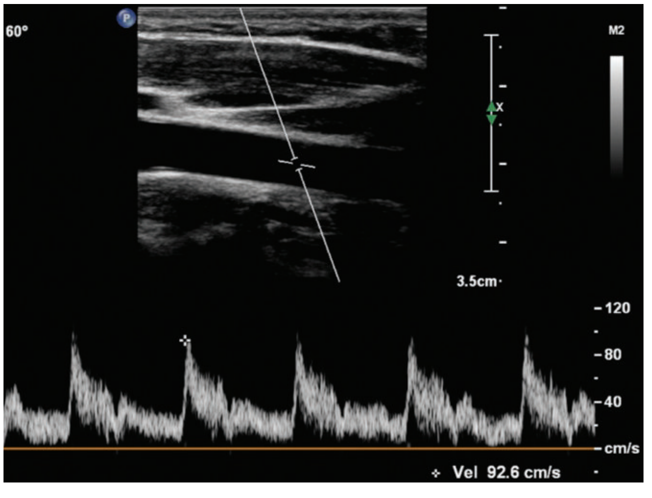


Figure S21-3. Spectral Doppler angle correction is correct and set at 60 degrees, which is acceptable. Note the little difference between 60 degrees and 50 degrees, 92 versus 90 cm/s.

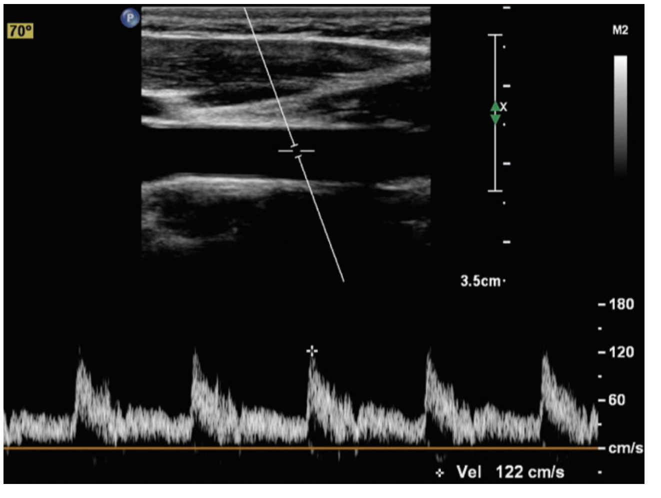


Figure S21-4. Spectral Doppler angle correction is incorrect. The vessel is at too high an angle (70 degrees) for an acceptable measurement. Note the large difference between 60 degrees, 122 versus 92 cm/s.

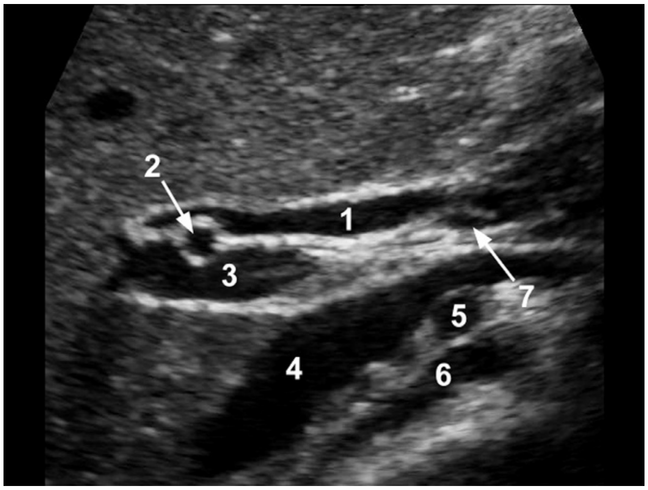


Figure S22-1. Longitudinal image of the porta hepatis with the following structures (1=common hepatic duct, 2=right hepatic artery, 3=portal vein, 4=inferior vena cava, 5=right renal artery, 6=crus of the diaphragm, 7=cystic duct).

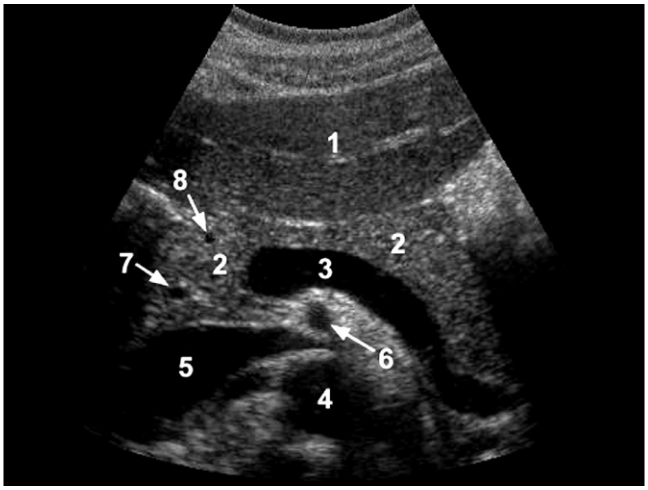


Figure S22-2. Transverse image of the peripancreatic area (1=left lobe of the liver, 2=pancreas, 3=portosplenic confluence, 4=aorta, 5=inferior vena cava, 6=superior mesenteric artery, 7=common bile duct, 8=gastro duodenal artery).

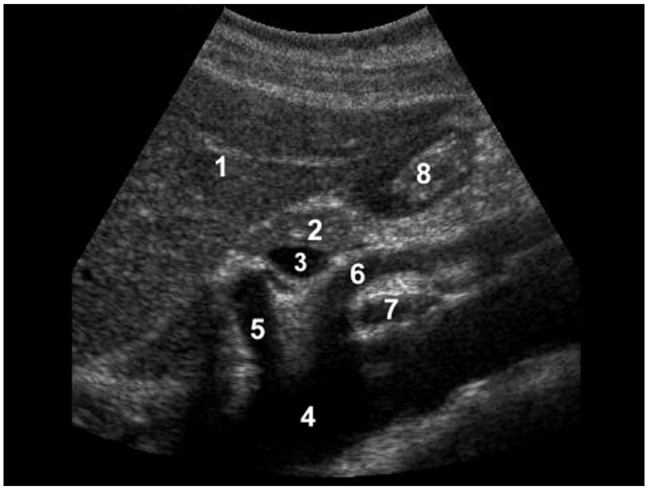


Figure S22-3. Longitudinal image of the abdomen (1=left lobe of the liver, 2=pancreas, 3=splenic vein, 4=aorta, 5=celiac axis, 6=SMA, 7=left renal vein, 8=gastric atrium).

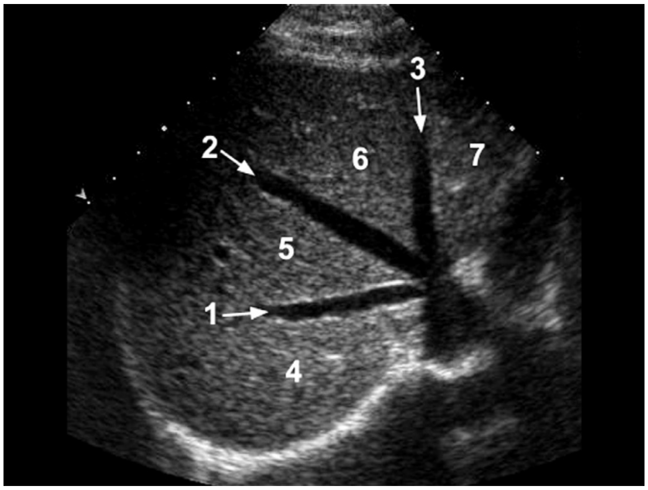


Figure S22-4. Transverse views of the liver (1=right hepatic vein, 2=middle hepatic vein, 3=left hepatic vein, 4=posterior segment 7, 5=anterior segment 8, 6=segment 4A, 7=segment 2 of the liver).

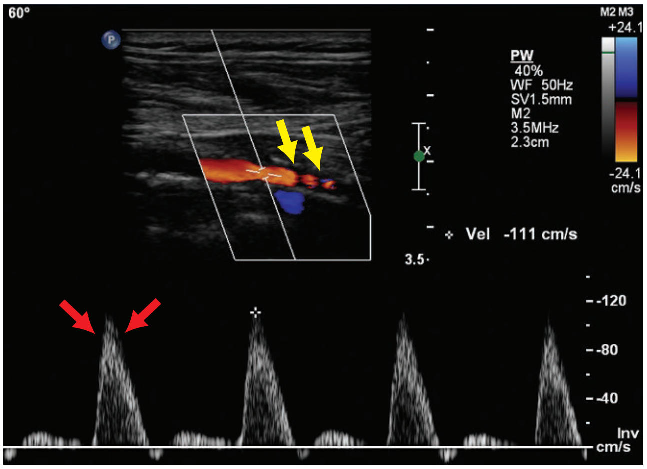


Figure S23-1. The popliteal artery demonstrates plaque and mild narrowing in the proximal popliteal artery. There is some dropout of the color lumen due to plaque (yellow arrows). Before the stenosis, the spectral analysis demonstrates a normal multiphasic waveform with a peak systolic velocity of 111 cm/s. Note there is minimal spectral broadening and the edge of the spectrum is whiter (red arrows) than the lower velocities below it in systole.

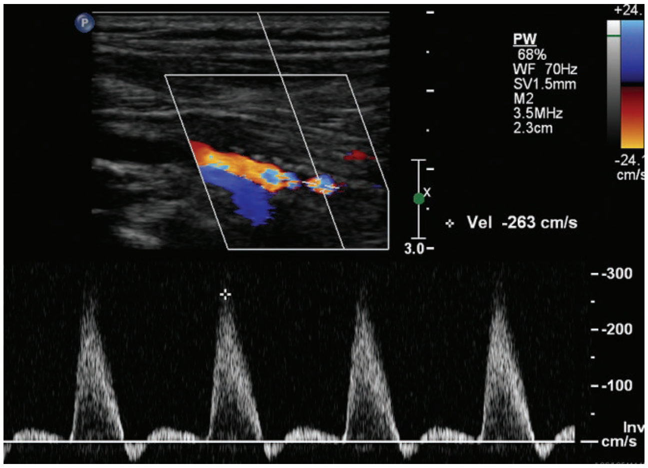


Figure S23-2. There is aliasing and narrowing in the mid popliteal artery. A spectral Doppler in the narrowing demonstrates increased velocity of 263 cm/s. The peak systolic velocity ratio is 2.4 indicating a stenosis greater than 50%.

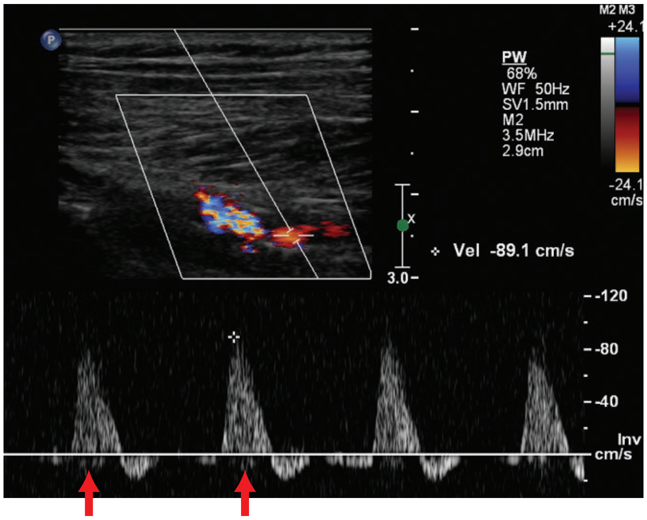


Figure S23-3. Beyond the area of stenosis, the velocity decreases to 89 cm/s. There is poststenotic disturbed flow. There is spectral broadening. The edge of the spectrum and the lower velocities below it are equal shades of gray. There is a small amount of simultaneous reversed flow in systole (arrows).

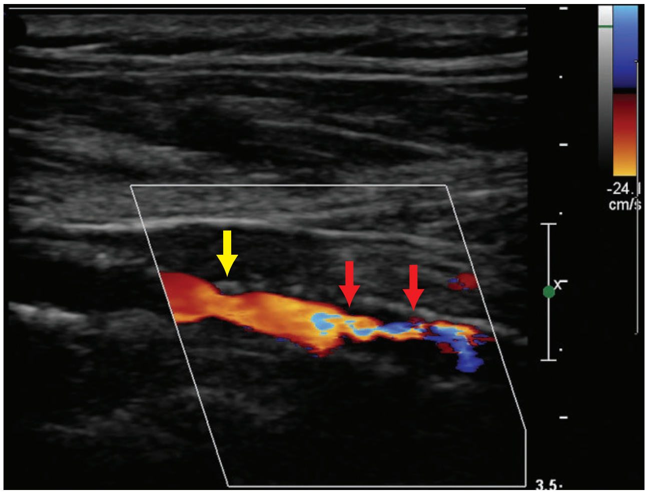


Figure S23-4. Color Doppler of the area of interest is optimized to show the narrowing of the popliteal artery. In a milder stenosis there is no change in color (yellow arrow). In the region of greater narrowing measured on Figure S23-2 there is narrowing and aliasing (red arrows) with a mixture of colors.

CASE 24

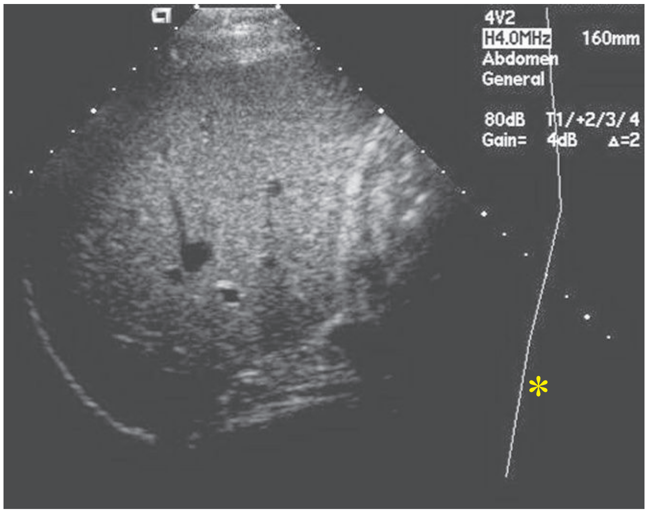


Figure S24-1. Improper time gain compensation. The liver is not uniform. While this could be due to attenuation from fatty liver, the actual cause is that weak deeper signals are not amplified enough. The gain curve is lower in the deep tissue (*) than in the more superficial. This is incorrect technique since the distance gain curve must compensate for the normal attenuation of sound by tissue.

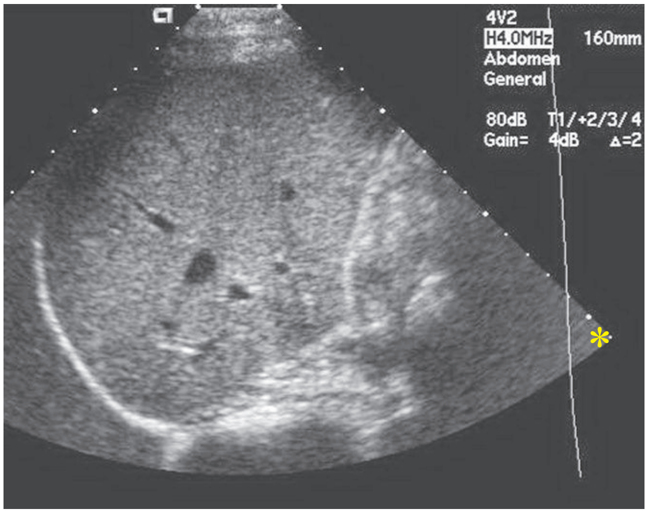


Figure S24-2. Proper time gain compensation. The curve amplifies the deeper tissue (*) more than the superficial tissue and is a satisfactory time gain compensation curve. The liver is uniform, and normal echoes are seen throughout the image. The probe (4V2), the frequency (H4.0MHz), the depth (160mm), and the overall gain (4dB) are the same in Figs. S24-1 and S24-2.

CASE 25

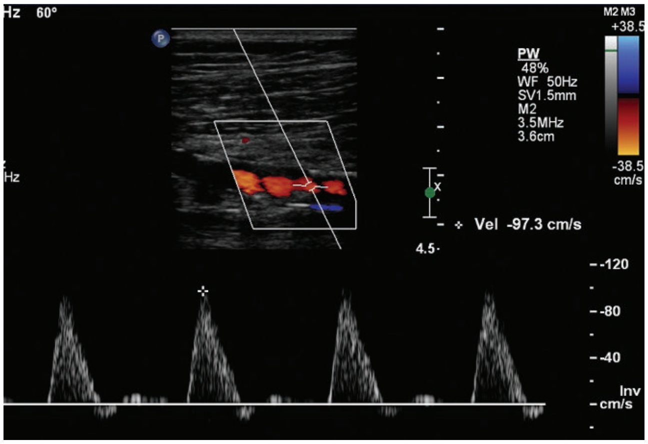


Figure S25-1. Color duplex Doppler of the superficial femoral artery demonstrates plaque and mild narrowing in the artery. The waveform shape is normal multiphasic (triphasic) with minimal spectral broadening in systole. The velocity in the vessel is within normal limits.

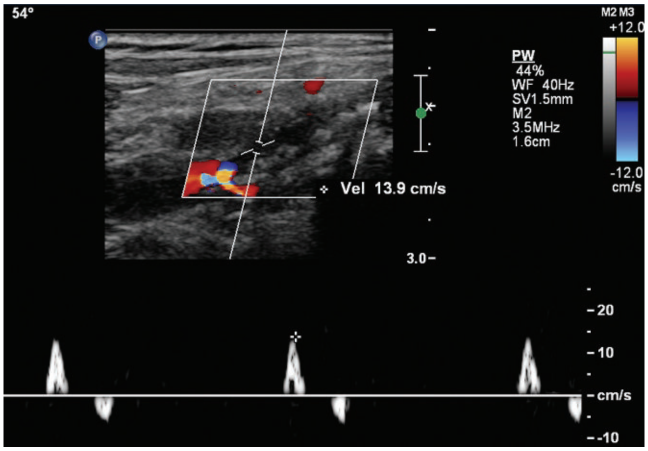


Figure S25-2. Color duplex Doppler of the popliteal artery shows an abnormal staccato waveform. The forward component has the characteristic shape with a rapid upstroke and immediate downstroke. There is virtually no reverse component. Peak systolic velocity is low, 14 cm/s, and reflects the low flow through the artery at this level. The absence of color in the vessel is a function of the absent flow and, to a lesser degree, attenuation of color signal by the plaque.

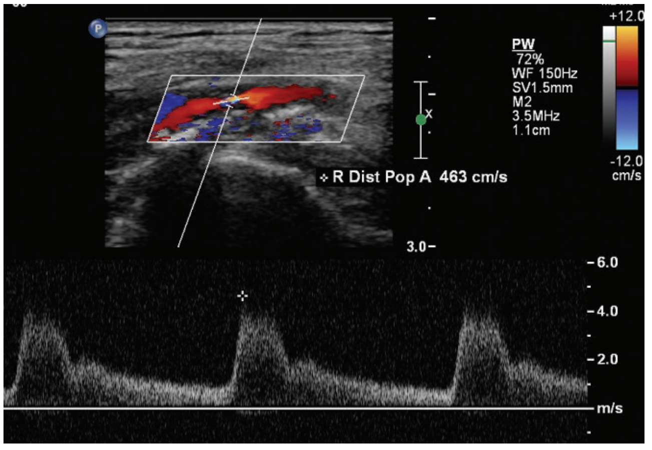


Figure S25-3. Popliteal artery stenosis is identified distal to the site obtained in Figure S25-2 , demonstrating a short area of narrowing with marked velocity elevation to 463 cm/s compared with the velocity before the stenosis. Color demonstrates the vessel is patent before and after the stenosis and aliasing in the site of narrowing. Blue outside the vessel is color noise.

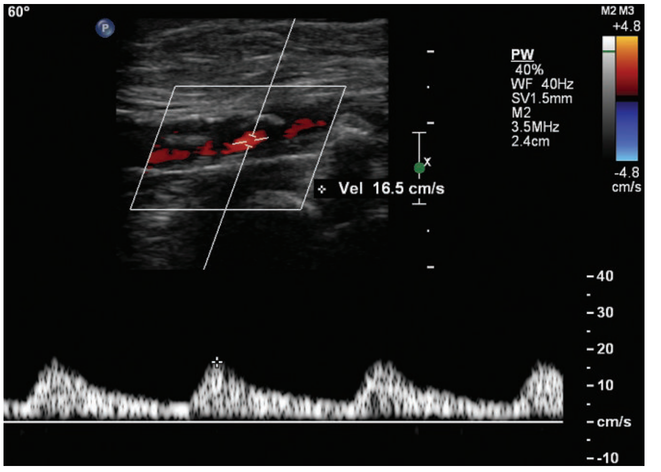


Figure S25-4. Distal to the stenosis, the distal popliteal artery waveform is tardus parvus. The velocity is low, 16 cm/s, there is prolonged time to peak velocity, and there is continuous antegrade flow.

CASE 26

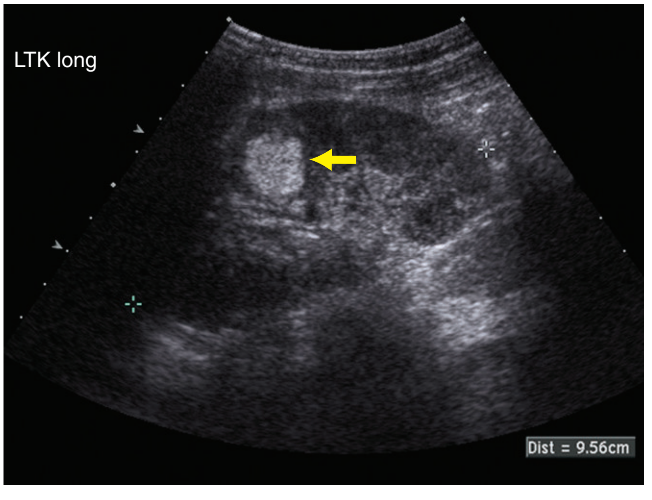


Figure S26-1. Real-time ultrasound examination of the left kidney demonstrates a well-demarcated echogenic mass (arrow) within the mid pole of the left kidney.

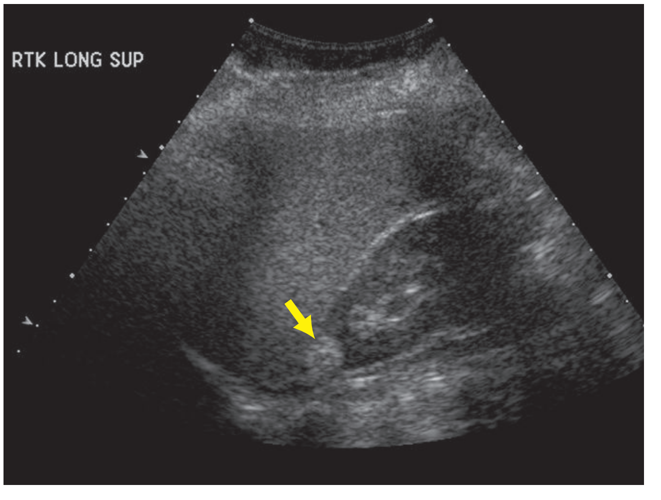


Figure S26-2. Real-time ultrasound examination of the right kidney demonstrates a well-demarcated echogenic mass (arrow) in the upper pole of the right kidney.

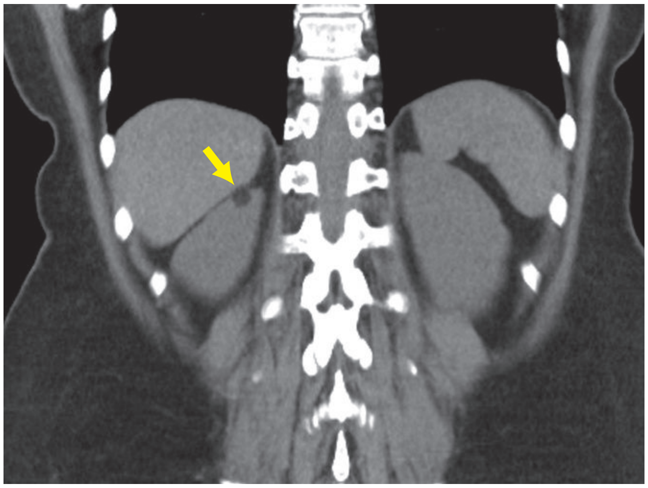


Figure S26-3. Reconstructed CT scan of the abdomen shows a well-demarcated mass (arrow) in the upper pole of the right kidney. Hounsfield units of this mass were –55.

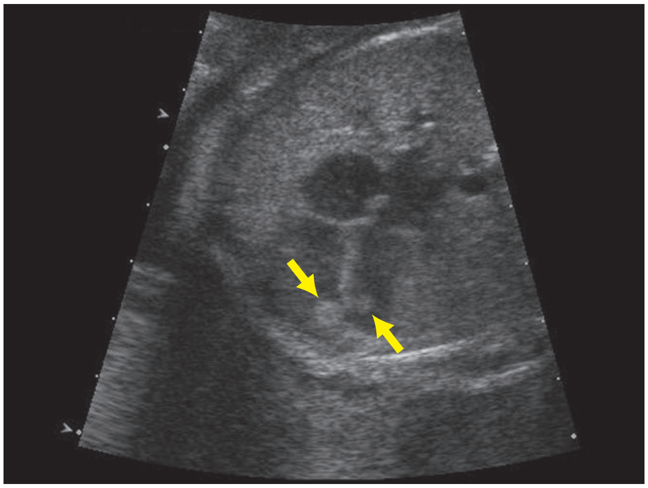


Figure S26-4. In utero fetal ultrasound demonstrating multiple echogenic masses (arrows) both within the right and the left ventricle of the heart corresponding to multiple cardiac rhabdomyomas.

CASE 27

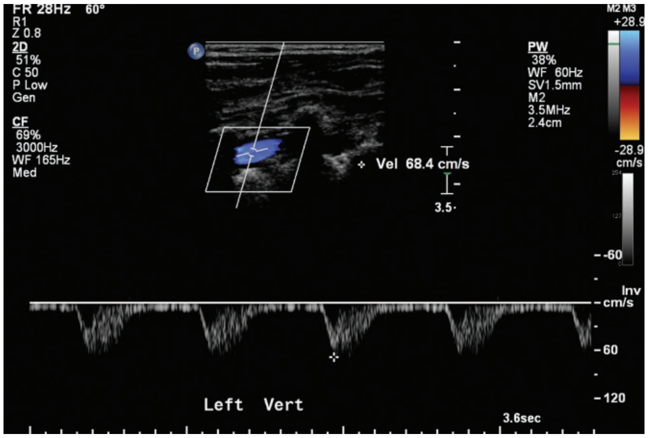


Figure S27-1. The vertebral artery color Doppler is blue, toward the transducer and toward the feet. The spectral Doppler is below the baseline, but the spectrum is inverted (Inv at right end of the scale). The direction of flow is therefore toward the transducer (+68.4 cm/s) and toward the feet. The flow is continuous toward the feet indicating a complete subclavian steal.

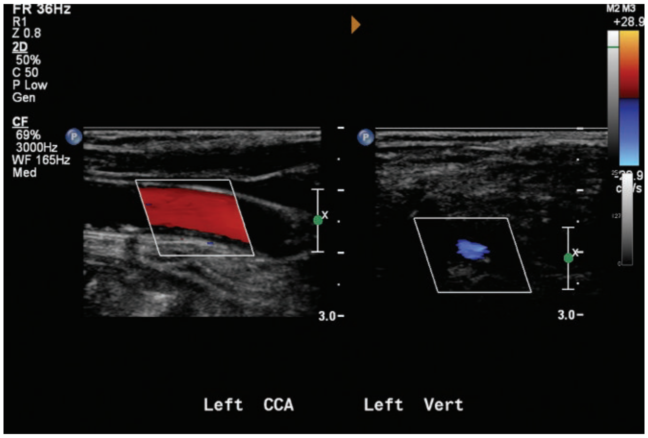


Figure S27-2. The vertebral artery color Doppler is blue, in opposite direction than the red common carotid artery. The vertebral artery flow is toward the feet.

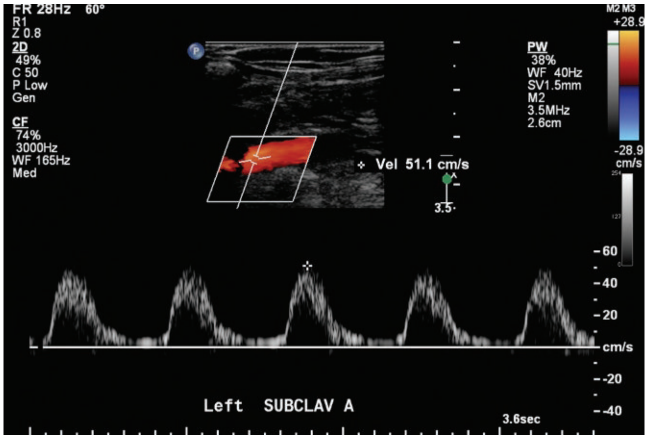


Figure S27-3. The left subclavian artery waveform shows a typical waveform of an artery distal to an obstruction. The upstroke is delayed, the top of the waveform is rounded, and the downstroke is also rounded. There is no reversal during diastole, instead there is continuous antegrade flow during the entire cardiac cycle. This waveform is described as monophasic continuous (monophasic refers to all of the flow is in one direction).

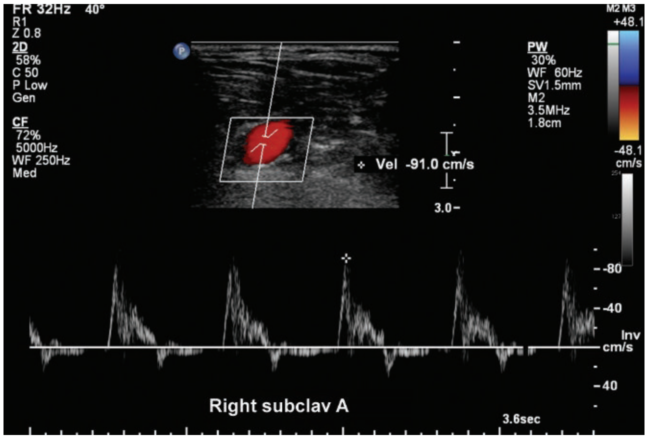


Figure S27-4. The comparison normal right subclavian artery waveform demonstrates a brisk upstroke, a sharp downstroke, and reversed diastolic flow. This waveform is described as multiphasic (multiphasic means the waveform has components in the forward and back directions).

CASE 28

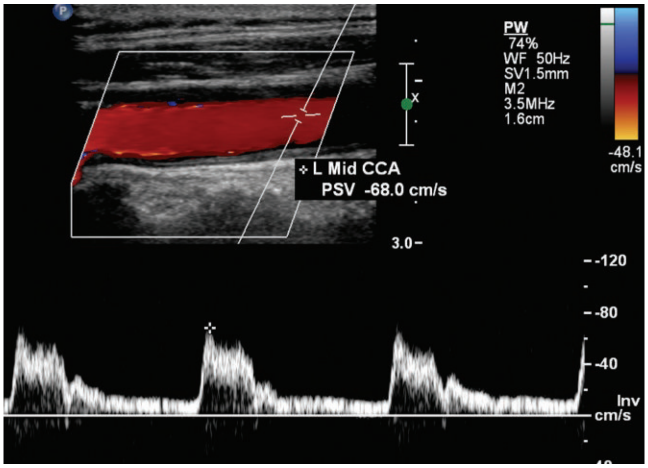


Figure S28-1. Left common carotid artery spectral and color Doppler shows the velocity is 68 cm/s.

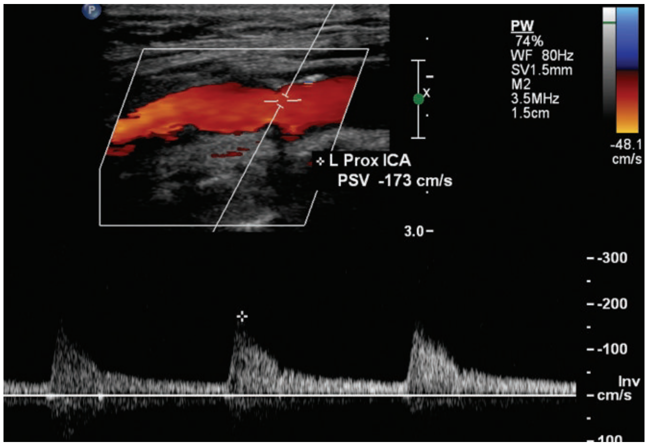


Figure S28-2. There is plaque narrowing the color lumen of the internal carotid. The peak systolic velocity (PSV) in the internal carotid artery is elevated to 173 cm/s confirming a stenosis. The IC:CC ratio is 2.5, also indicative of a stenosis.

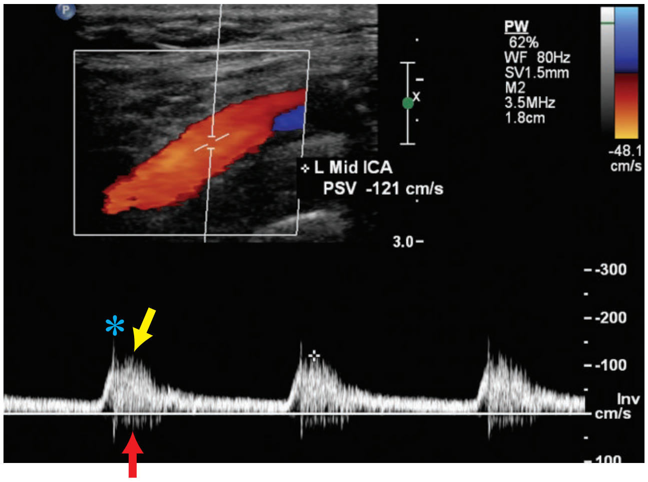


Figure S28-3. The peak velocity diminishes to 121 cm/s and there is turbulence in the waveform. Turbulence is identified by simultaneous forward and reverse flow (red arrow) and an irregular edge of the waveform with transient higher velocities creating a picket fence appearance (yellow arrow). The highest transient velocity (*) may be higher than the velocity of the blood flow and should not be used to measure peak systolic velocity. The correct velocity is measured on the second waveform.

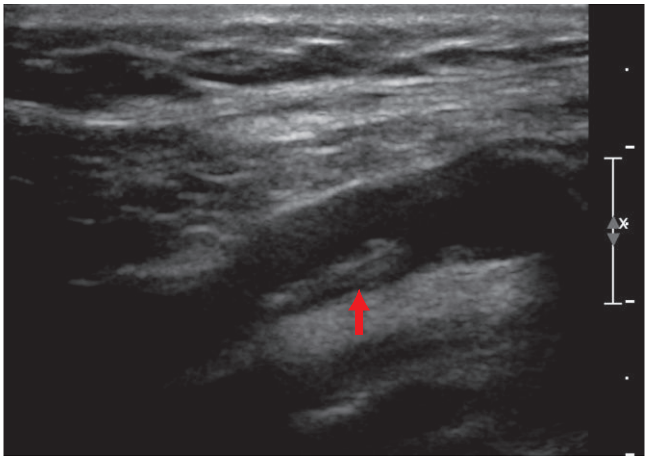


Figure S28-4. Gray scale ultrasound of the left internal carotid artery demonstrates plaque narrowing the lumen (arrow). The color Doppler in Figure S28-3 may underestimate the amount of plaque because the color can overwrite the lumen or, since plaque is eccentric, the scan can be over a less involved section of the vessel. Estimates of the amount of plaque should be made with gray scale, not color Doppler.

CASE 29

Figure 29-1. A 25-year-old male with an enlarged hypoechoic appearing right kidney.

Figure 29-2. Two-month follow-up ultrasound of the right kidney, which is now small kidney, and increased cortical echogenicity. This is a case of treated lymphoma.

CASE 30

Figure S30-1. Image of the gallbladder in a patient with recent placement of biliary drainage tube demonstrates a nonshadowing echogenic mass.

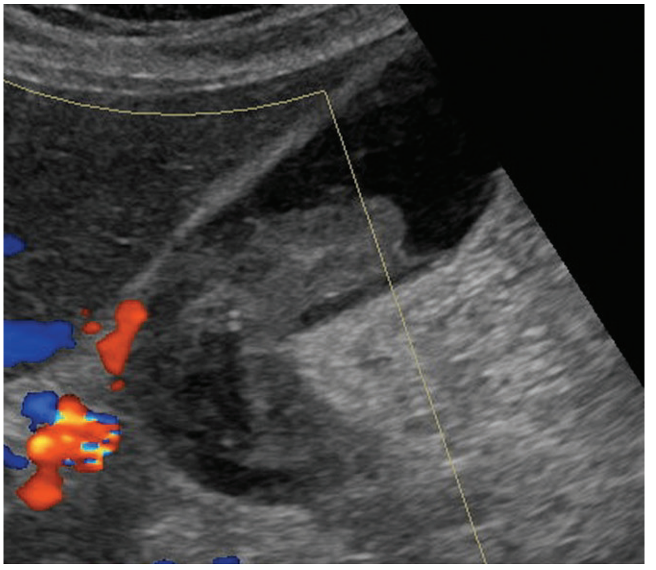


Figure S30-2. Doppler evaluation does not demonstrate internal vascularity.

CASE 31

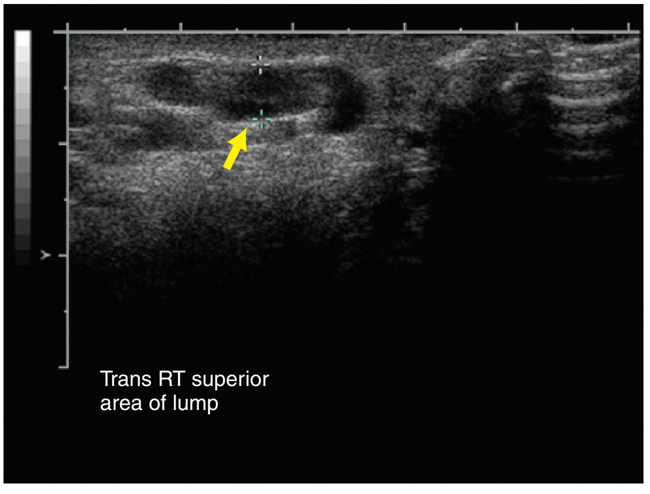


Figure S31-1. Transverse gray scale ultrasound through the right scrotal region shows a dilated 4.9-mm tubular structure just cephalad to the superior pole of the testis (arrow).

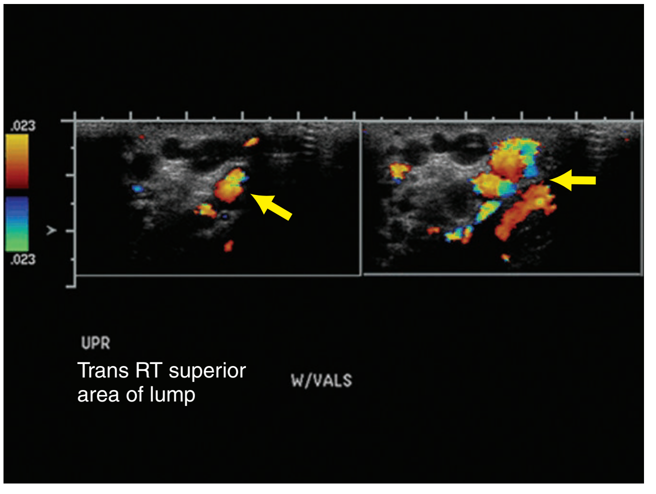


Figure S31-2. Transverse ultrasound with color Doppler upright and with valsalva (side by side, respectively) confirms that the hypoechoic serpiginous structures are indeed vessels and increase in caliber with valsalva maneuver (arrow). This is characteristic for varicocele.

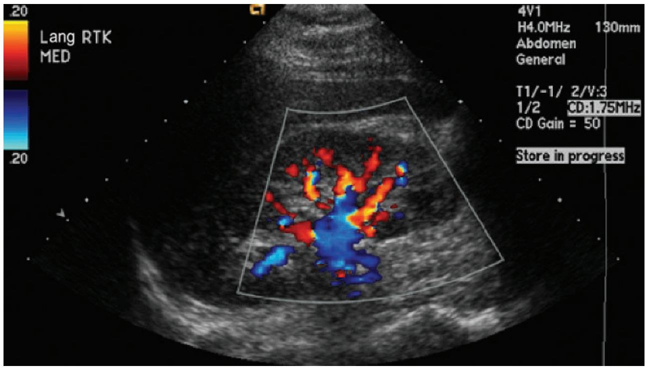


Figure S31-3. Longitudinal ultrasound with color Doppler of the right kidney shows that the right renal vein is patent. The IVC was also patent (not shown). In cases of right-sided varicocele, especially if acute, the kidney should be interrogated.

CASE 32

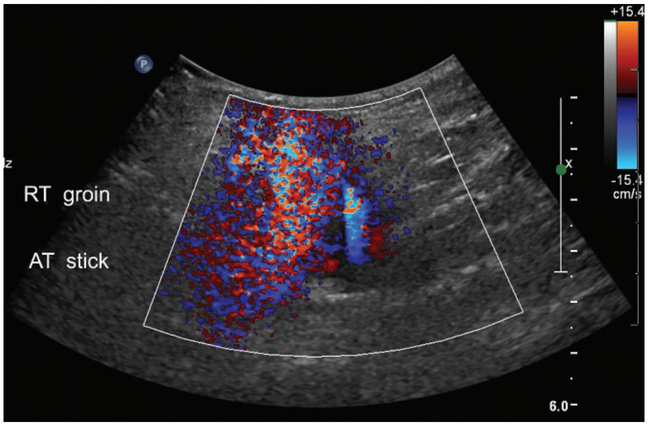


Figure S32-1. In the right groin, there is a large area of color Doppler that does not conform to a normal vessel. This is perivascular tissue vibration (color bruit) caused by turbulence in the soft tissues caused by a pseudoaneurysm. The vibrations are interpreted as moving blood and improperly color encoded.

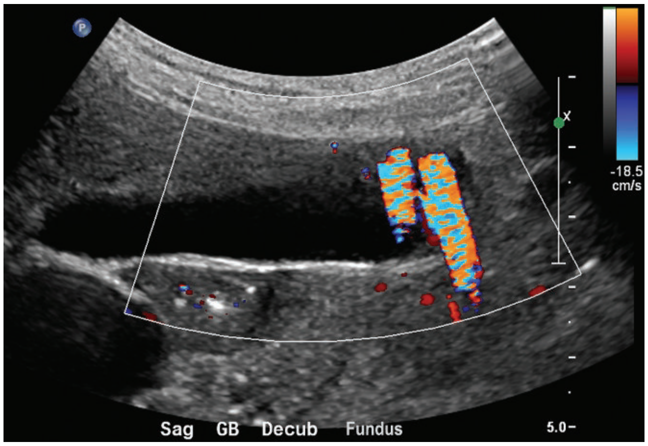


Figure S32-2. In the gallbladder fundus, there is a heterogeneous soft tissue density. On color Doppler nonmobile material in the area creates the twinkle artifact, which extends some distance behind a bright reflector. This helps confirm the diagnosis of adenomyomatosis. Irregular calcification produces the artifact.

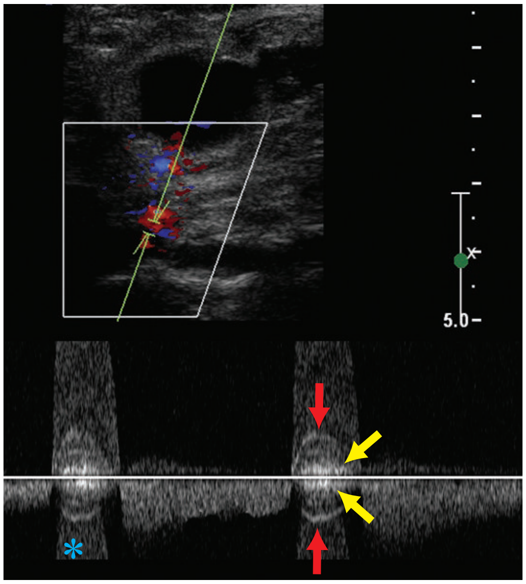


Figure S32-3. As the same patient as Figure S32-1, the spectral Doppler near the common femoral artery shows the typical to and fro waveform from the neck of the pseudoaneurysms (the flow into the waveform is aliased [*]). The fro portion is below the baseline. Inside the systolic portion of the waveform is a bright area above and below the baseline (yellow arrows). These are spectral bruits and they demonstrate both directions because vibrating tissue does not have a single direction. The curved signal above and below are harmonics of the bruit (red arrows).

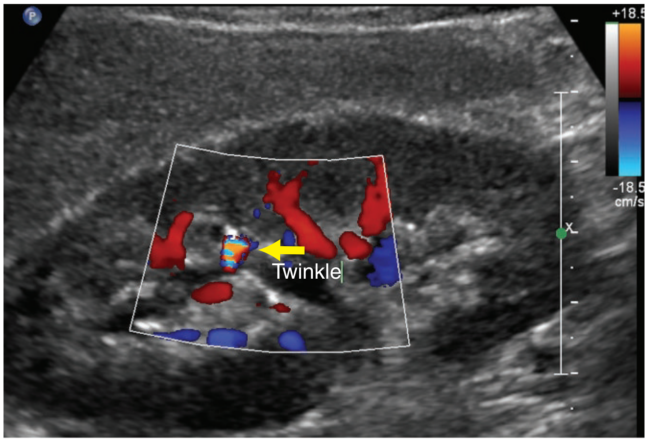


Figure S32-4. Twinkle artifact from stone. A color image of the kidney demonstrates arterial and venous flow in dark blue and red. Behind an echogenic focus is a mixture of colors (arrow), different from blood flow. This is the twinkle artifact created behind hard rough objects like stones.

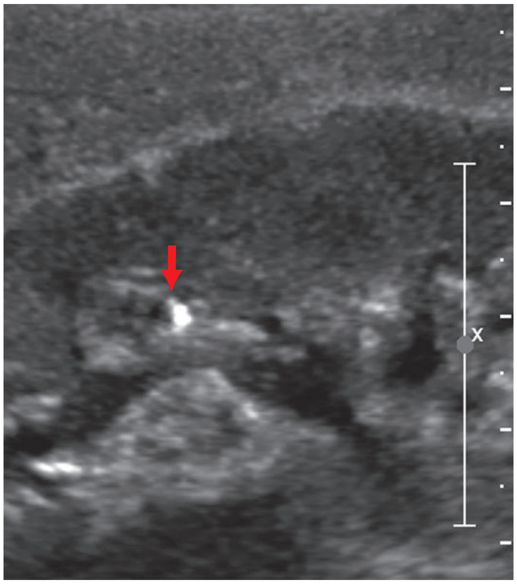


Figure S32-5. The stone causing the twinkle artifact is seen in this gray scale toned down image. The echogenic focus (arrow) is apparent but there is no shadow. This is not unusual with deep and small stones. The twinkle artifact is not dependent on shadowing, and it can be detected, as in this case, whether or not there is a shadow.

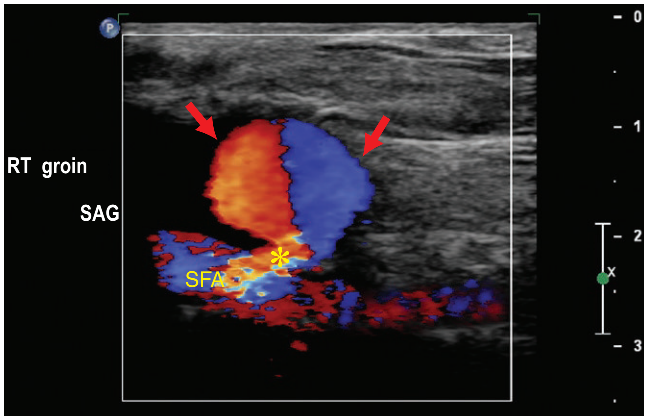


Figure S33-1. Long axis color Doppler image of right superficial femoral artery (SFA) demonstrates a collection of extravascular flow indicating a pseudoaneurysm (arrows). The neck of the pseudoaneurysm (*) is short.

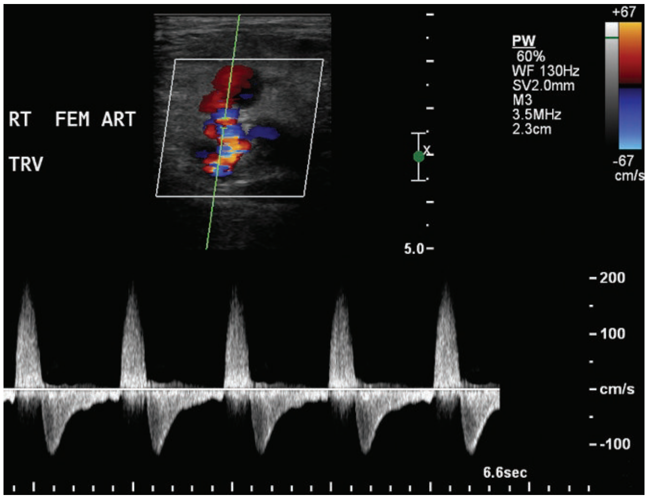


Figure S33-2. Spectral Doppler of the neck of the pseudoaneurysm demonstrates the typical to and fro waveform. Flow goes into the pseudoaneurysm during systole, and the pressure in the pseudoaneurysm rises and flow exits the pseudoaneurysm during diastole when the pressure in the native vessel is lower.

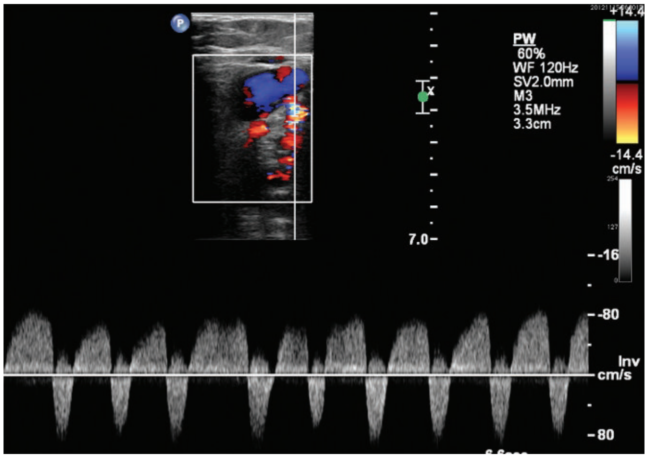


Figure S33-3. In another to and fro waveform, the diastolic reversal has a different shape with higher velocity later in diastole. The portion of the waveform is variable based on the pressure in the pseudoaneurysm relative to the native vessel. The waveform is inverted, and systole and diastole are on opposite sides compared with Figure S33-2.

CASE 34

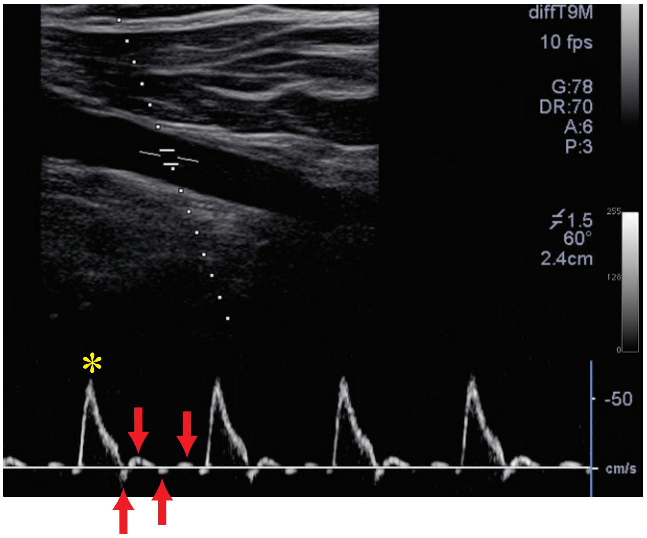


Figure S34-1. Normal multiphasic (high resistance) waveform in a peripheral artery. The subclavian artery demonstrates a sharp upstroke ending at peak systole (*) followed by a downstroke which crosses the baseline. The waveform reverses in early diastole. Systole is followed by multiple oscillating reverse and forward components (arrows). A multiphasic waveform may have as few as one forward and one reverse component. In compliant circulations, three or more phases may be present.

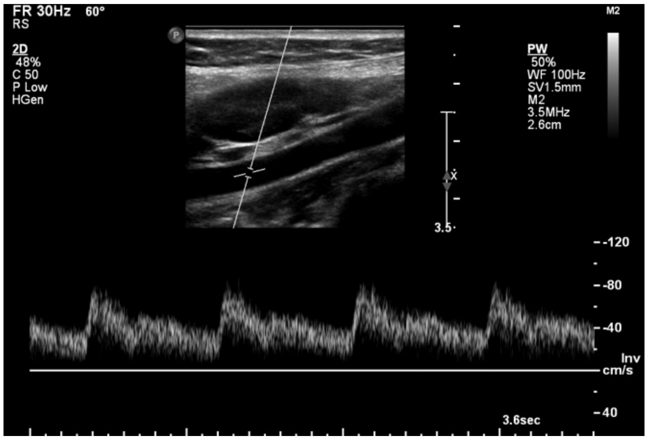


Figure S34-2. Normal low resistance waveform in the internal carotid artery. There is a sharp upstroke in systole followed by a very gradual downstroke. The flow stays forward (antegrade) throughout the cardiac cycle. There is a single forward phase, also called monophasic waveform.

Figure S34-3. Normal waveform in the external carotid artery intermediate between the low and high resistance waveforms. There is a sharp upstroke in systole followed by a sharper downstroke. The velocity goes almost to zero in diastole but stays forward (antegrade). There is a greater difference between peak systole and end diastole compared with the internal carotid artery. The waveform is more pulsatile compared with the internal carotid artery.

CASE 35

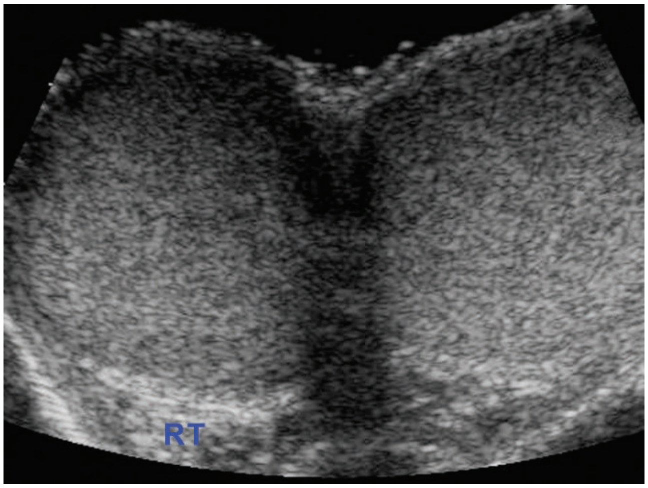


Figure S35-1. Slightly hypoechoic right testis. RT=right.

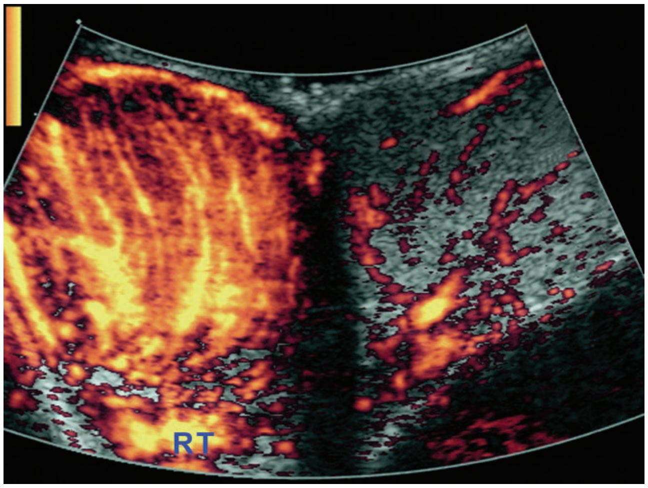


Figure S35-2. Hyperemia of right testis as noted on power Doppler. RT=right.

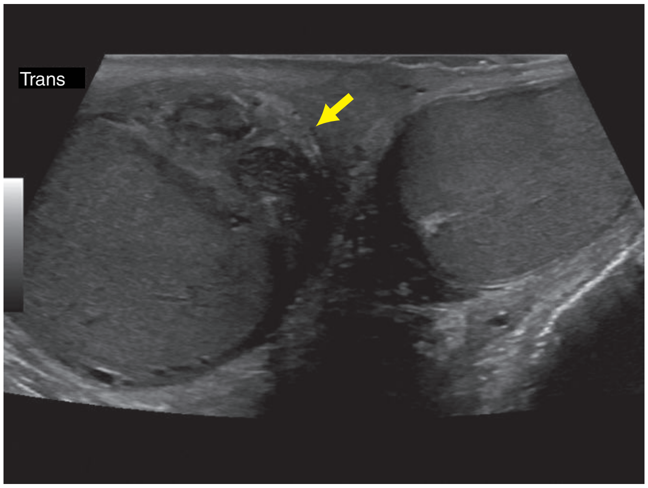


Figure S35-3. Transverse ultrasound in another patient showing enlarged epididymis (arrow).

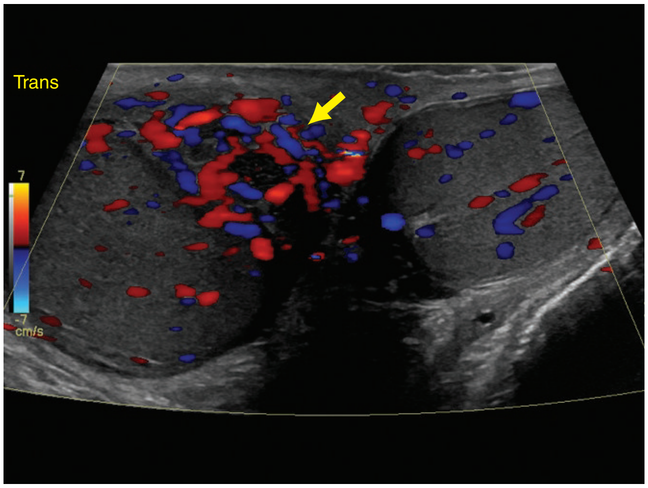


Figure S35-4. Color Doppler shows increased color in the enlarged right epididymis (arrow) and slight increased color in the right testis indicating mild orchitis.

CASE 36

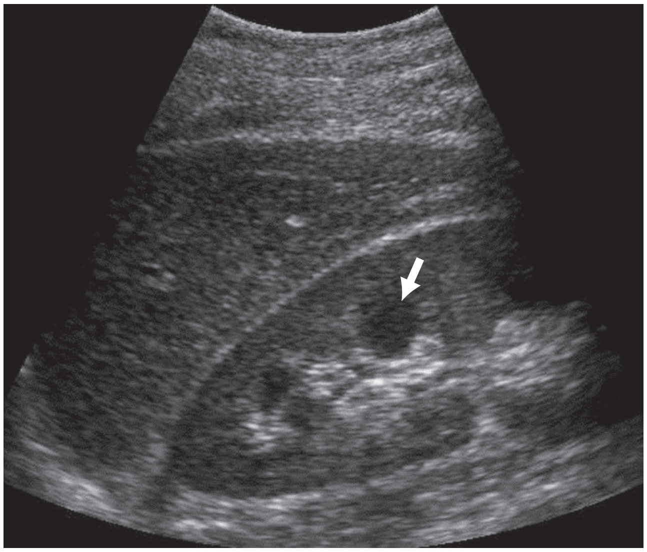


Figure S36-1. Real-time ultrasound image demonstrates a normal right kidney seen along with the right lobe of the liver. Normal liver is more echogenic than the kidney. Hypoechoic renal medullary pyramids are seen (arrow).

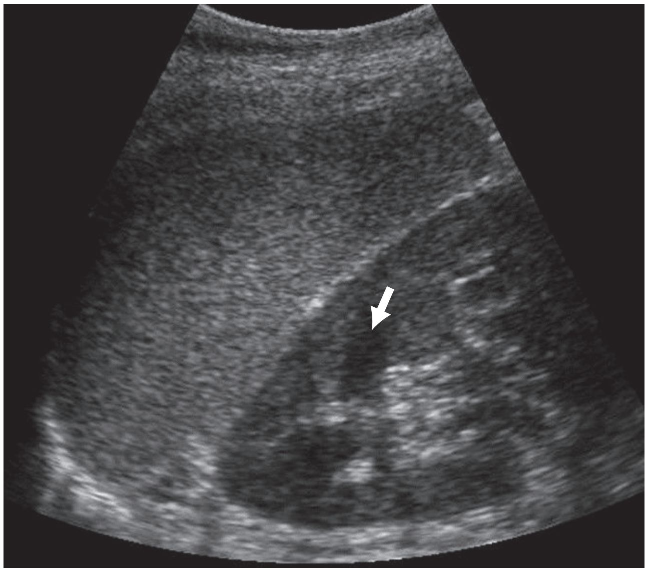


Figure S36-2. Real-time ultrasound image demonstrates a normal left kidney seen along with the spleen, which is considerably more echogenic compared to the kidney. Hypoechoic renal medullary pyramids are seen (arrow).

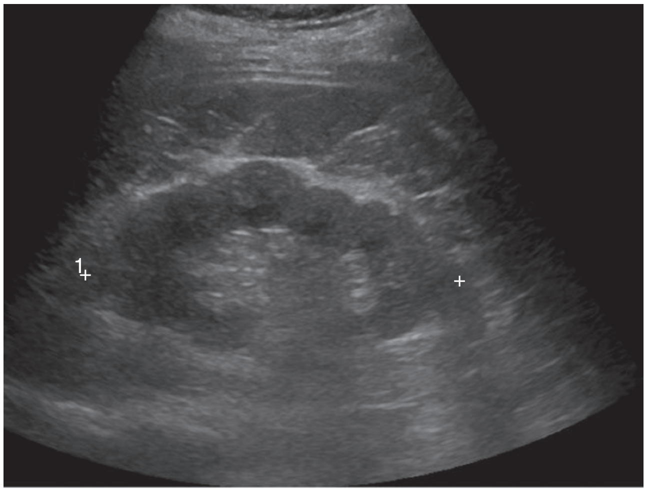


Figure S36-3. Real-time ultrasound image demonstrates a normal variant of persistent fetal lobulations. The indentations of fetal lobulations on the surface of the kidneys project in-between renal pyramids. This should be carefully differentiated from scarring, which occurs opposite to the renal pyramids.

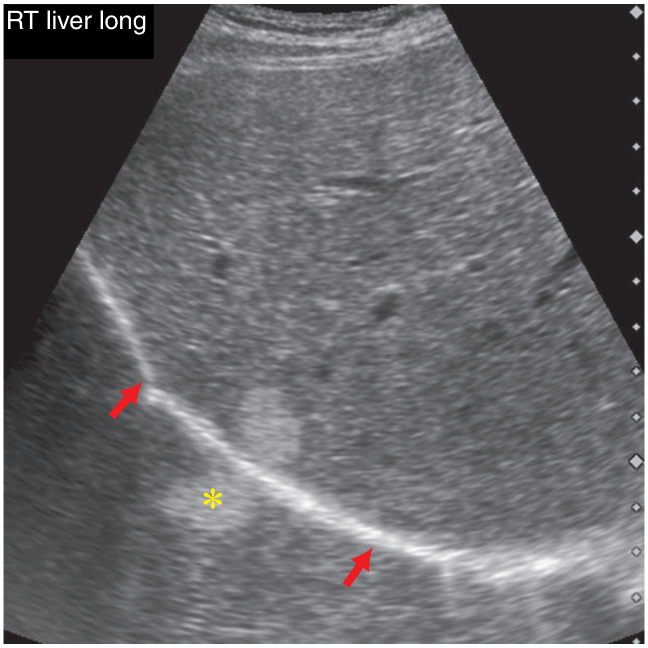


Figure S37-1. Mirror image artifact showing a duplication of the liver and of a subcapsular hemangioma (*) behind the diaphragm (arrows). The shape of the hemangioma is not an exact replica since the diaphragm and lung is curved and distorts the artifactual image.

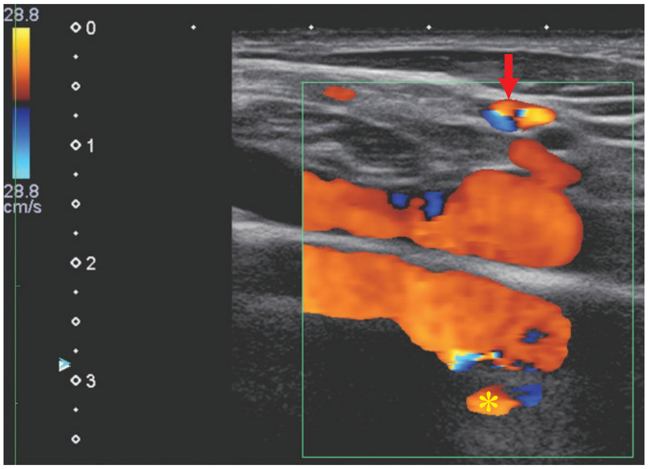


Figure S37-2. Mirror image artifact of the subclavian artery caused by the lung apex. Two color-filled vessels are seen in the same direction representing the subclavian artery and it mirror image. A smaller vessel above the subclavian artery (arrow) is also duplicated in the mirror image artifact (*).

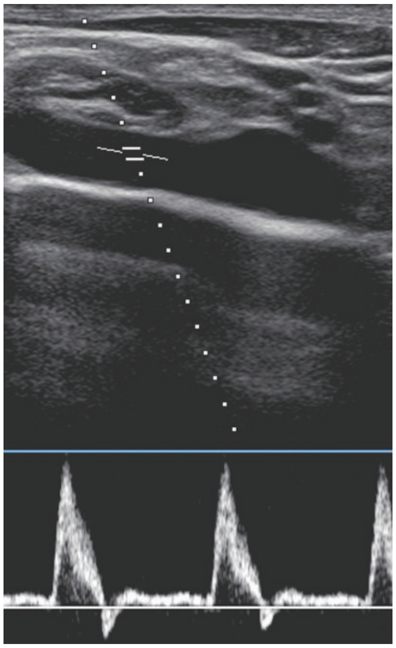


Figure S37-3. Same patient as Figure S37-2. Normal subclavian artery waveform seen in the more superficial artery. This is the actual artery. A gray scale mirror image of the artery is present below the echogenic line of the pleura.

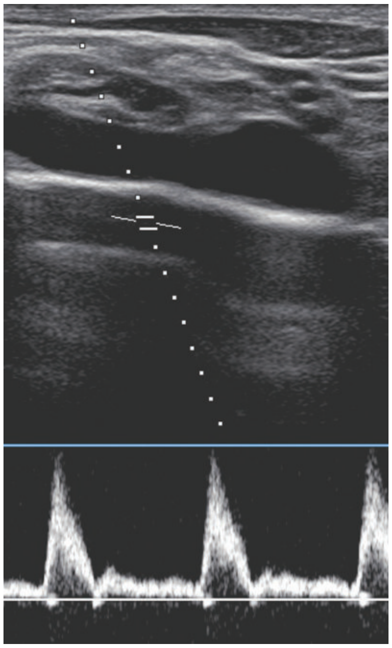


Figure S37-4. A mirror image subclavian artery spectral Doppler is present below the true artery. The presence of a spectral signal does NOT exclude a mirror image. Anatomically there is not a second artery below and parallel to the subclavian artery.

CASE 38

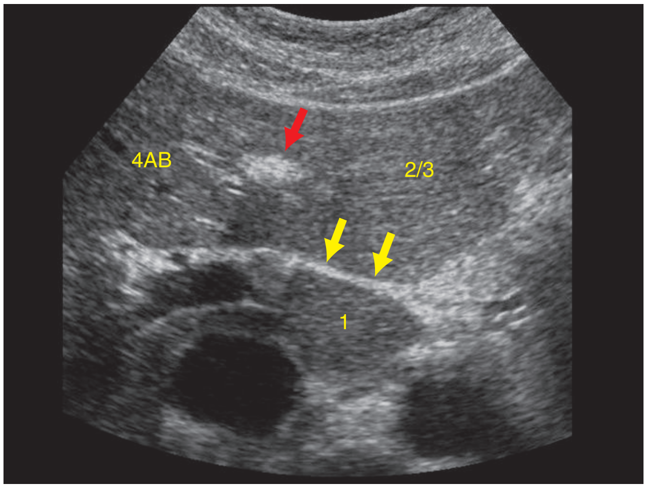


Figure S38-1. Transverse imaging of the upper abdomen demonstrating echogenic structure in the left lobe of liver (red arrow = ligamentum teres) (yellow arrows = fissure of ligamentum venosum) (Segments 1, 2/3 and 4AB).

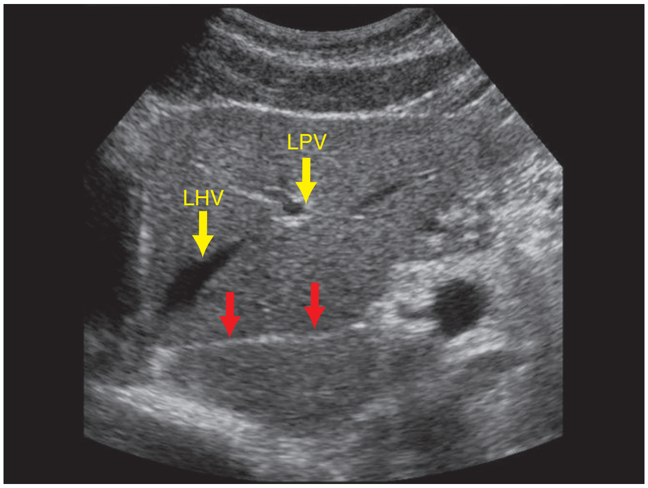


Figure S38-2. Longitudinal image of the liver with red arrows pointing to fissure of ligmaentum venosum. (LHV = left hepatic vein and LPV = left portal vein).

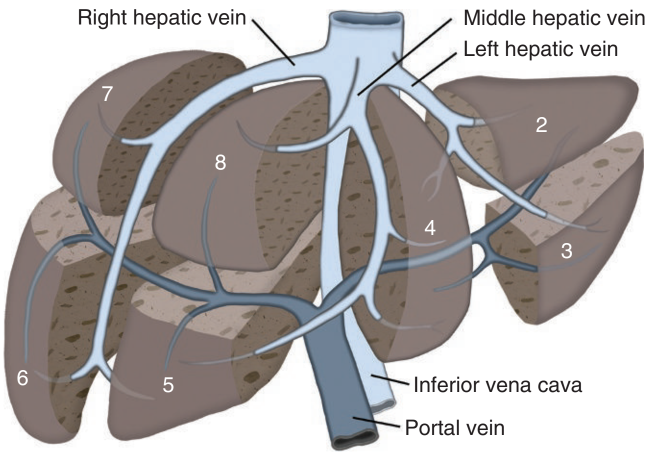


Figure S38-3. Drawing shows the subsegmental anatomy of the liver for segments 2-8, including the right hepatic vein, middle hepatic vein, and left hepatic vein, as well as the portal vein.

CASE 39

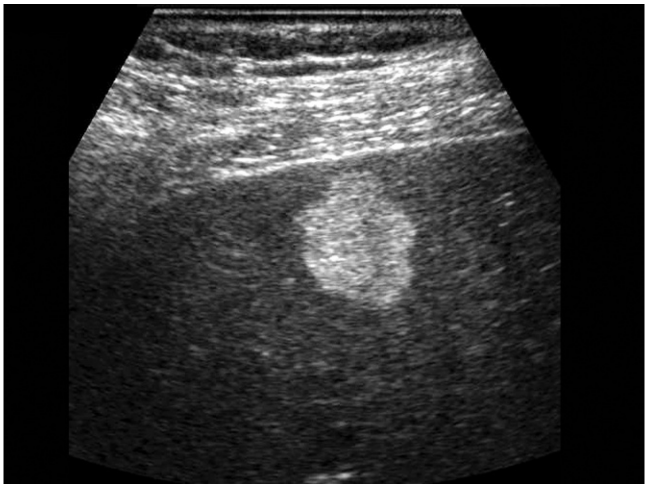


Figure S39-1. Real-time image and magnified view of well marginated echogenic liver mass with sharp borders.

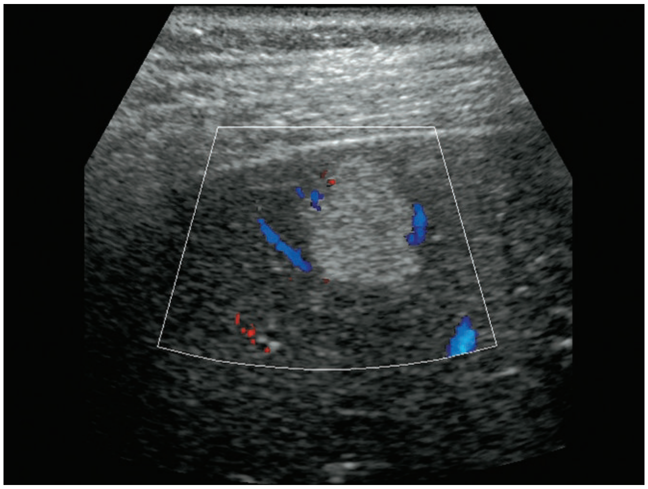
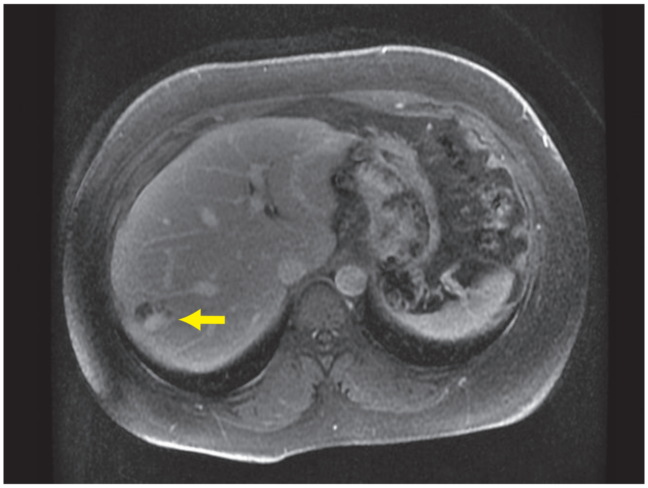


Figure S39-2. Color Doppler view of the same mass shows no flow within this mass, but vessels surrounding the mass.



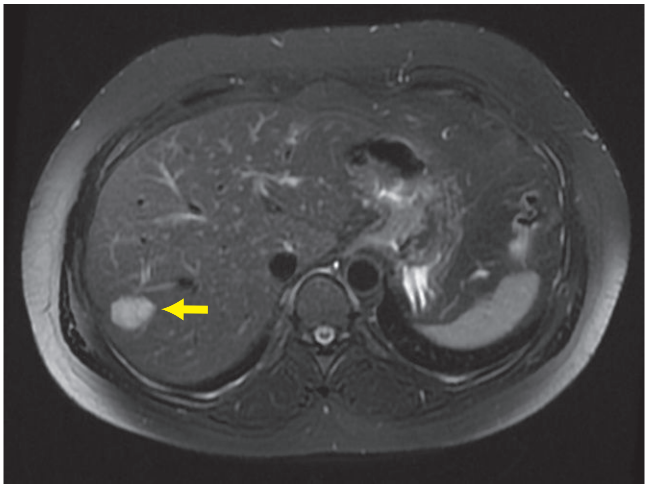
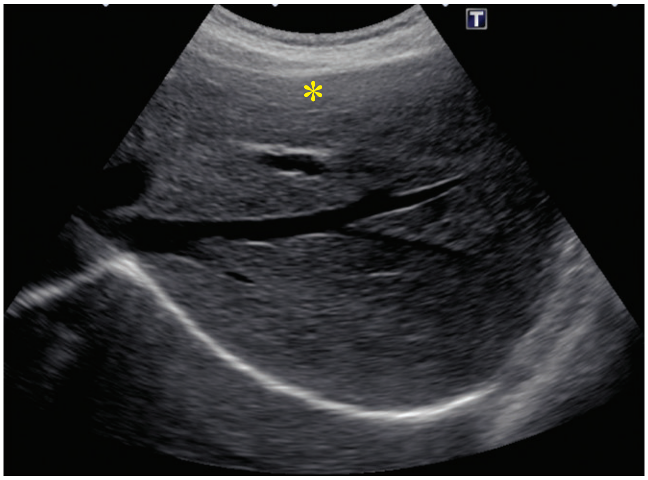


Figure S39-3. Delayed contrast-enhanced MRI shows a nodular rim of enhancement (arrow).

Figure S39-4. Heavy T2-weighted MRI shows increased signal intensity (arrow), which is a typical feature of a cavernous hemangioma.

CASE 40



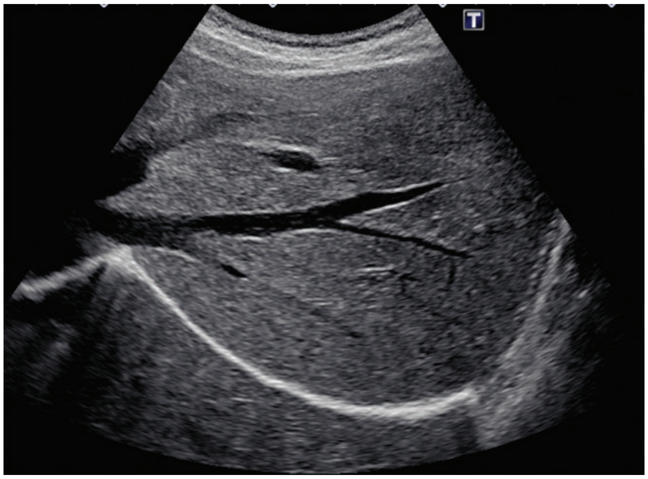
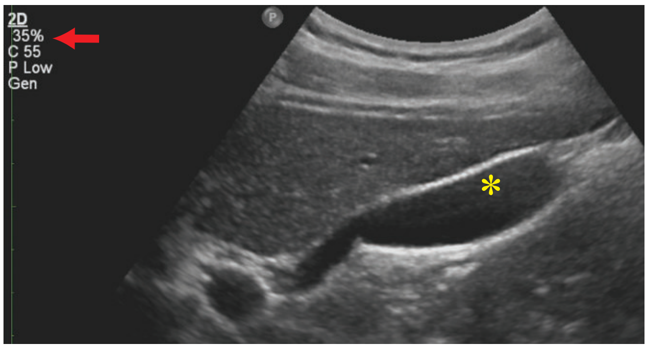


Figure S40-1. Fundamental gray scale ultrasound shows no abnormalities. There is distortion of the near field by artifacts from the body wall reverberations (*).

Figure S40-2. Tissue harmonic imaging shows no abnormalities. There are decreased effects of the body wall. There is also increased tissue contrast compared with fundamental imaging. This may make some pathology stand out compared with fundamental imaging.



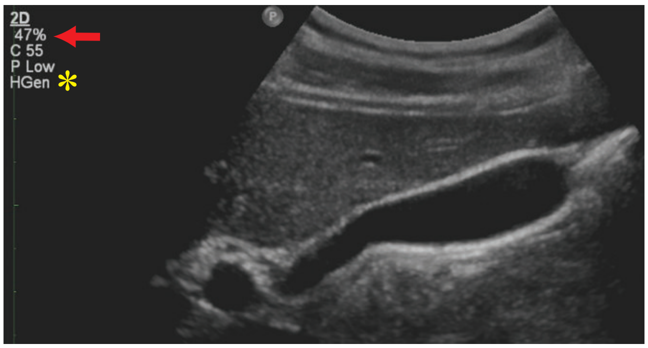


Figure S40-3. Fundamental imaging of the gallbladder demonstrates reverberation artifacts (*). Note the gain is set at a low value, 35% (arrow).

Figure S40-4. Harmonic imaging reduces the reverberation artifact. This is true even though the gain (47%) (arrow) is higher than the fundamental image gain (35%). There are several harmonic modes; this is a general purpose setting (HGen) seen in the left upper image (*).

CASE 41

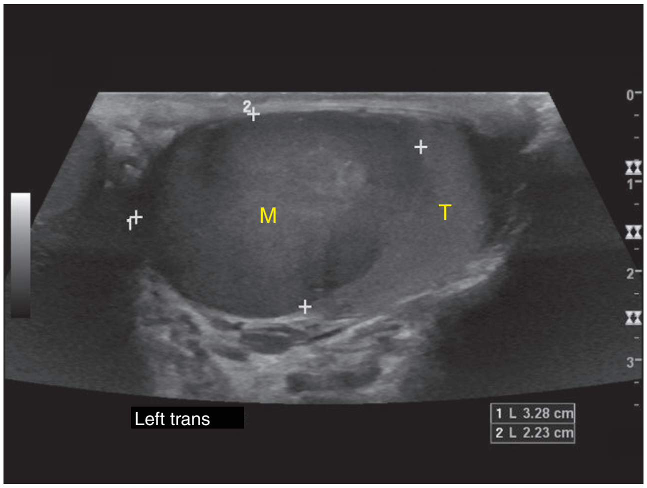


Figure S41-1. Longitudinal ultrasound through the testis (T) demonstrates a hypoechoic mass (M) noted by calipers.

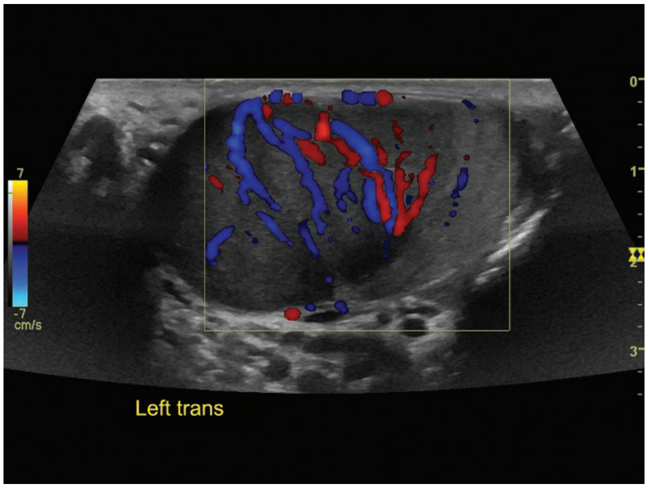


Figure S41-2. Color Doppler ultrasound demonstrates increase vascularity of the mass.

CASE 42

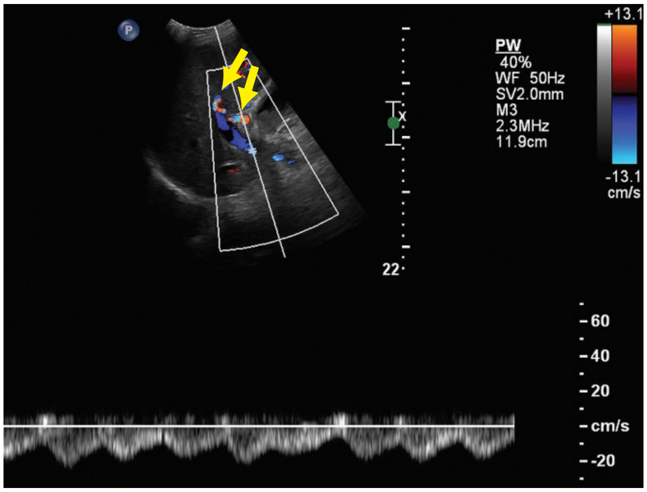


Figure S42-1. Color duplex of the porta hepatis demonstrates a blue portal vein (away from the transducer) with flow exiting the liver. This is confirmed by the spectral Doppler, which is also away from the transducer and hepatofugal. Hepatic arteries (arrows) are segmentally seen.

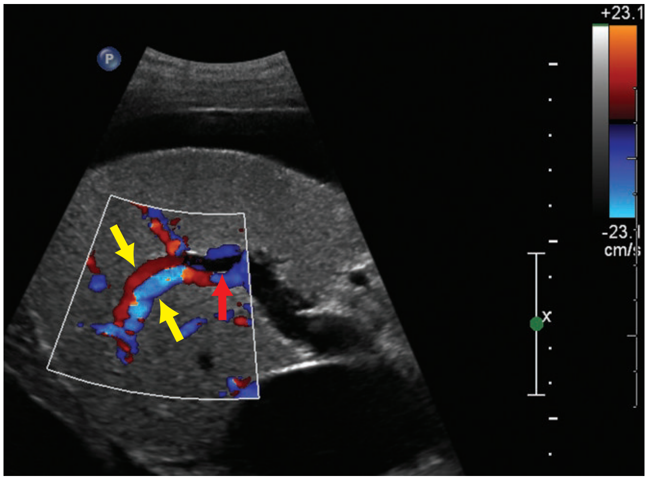


Figure S42-2. Color Doppler of the right lobe shows the adjacent portal vein and hepatic artery (between yellow arrows). The hepatic artery always flows into the liver and it is blue. The portal vein should also be flowing into the liver but it is red indicating hepatofugal flow. Near 90° (red arrow), the color is undetectable due to the poor Doppler angle.

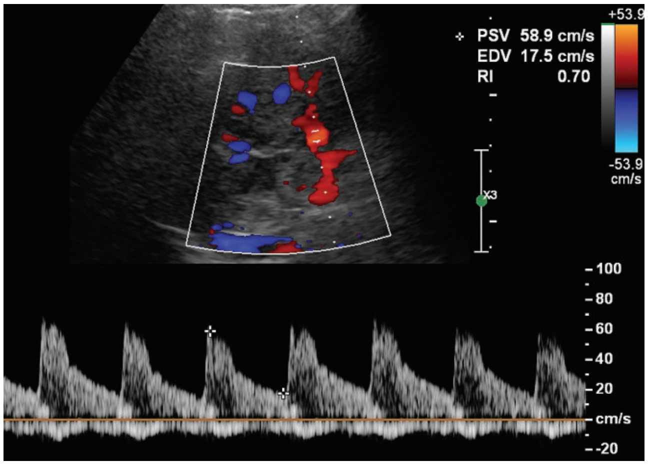


Figure S42-3. Doppler of the portal vein and hepatic artery can be obtained by having a large enough sample volume size to record both vessels. In this case hepatofugal portal flow is confirmed by demonstrating the two vessels flowing in opposite directions. The reversed flow portal vein is below the baseline and the normal hepatic artery is above the baseline. In normal the two waveforms are superimposed.

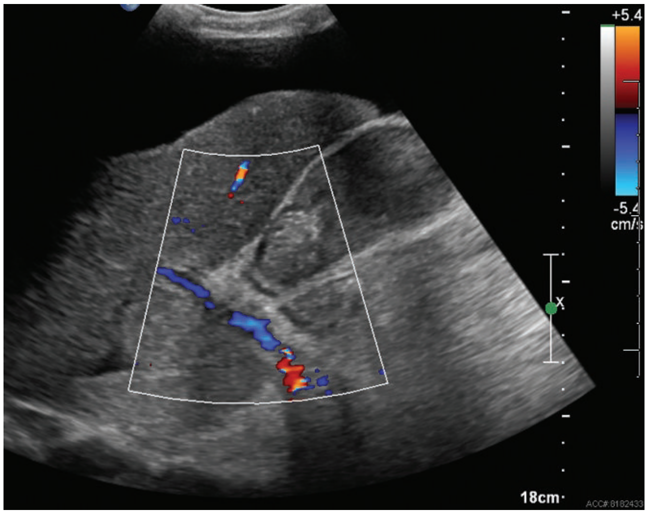


Figure S42-4. As flow diminishes and reverses in portal hypertension, the portal vein may actually decrease in size. In another patient with portal hypertension and hepatofugal (blue main portal) flow, the portal vein is small. Note the low color velocity (the color scale is only 5 cm/s). The red color at the bottom of the color box is an adjacent vessel.

CASE 43

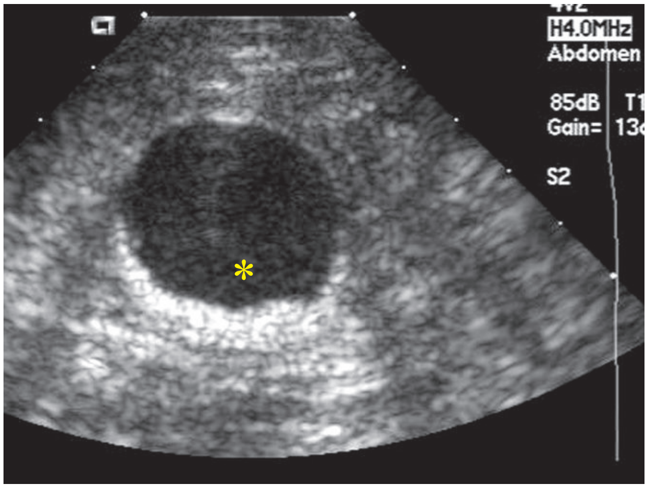


Figure S43-1. Sludge and gallstones without shadowing. There is weakly echogenic sludge in the gallbladder (*). There are high level echoes in the dependent gallbladder. No shadowing is present.

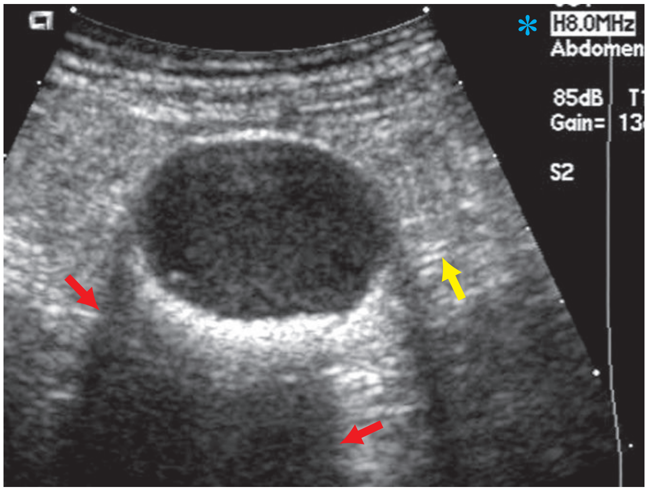


Figure S43-2. Gallstones. By increasing the frequency from 4 Hz to 8 Mhz (*), shadowing from the echogenic stones is now apparent (between red arrows). Note a refractive (edge) shadow is also present (yellow arrow).

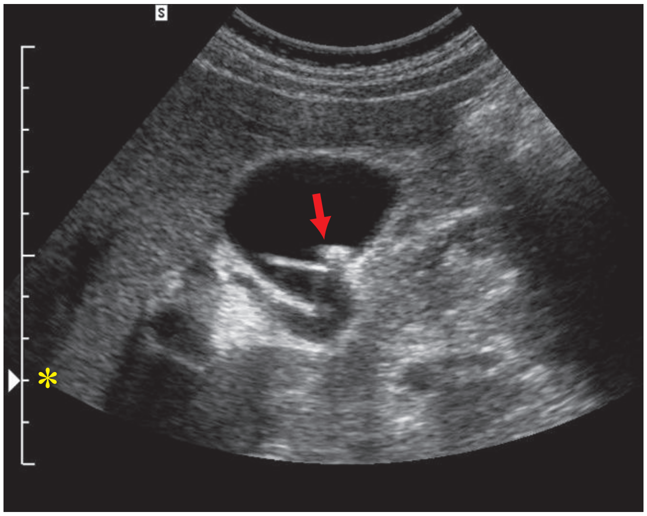


Figure S43-3. Gallstone with a weak shadow is identified as an echogenic focus (arrow). A weak shadow behind the stone is noted. The focus is below the area of interest (*).

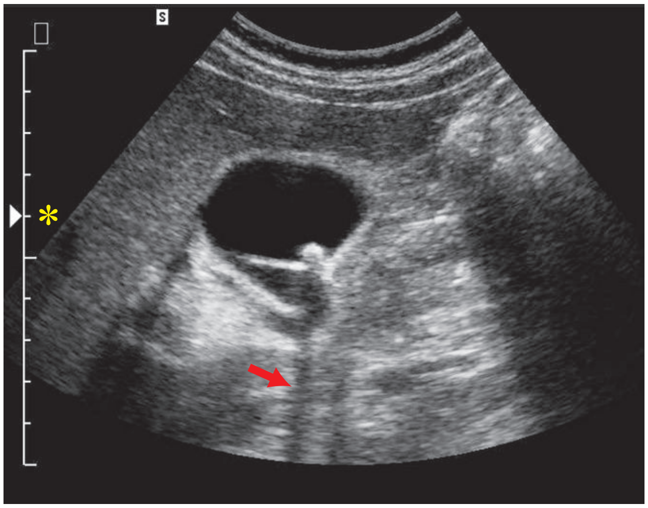


Figure S43-4. Shadow from the gallstone (arrow) is made apparent by moving the focus to the level of the stone (*).

CASE 44

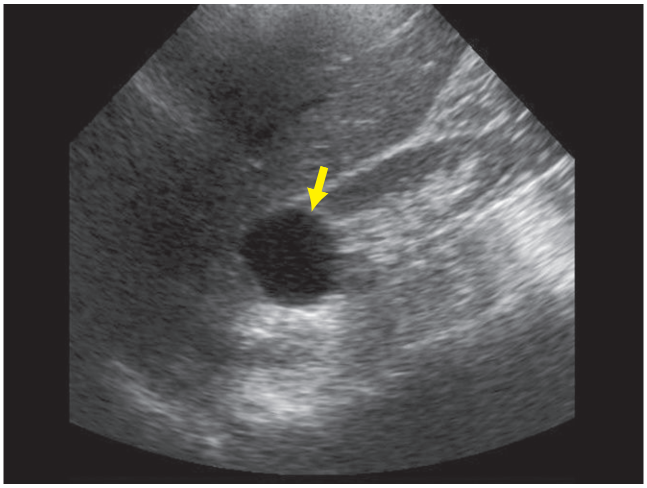


Figure S44-1. Image of the right kidney shows a unilocular, anechoic lesion (arrow) with increased through transmission in the upper pole.

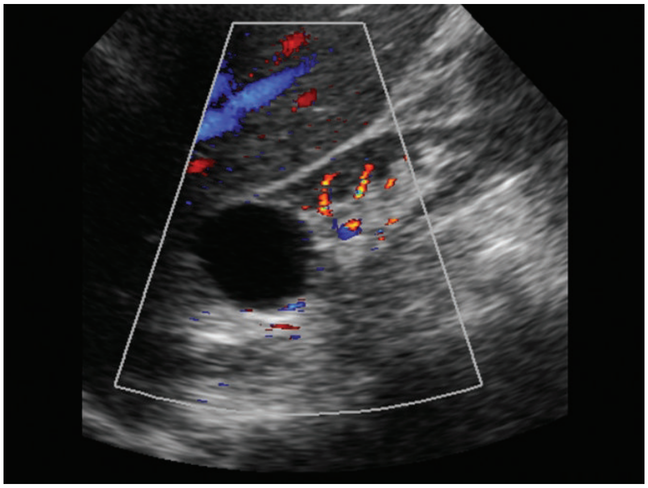


Figure S44-2. Color Doppler evaluation does not demonstrate internal vascularity.

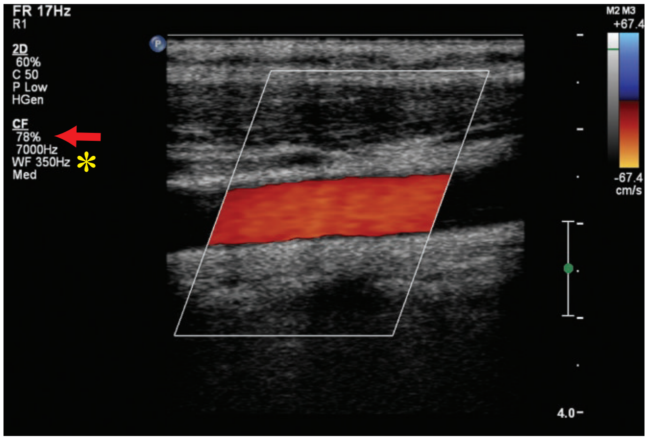


Figure S45-1. Color Doppler shows the color in the artery outlines the wall of the vessel. Note the color gain (arrow) and the wall filter (*).

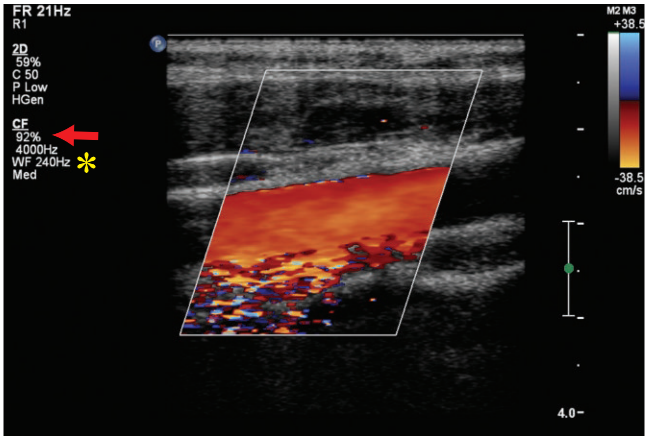


Figure S45-2. The color is bleeding and extends beyond the confines of the vessel wall. There is now noise introduced because of increasing the gain (arrow) to 92% from 78%. The wall filter (*) has also been lowered to allow slower flow to be demonstrated. The tissue echogenicity is unchanged.

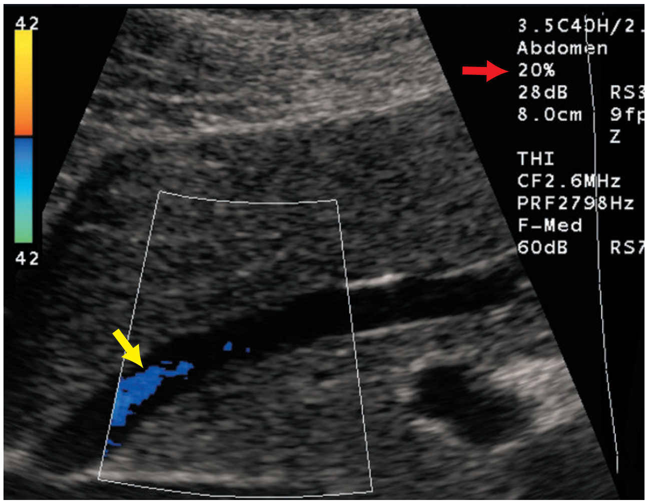


Figure S45-3. Color Doppler of the hepatic vein. There is a very small amount of color in the vessel (yellow arrow). It is at the left side of the color box where the Doppler angle is lowest. The power is set to 20% (red arrow).

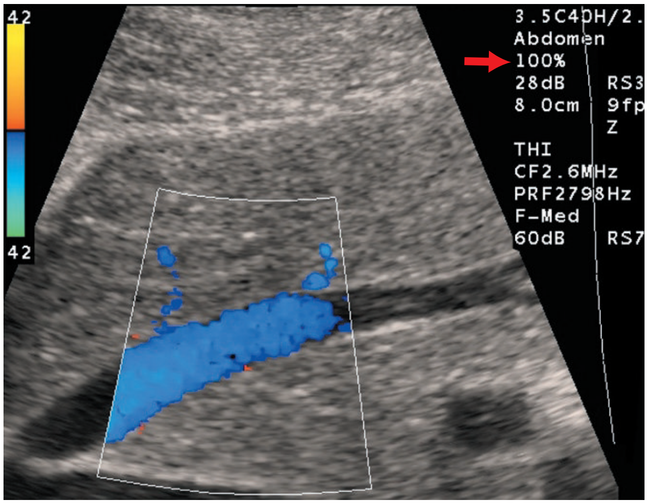


Figure S45-4. Same case as Figure S45-3. The power has increased to 100% (arrow) and the color in the vein fills the vein. The echogenicity of the liver and the entire image is increased as power is increased. As a rule, gain is increased before power since power affects patient exposure.

CASE 46

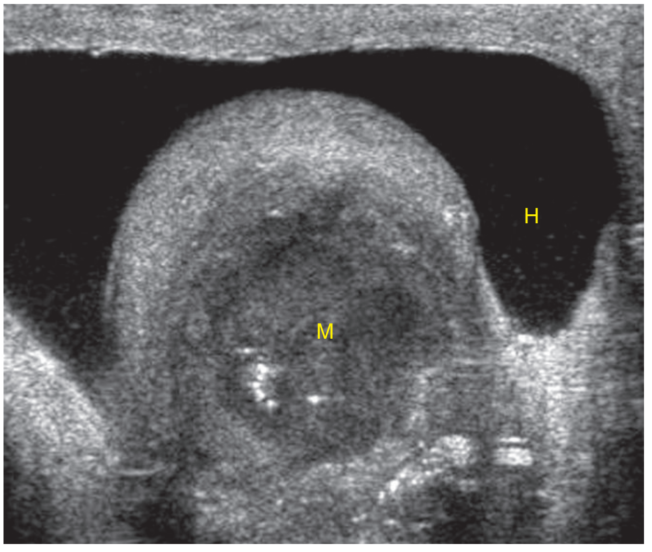


Figure S46-1. Transverse gray scale ultrasound view of the testis in this patient showing an intratesticular mass (M) and a hydrocele (H).

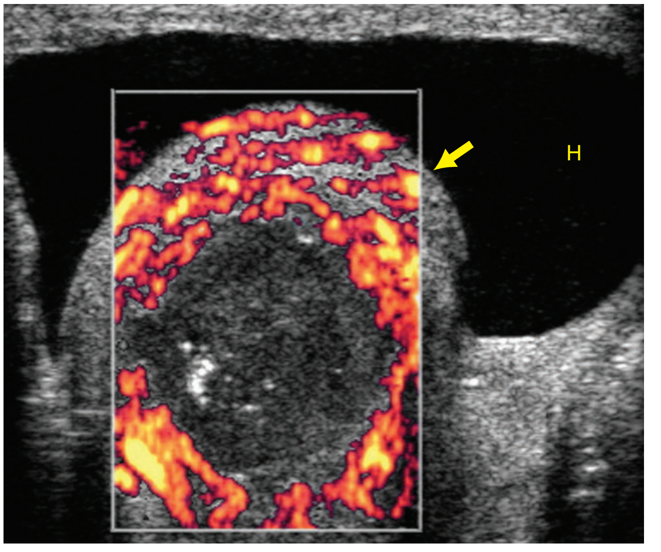


Figure S46-2. Transverse ultrasound or power Doppler ultrasound of the testis in this same patient showing increased flow (arrow). (H=Hydrocele)

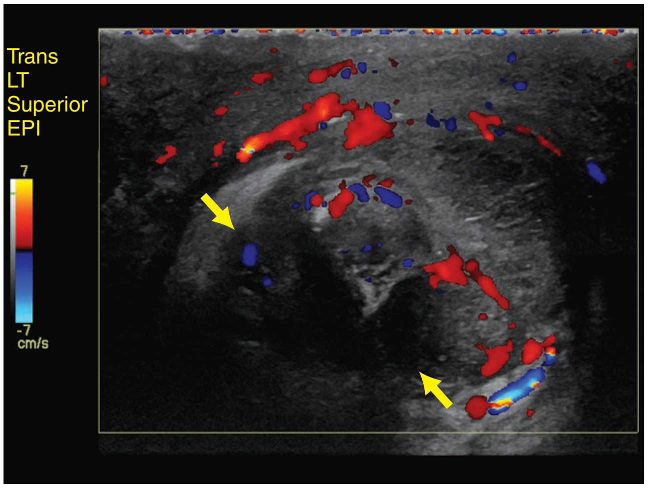


Figure S46-3. Transverse ultrasound of another patient through the region of the epididymis shows hypoechoic masses (arrows).

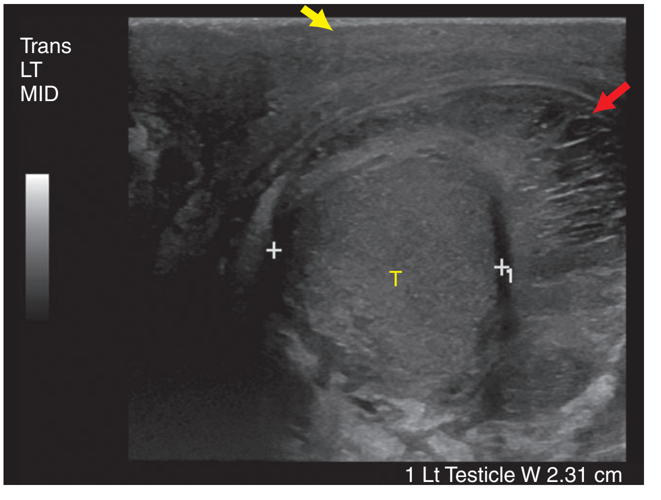


Figure S46-4. Other images demonstrate more normal appearing testis (T) surrounded by a pyocele (red arrow) and scrotal wall thickening (yellow arrow).

CASE 47

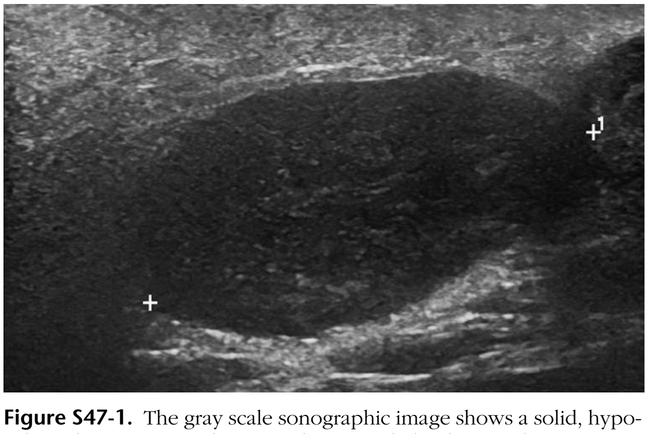


Figure S47-1. The gray scale sonographic image shows a solid, hypoechoic, homogeneous lesion in the parotid gland, a Warthin's tumor.

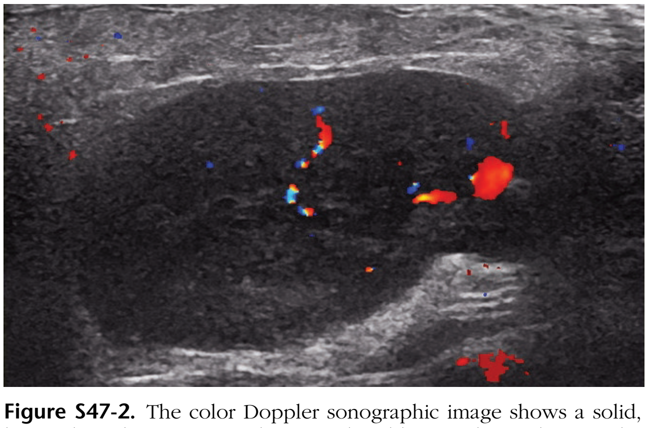


Figure S47-2. The color Doppler sonographic image shows a solid, hypoechoic, homogeneous lesion with mild internal vascularity in the parotid gland, a Warthin's tumor.

CASE 48

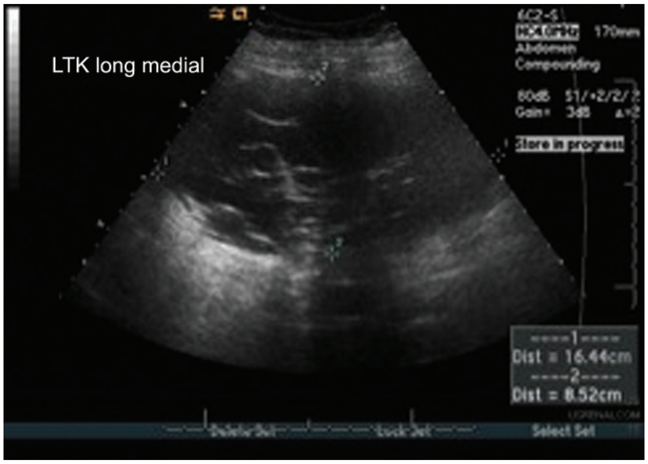


Figure S48-1. Gray scale sonographic image demonstrates large multicystic left renal mass with echogenic septa. No color flow was identified on color Doppler images within the septa (image not shown).

Figure S48-2. Contrast-enhanced axial CT in the portal venous phase through the upper abdomen demonstrates a multicystic, well-circumscribed, encapsulated mass with enhancing septa.

CASE 49

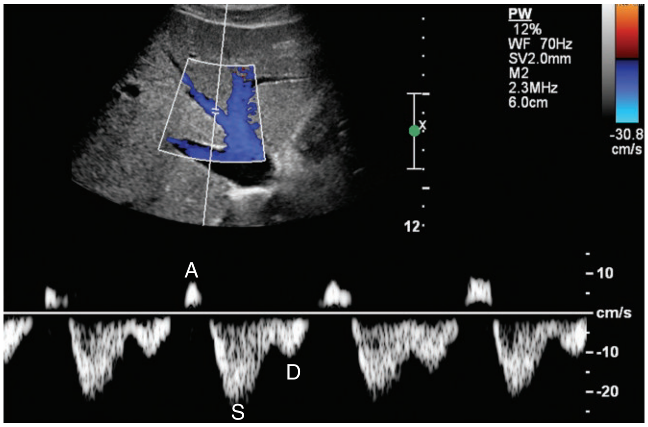


Figure S49-1. Spectral Doppler of normal middle hepatic vein. The normal hepatic vein waveform varies with the cardiac cycle. In the normal patient, during quiet breathing, there are three phases. Forward flow is seen in ventricular systole (S) and diastole (D). A transient reversal occurs during atrial systole (A). The absence of flow near the baseline is caused by the wall filter, which eliminates signals from the moving vessel wall and slow moving blood.

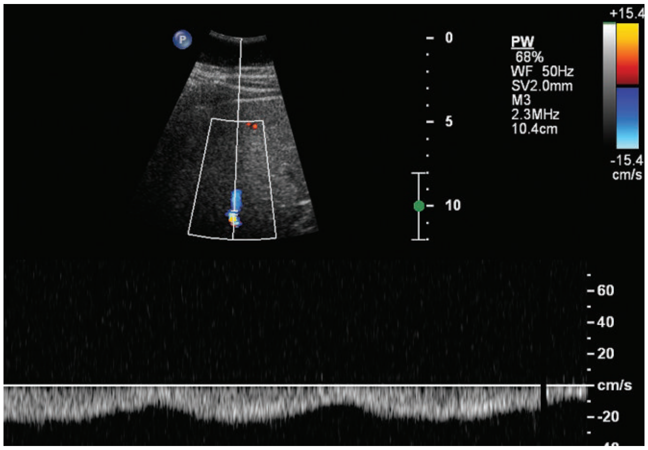


Figure S49-2. Spectral Doppler of middle hepatic vein in cirrhosis. The cardiac pulsatility seen in normal patients is absent. The waveform changes minimally indicating it is blunted. This can be seen in cirrhosis or if there is a venous obstruction between the sample volume and the heart (e.g., Budd Chiari syndrome). A deep inspiration can cause some blunting of the normal hepatic vein waveform but not to this extent.

Figure S49-3. Gray scale of a normal hepatic vein entering the inferior vena cava.

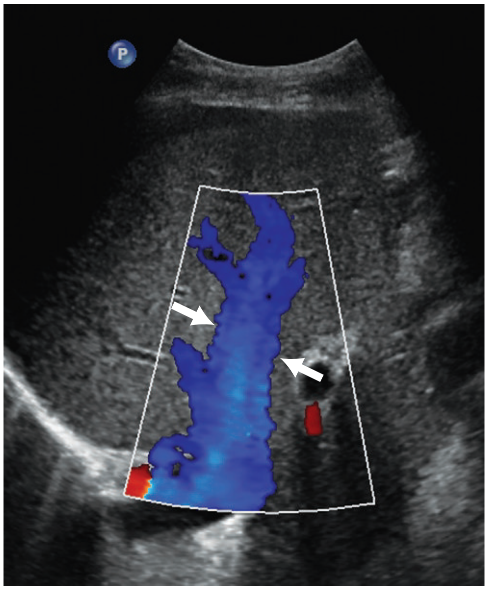


Figure S49-4. Color Doppler of a normal hepatic vein entering the inferior vena cava. The vein appears to be larger in color (arrows) than in gray scale. This is because of excess color gain.

CASE 50

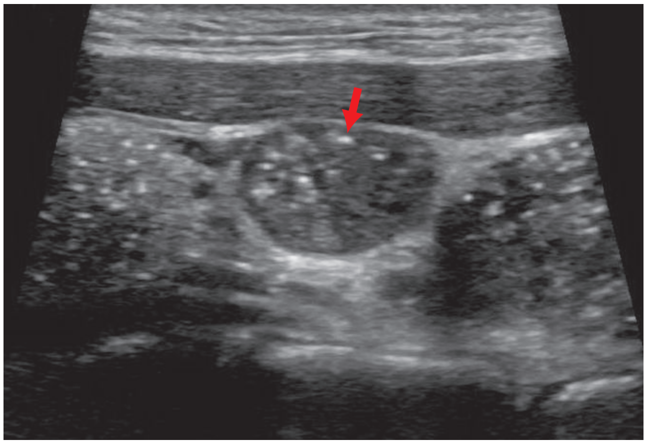


Figure S50-1. The longitudinal gray scale image of the left neck lateral to the internal jugular vein shows multiple morphologically abnormal lymph nodes. The nodes are round, hypoechoic, and contain multiple microcalcifications (arrow).

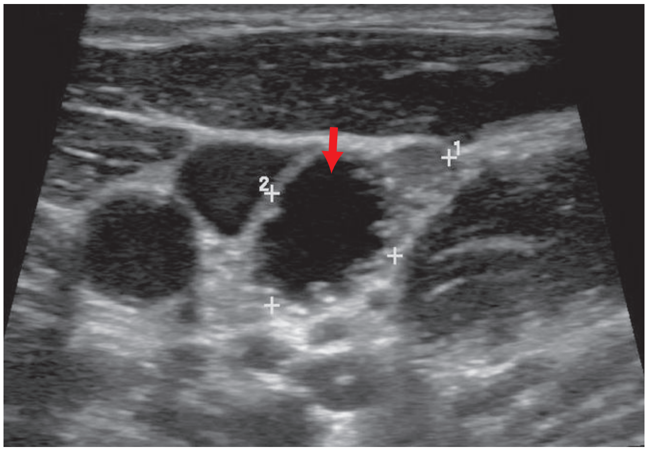


Figure S50-2. The transverse gray scale image of the right neck medial to the internal jugular vein and carotid artery shows a morphologically abnormal lymph node that is largely cystic (arrow) with a small hypoechoic solid component with microcalcifications.

CASE 51

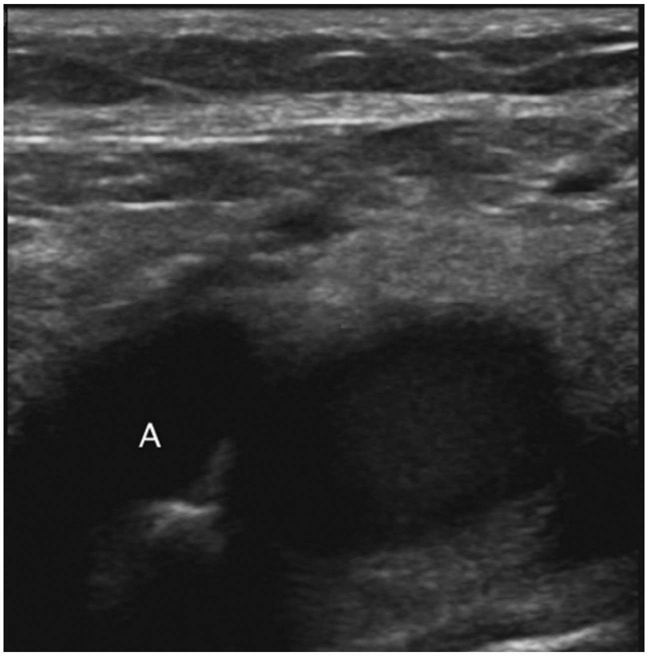


Figure S51-1. The vein adjacent to the artery (A) has multiple mid-level echoes from rouleaux formation. The intravenous echoes are along one side and the middle of the vessel and there is an anechoic area on the side of the vein adjacent to the artery.

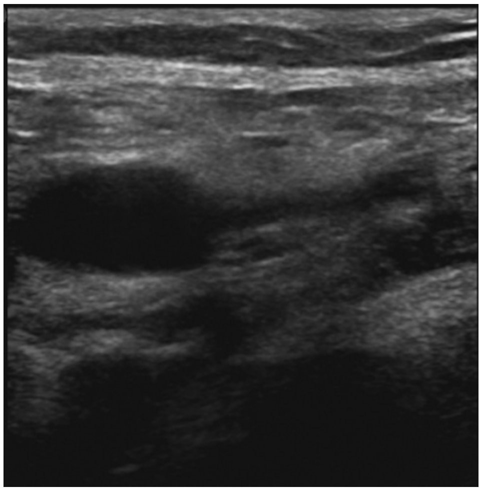


Figure S51-2. The vein compresses normally indicating there is no thrombus within it. Note the artery has anterior echoes from reverberation artifact.

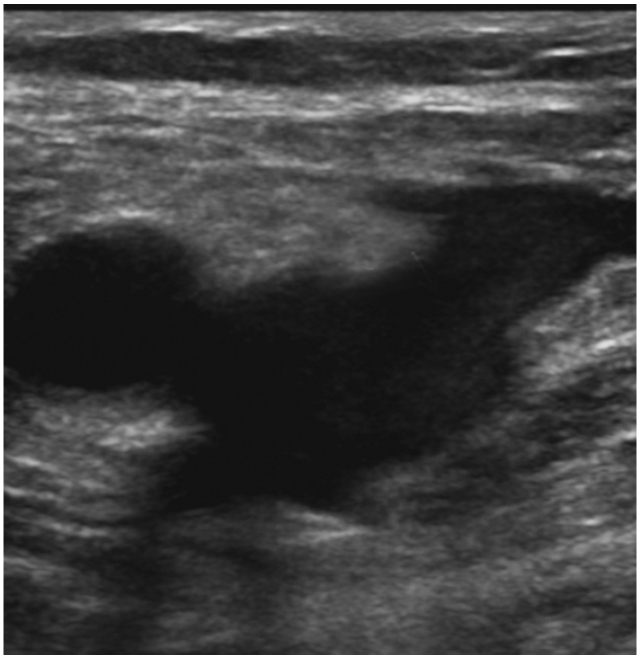


Figure S51-3. In another image from the study, the rouleaux is seen at the saphenofemoral junction and the size and shape of the echoes are different. In real time echoes move from the saphenous vein toward the common femoral vein. The spectral Doppler (not shown) was normal, indicating no significant obstruction.

Figure S51-4. In a different patient, anterior echoes from reverberation are seen in the artery (A) and vein along their anterior aspects. This is not

Figure S51-5. With compression, the vein compresses normally. Echoes in the artery (A) from reverberation are still present.

CASE 52

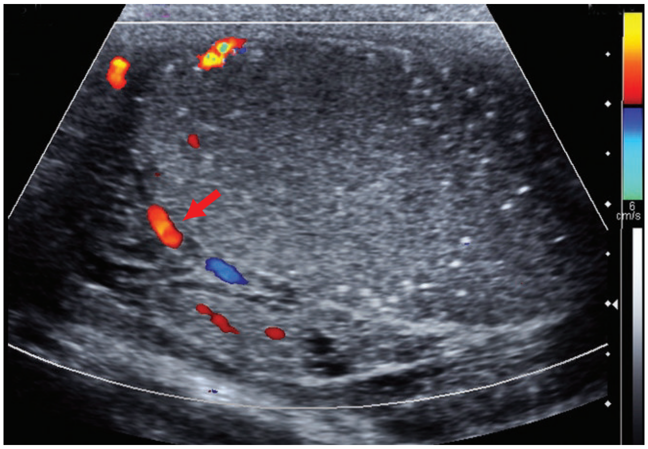


Figure S52-1. The longitudinal color Doppler sonogram of the testis shows minimal peripheral flow (arrow).

Figure S52-2. The gray scale sonographic image shows a twisted cord (torsion knot) (arrow).

CASE 53

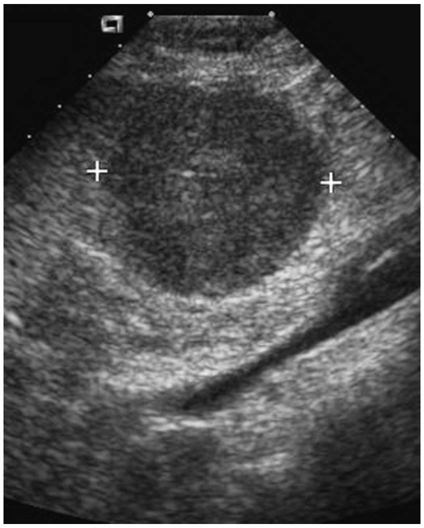


Figure S53-1. Transabdominal ultrasound shows focal well-encapsulated hypoechoic liver mass (calipers).

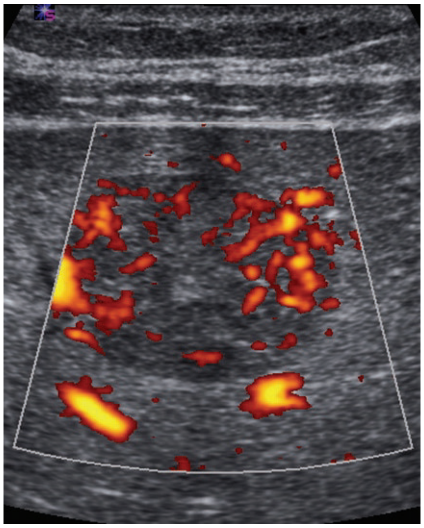


Figure S53-2. Transabdominal scan shows increased color flow in the mass.

Figure S53-3. Large hepatocellular carcinoma (HCC) which is well encapsulated and echogenic.

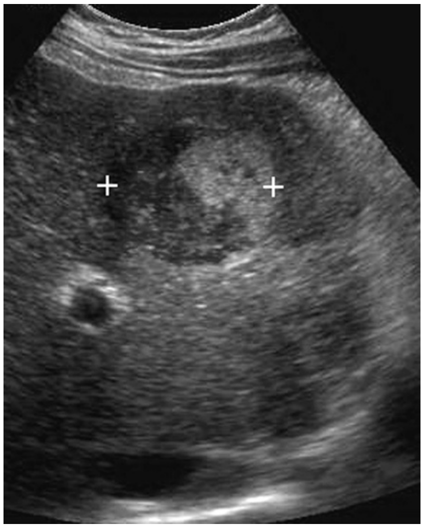


Figure S53-4. HCC that appears both hypoechoic and echogenic (calipers). HCCs may contain fat, which appears echogenic.

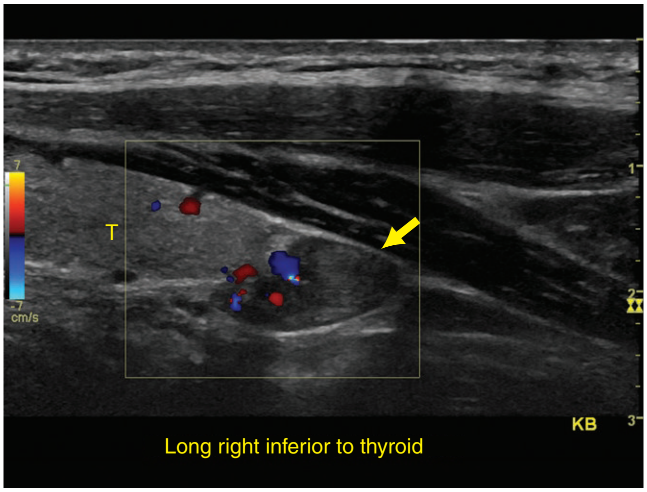


Figure S54-1. Longitudinal ultrasound through the thyroid (T) demonstrating elongated hypoechoic mass (arrow) posterior and inferior to the thyroid. There is mild increased color flow.

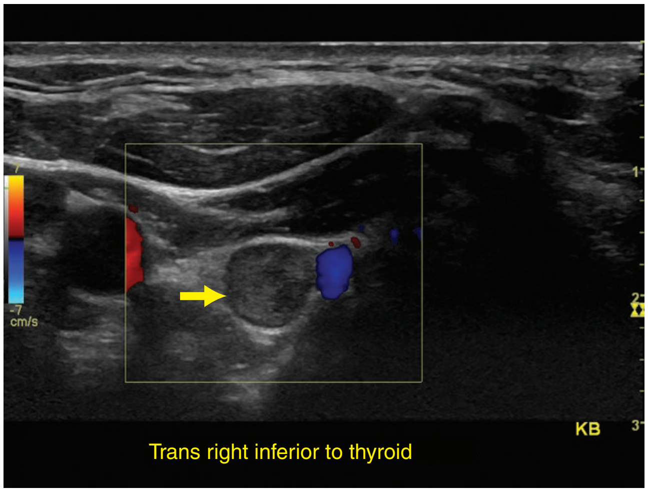


Figure S54-2. Transverse imaging through the same region demonstrating this mass (arrow).

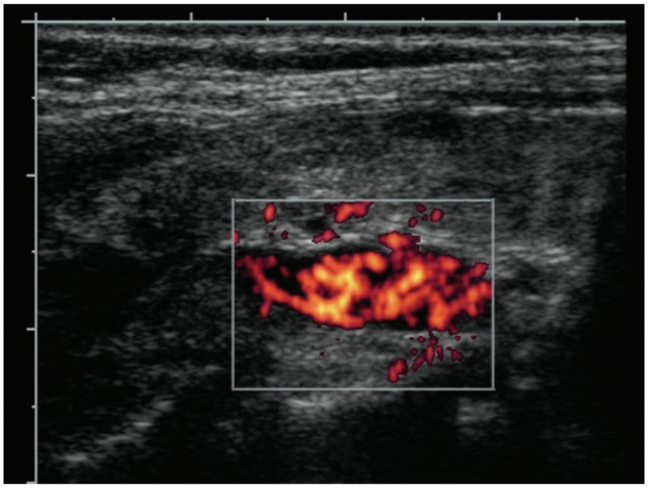


Figure S54-3. In another patient there is increased power Doppler in this adenoma.

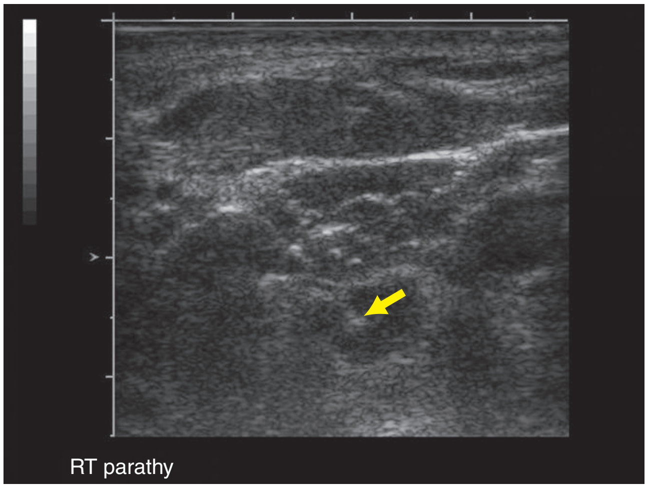


Figure S54-4. FNA of adenoma with needle (arrow) in the mass.

CASE 55

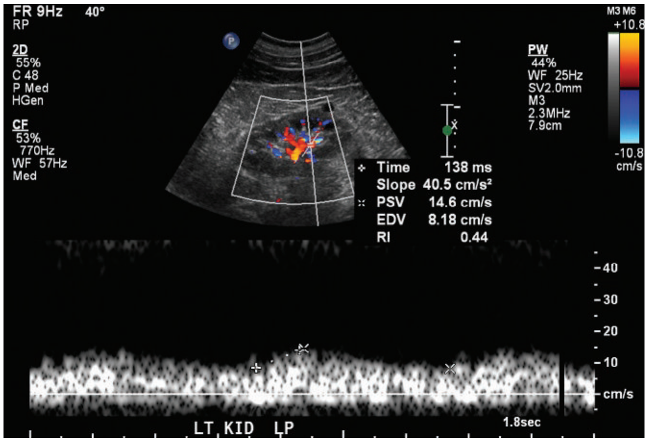


Figure S55-1. Spectral Doppler of left lower pole intrarenal artery. There is a tardus parvus waveform. The time to peak systole is delayed, 138 ms. There is little difference between systole and diastole. The waveform indicates upstream obstruction.

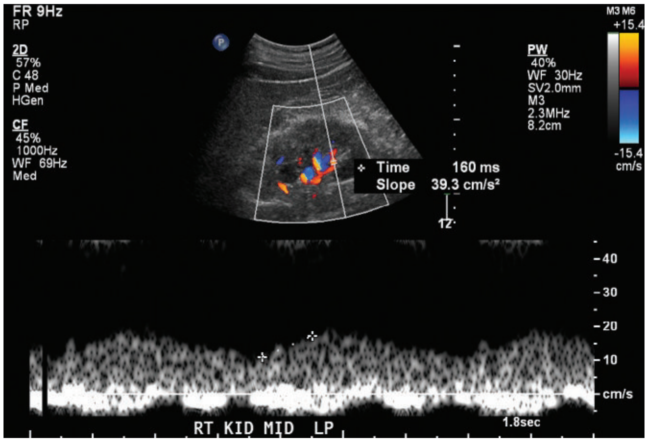


Figure S55-2. Spectral Doppler of right lower pole intrarenal artery. There is a tardus parvus waveform. The time to peak systole is delayed, 160 ms. There is little difference between systole and diastole. The findings indicate upstream obstruction is bilateral. This can be due to bilateral renal artery stenosis or obstruction higher up in the circulation, such as the aorta.

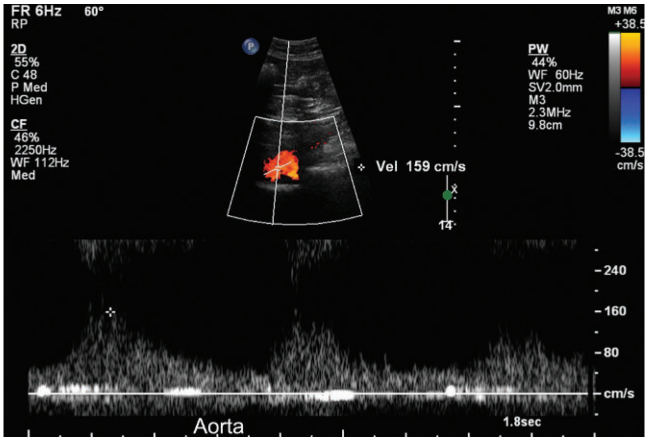


Figure S55-3. Spectral Doppler of the aorta above the renal artery shows a slow upstroke and gradual downslope. The finding indicates upstream obstruction. In this case the obstruction was in the thoracic aorta from aortic coarctation.

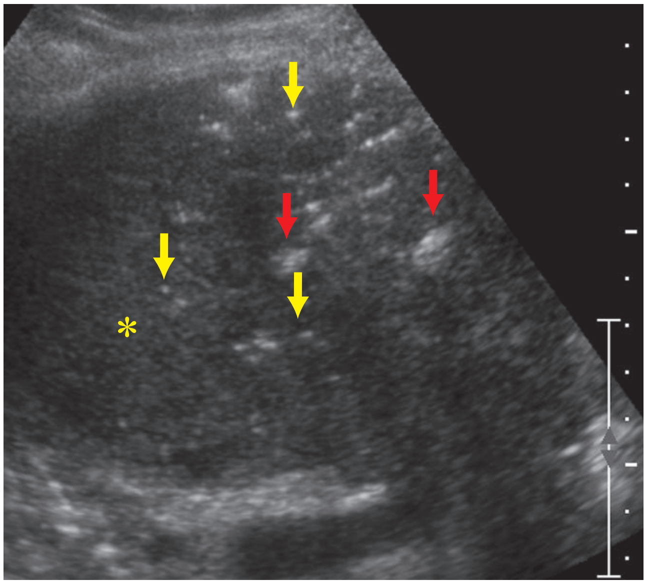


Figure S56-1. Transverse scan of the liver. There are punctate echoes (yellow arrows) and more fluffy areas of increased echogenicity (red arrows) in the hepatic parenchyma. The right aspect of the liver has normal echogenicity (*).

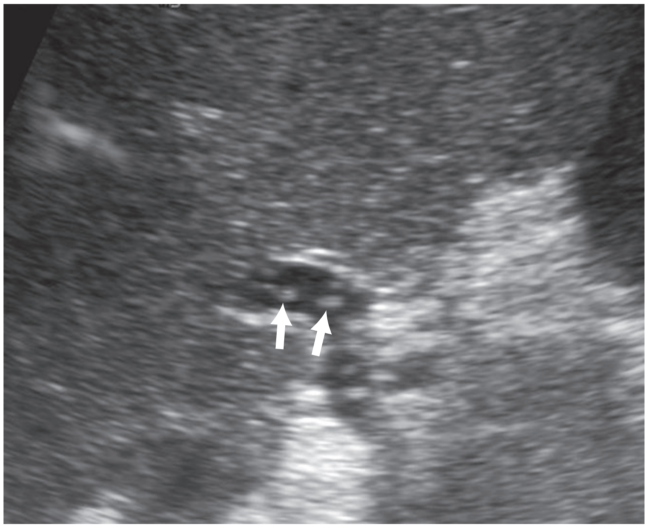


Figure S56-2. The portal vein has several punctate echoes (arrows) indicating portal venous gas. These moved into the liver in realtime.

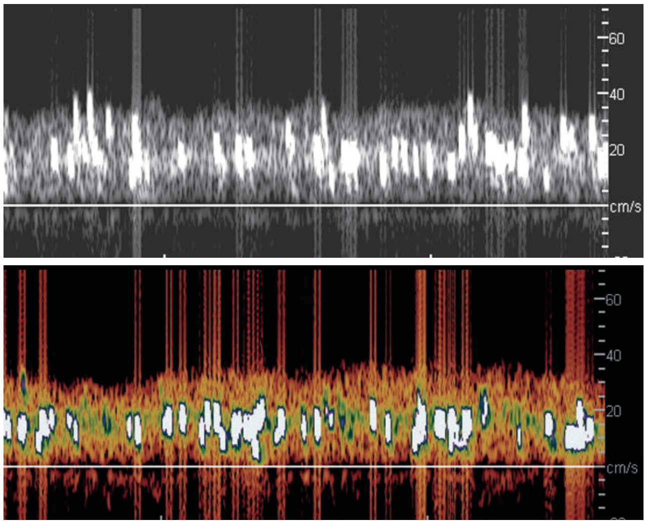


Figure S56-3. The characteristic spectral Doppler spikes from gas are seen superimposed on the normal portal blood flow. Additionally dense white echoes in the spectrum indicate gas that has not produced a spike. The image on the bottom represents a colorized spectrum that some laboratories use to make some gray scale findings more conspicuous.

CASE 57

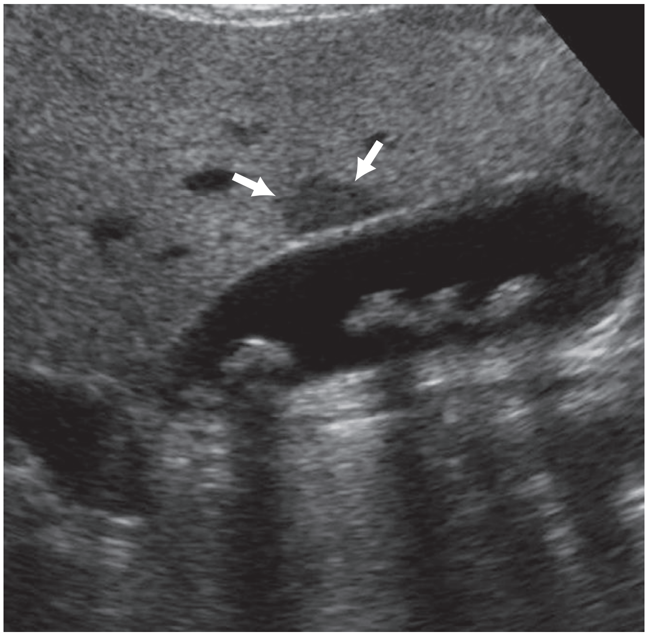


Figure S57-1. Longitudinal real-time ultrasound examination of the liver and gallbladder demonstrates presence of cholelithiasis and a hypoechoic region (arrows) adjacent to the gallbladder in an otherwise echogenic liver.

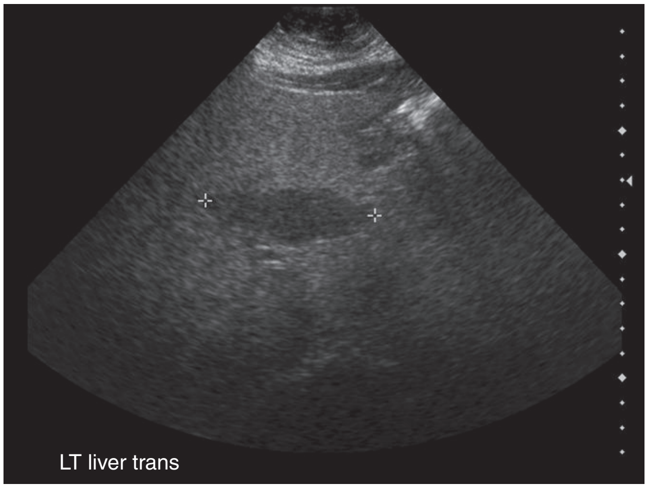


Figure S57-2. Within the left lobe of the liver in another patient there is a hypoechoic mass (calipers) in an otherwise echogenic liver.

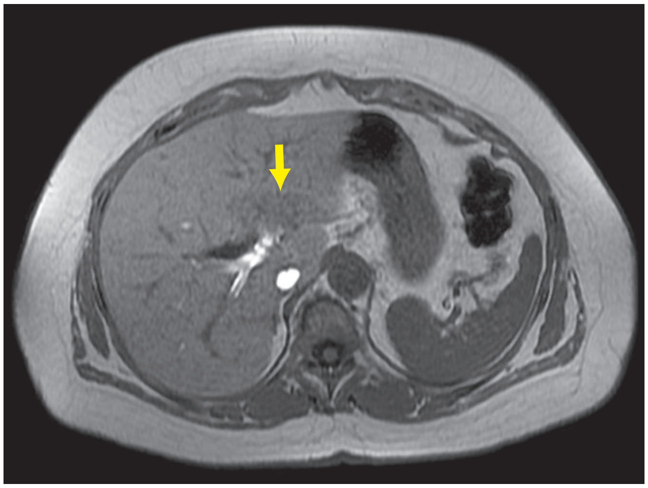


Figure S57-3. The in-phase chemical shift image of a 1.5 Tesla magnet with a TR of 150 and a TE of 4.4 demonstrates a slight area of decreased signal intensity that is barely perceivable (arrow).

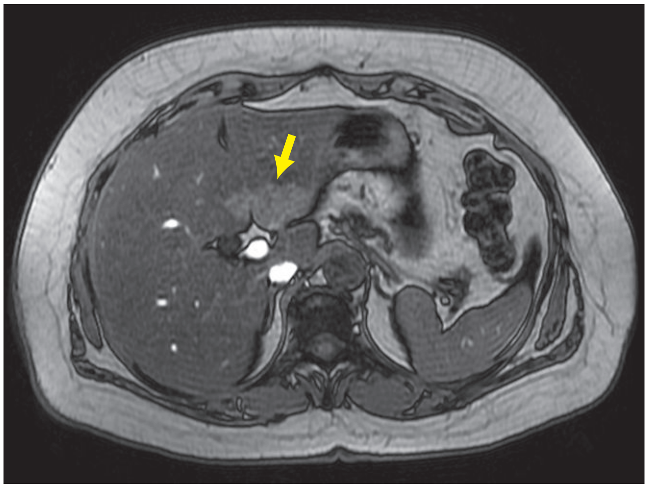


Figure S57-4. The out-of-phase imaging with a TR of 150 and a TE of 2.2 demonstrates there is intensity drop off of the entire liver consistent with diffuse fatty infiltration. There is a portion in the left lobe of the liver that maintains a similar signal as seen on the in-phase imaging (arrow). This would indicate an area of focal fatty sparing in a liver otherwise affected by diffuse fatty infiltration.

CASE 58

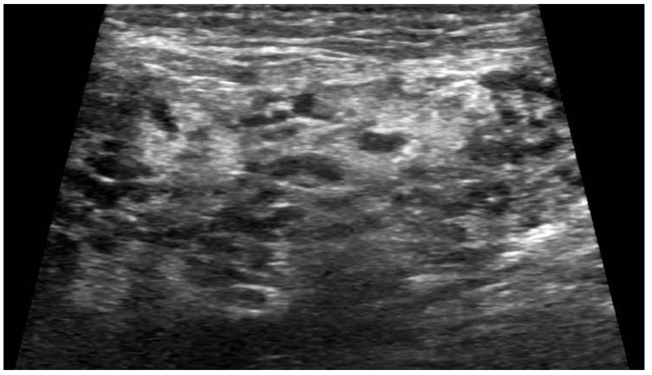


Figure S58-1. The longitudinal gray scale sonogram of the right submandibular gland contains multiple small hypoechoic nodules scattered diffusely throughout the gland.

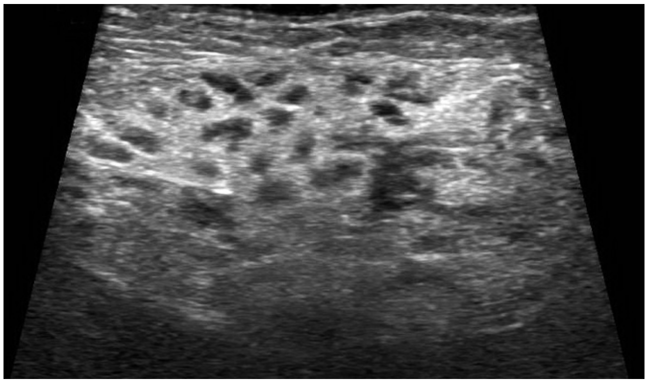


Figure S58-2. The longitudinal gray scale sonogram of the left submandibular gland also contains multiple small hypoechoic nodules scattered diffusely throughout the gland.

CASE 59

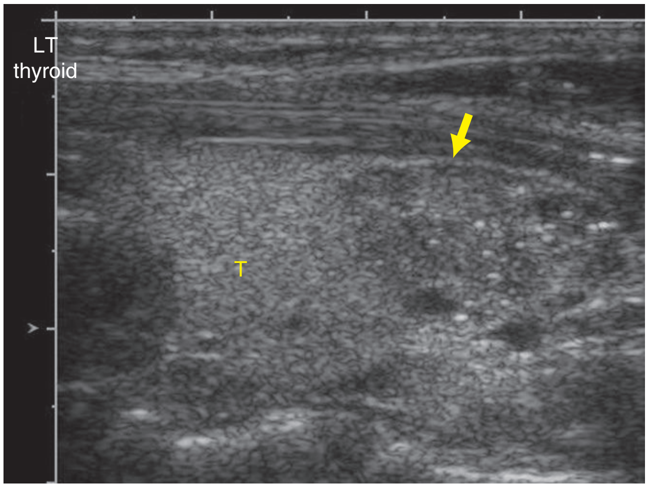


Figure S59-1. Longitudinal ultrasound of the thyroid (T) demonstrating mass (arrow) with multiple microcalcifications.

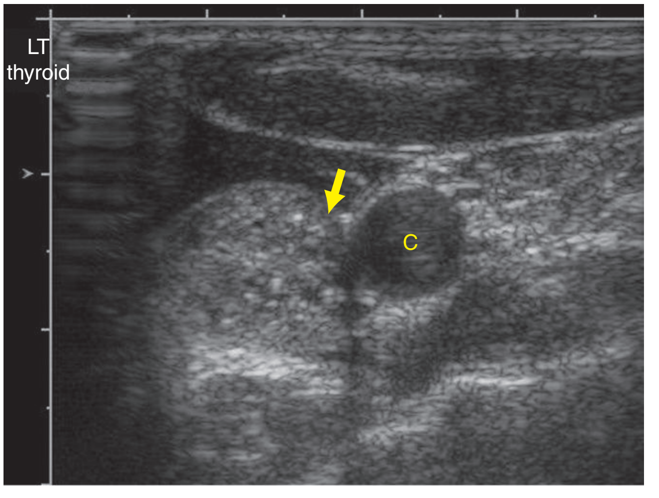


Figure S59-2. Transverse ultrasound through the mass (arrow) demonstrating multiple microcalcifications. (C=carotid.)

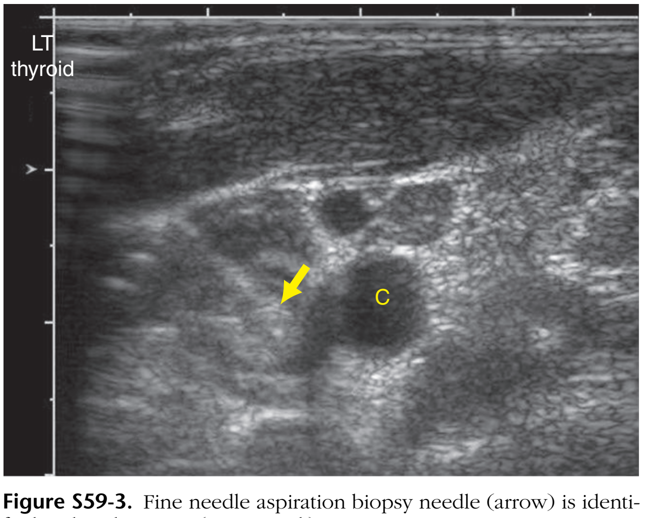


Figure S59-3. Fine needle aspiration biopsy needle (arrow) is identified within the mass. (C=carotid.)

CASE 60

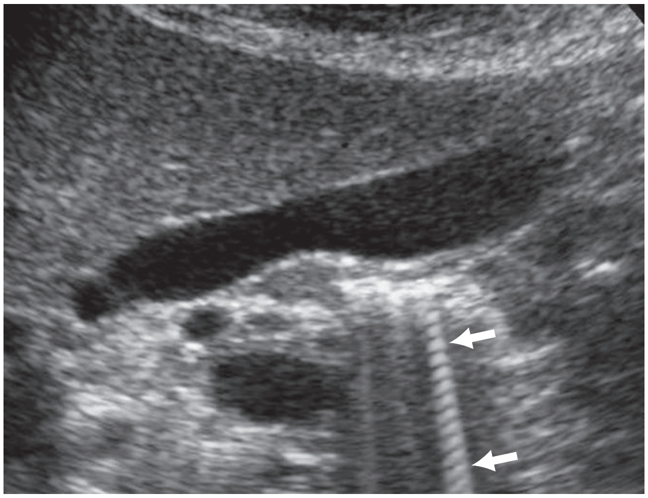


Figure S60-1. View of the gallbladder shows an area of ring-down artifact behind the gallbladder (arrows). This is due to normal bowel gas.

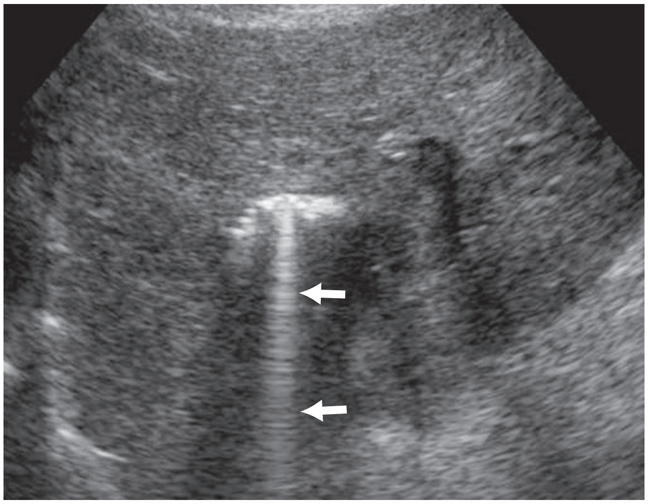


Figure S60-2. A scan of the liver shows a ring-down artifact from within the liver (arrows). This is abnormal and indicates the presence of air in the liver due to a gas-containing liver abscess.

CASE 61

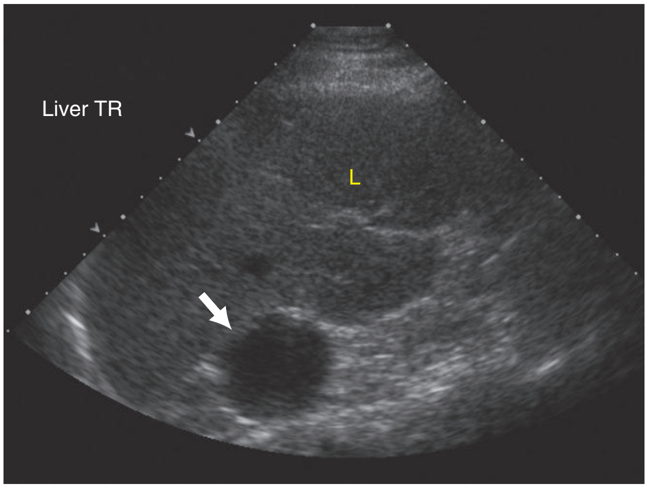


Figure S61-1. Longitudinal image of the hepatorenal fossa demonstrates well-marginated hypoechoic mass (arrow). (L=liver.)

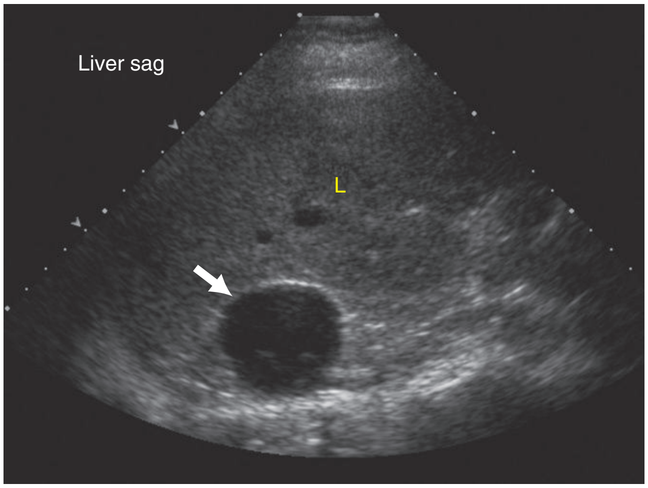


Figure S61-2. Transverse image of the hepatorenal fossa demonstrates well marginated hypoechoic mass (arrow). (L=liver.)

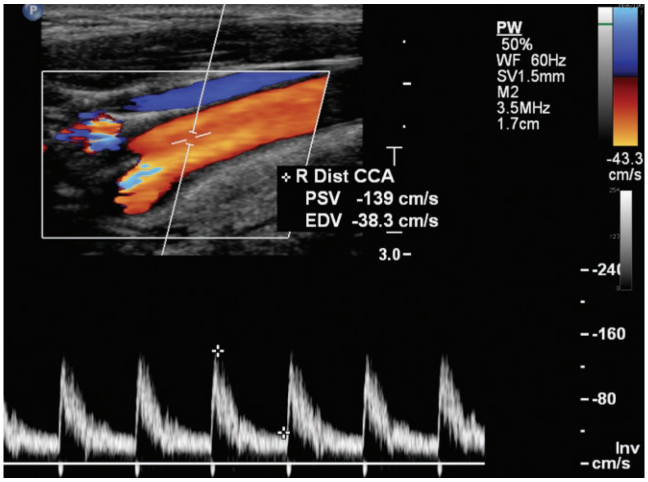


Figure S62-1. Spectral Doppler of the common carotid artery has a peak systolic velocity of 139 cm/s. This velocity is higher than usual. The common carotid is widely patent by color Doppler.

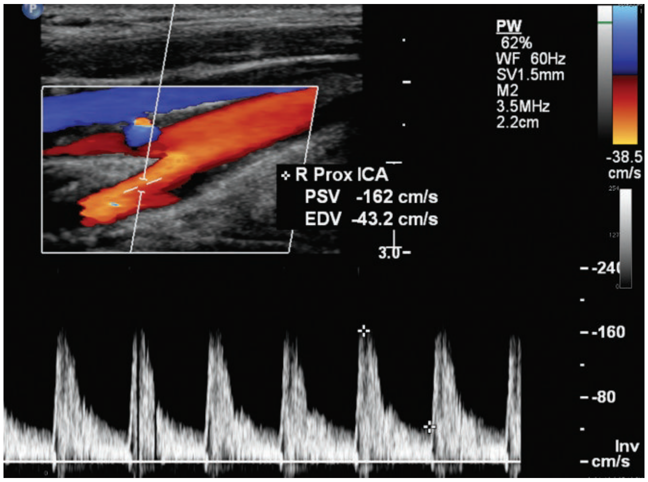


Figure S62-2. Spectral Doppler of the proximal internal carotid has a peak systolic velocity of 162 cm/s. The internal carotid is widely patent by color Doppler. While there are elevated velocities in the ICA, the velocity is not focally elevated but generally elevated in the carotid circulation. The IC:CC ratio is only 1.16, which does not support a stenosis above 50%. There is mild irregularity at the origin of the internal representing very mild plaque. The generalized increase in velocity was caused by a hyperdynamic state and hyperthyroidism and also explains the neck bruit.

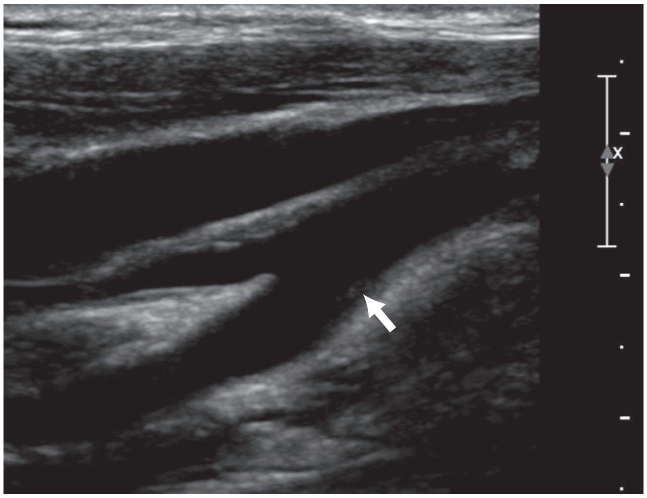


Figure S62-3. Gray scale ultrasound of the carotid bifurcation confirms that there is only a small plaque at the internal carotid origin (arrow). The plaque barely encroaches into the carotid bulb.

CASE 63

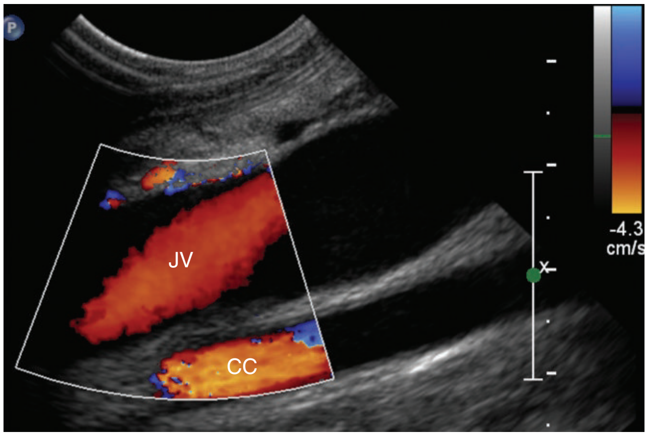


Figure S63-1. Color Doppler of the internal jugular vein (JV) and the common carotid (CC) artery demonstrates both are flowing in the same direction indicating the jugular vein is flowing in the wrong direction. Reversed flow is possible in upper extremity veins in the neck and thorax because collaterals can cross the neck or mediastinal to return flow to the heart.

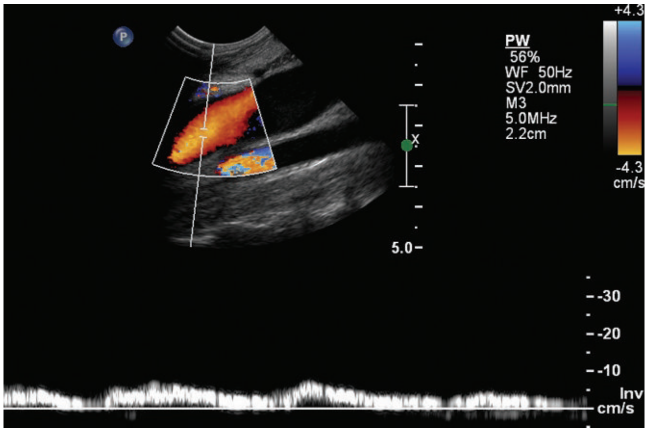


Figure S63-2. Spectral Doppler of internal jugular vein confirms the retrograde direction of flow. The waveform is above the baseline because the spectrum is inverted.

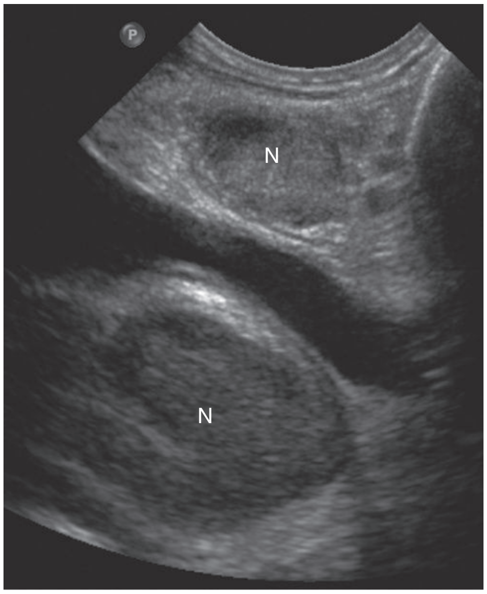


Figure S63-3. Gray scale ultrasound in the sagittal plane shows several enlarged malignant nodes (N) in the neck and upper mediastinum creating an obstruction in the vein.

CASE 64

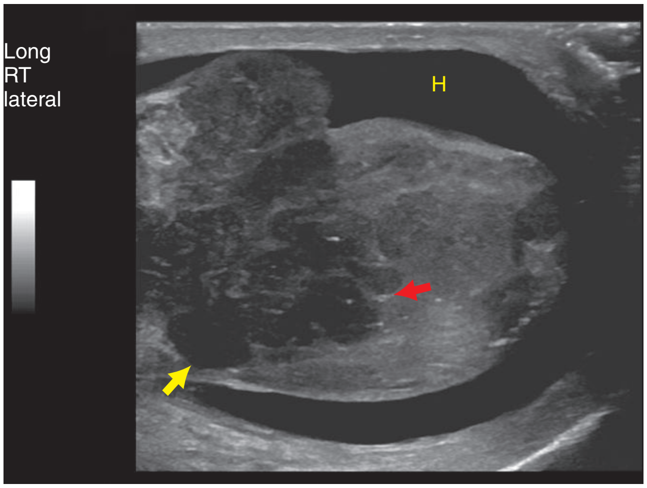


Figure S64-1. Ultrasound demonstrated nearly the entire testis replaced by a heterogeneous mass. There are almost cystic regions in the mass (yellow arrow), as well as subtle microcalcifications (red arrow) (H=hydrocele).

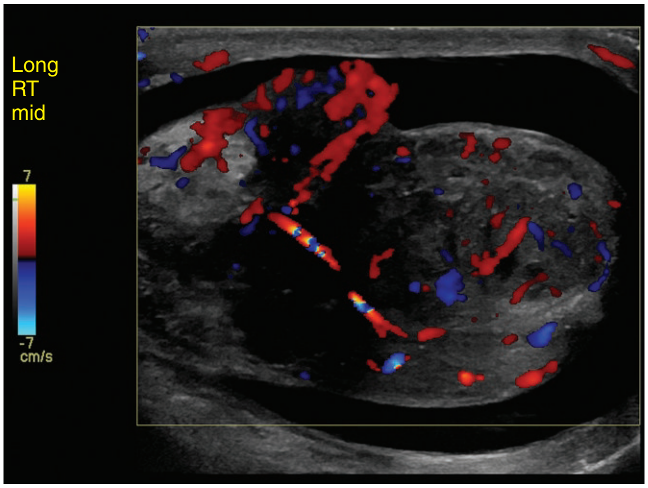


Figure S64-2. Color flow demonstrates marked increased vascularity of the mass.

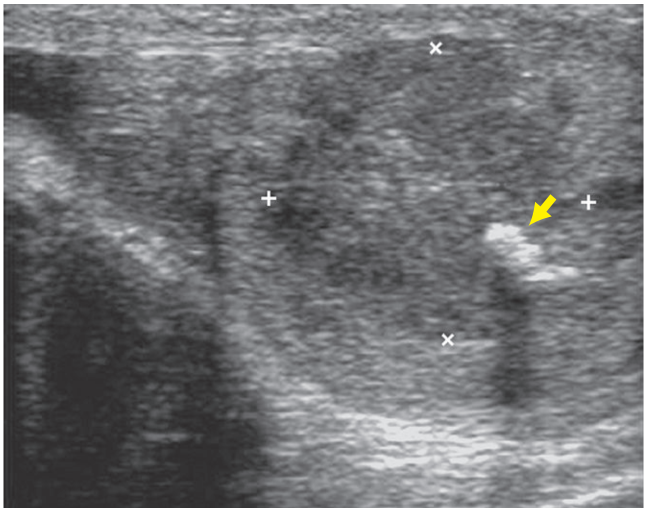


Figure S64-3. In another patient, with a mixed germ cell tumor, the margins of the mass are irregular (calipers) and there is a course calcification in the mass (arrow).

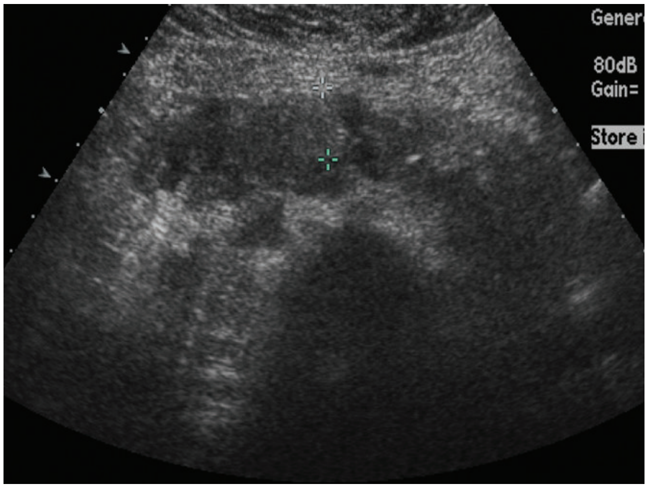


Figure S65-1. Ultrasound image at mid abdomen demonstrates a lobulated, rather homogeneous mass anterior to the aorta (calipers).

Figure S65-2. Another ultrasound image to the right demonstrates the mass connecting to the lower pole of the right kidney. Similar connection was seen on the left side (not shown), confirming the diagnosis of horseshoe kidney.

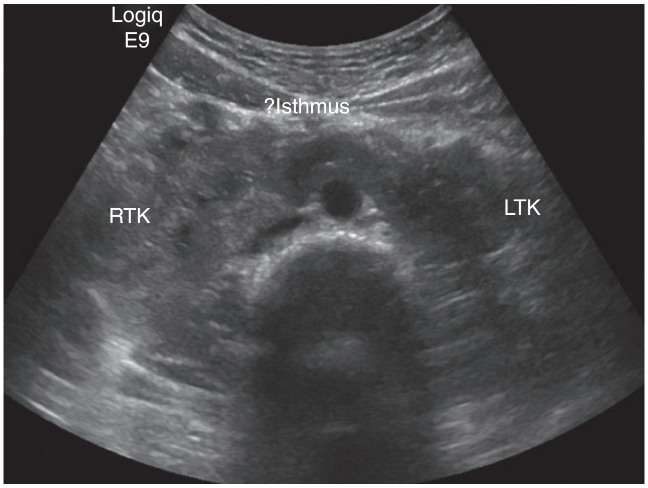


Figure S65-3. Ultrasound image in a different patient demonstrates a horseshoe kidney, with renal parenchyma connecting the inferior poles of bilateral kidneys, anterior to the aorta. (RTK = right kidney and LTK = left kidney).

Figure S65-4. Contrast-enhanced CT image demonstrating a horseshoe kidney. Note the aberrant orientation of the collecting systems pointing anteromedially (arrows).

CASE 66

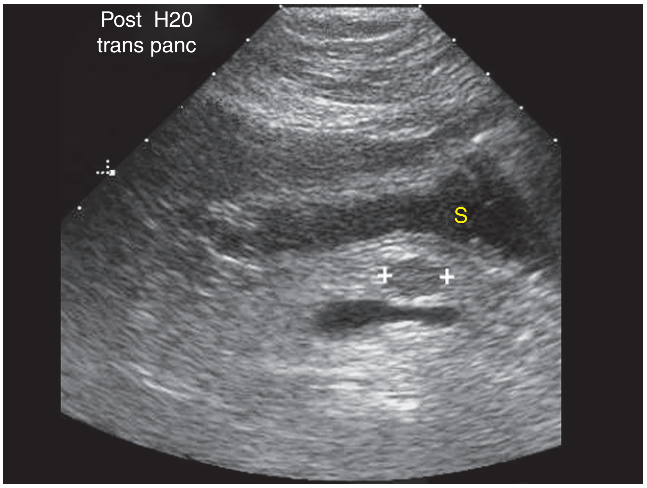


Figure S66-1. Transabdominal ultrasound performed after ingesting water shows the stomach (S) and a small hypoechoic mass (calipers) within the body of the pancreas.

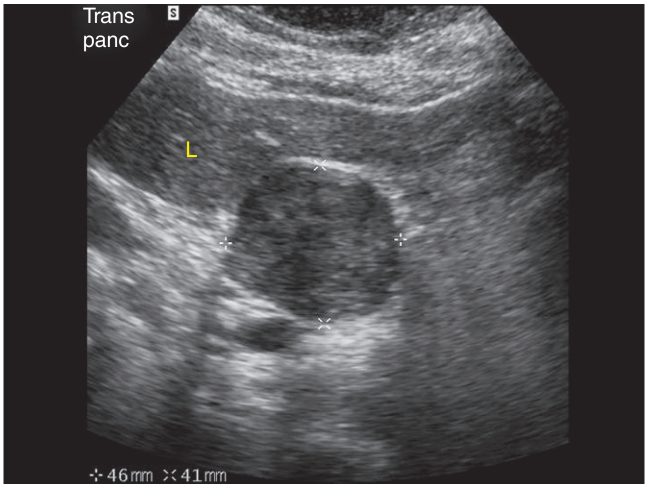


Figure S66-2. In another patient, there is a larger hypoechoic mass measuring 4.6 by 4.1 cm (calipers) detected within the body of the pancreas. (L = liver.)

CASE 67

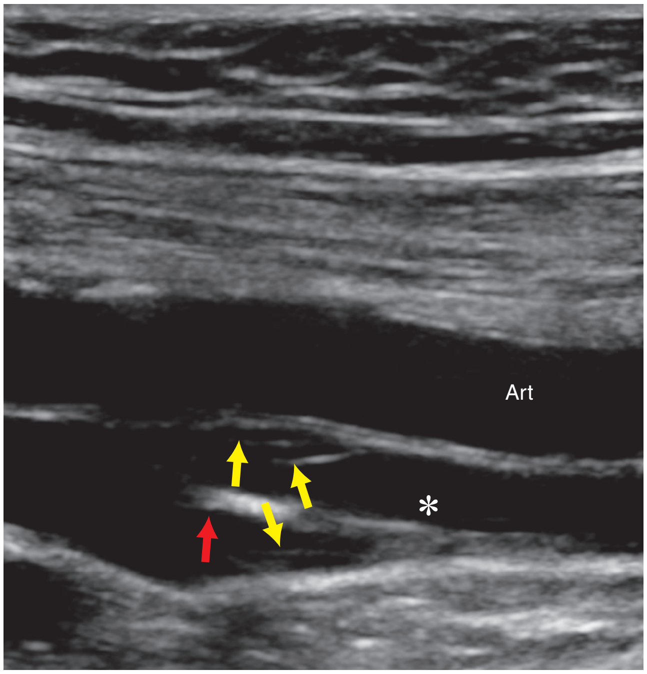


Figure S67-1. The vein is deep to the artery and the lumen is narrowed distally (toward the foot, right side of image) and wider proximally (toward the head). There is linear material in the vein of varying thicknesses. There are fine webs called synechiae (yellow arrows). A thicker but flat web (red arrow) has variable echogenicity, being more echogenic at its tip, and was immobile on realtime. This has a long attachment to the wall (*).

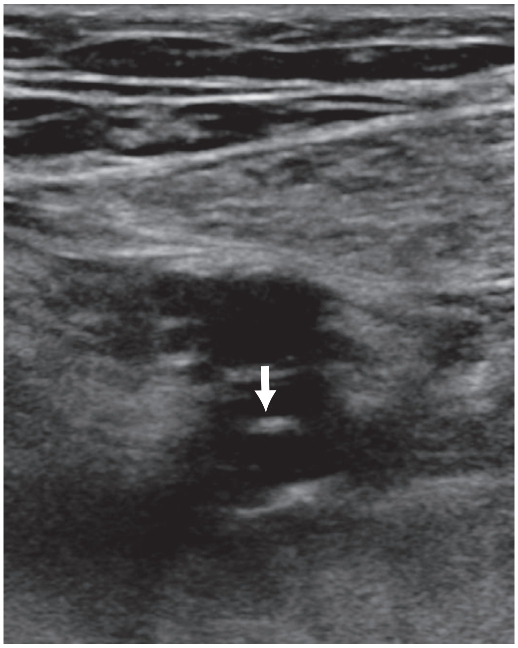


Figure S67-2. Transverse image of the vein at this level demonstrates the larger flat web (arrow). The fine synechiae are more difficult to see in short axis.

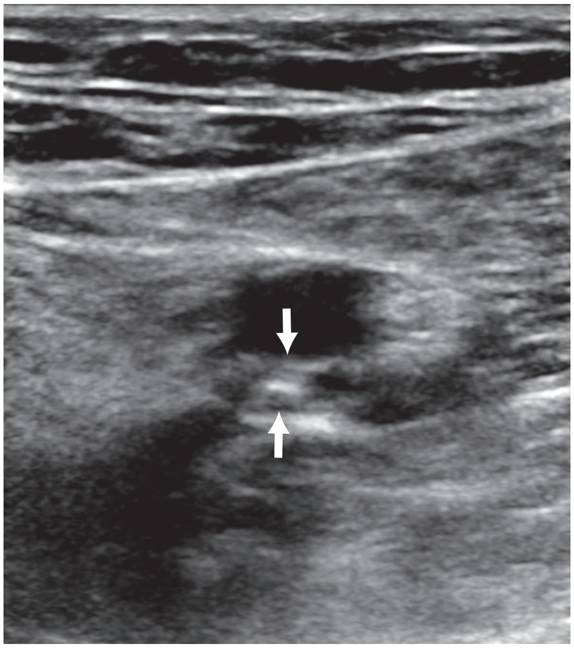


Figure S67-3. Transverse image of the vein at the level of Figure S67-2 with compression confirms there is no additional acute deep venous thrombosis. The vein walls cannot touch because the scar is not compressible.

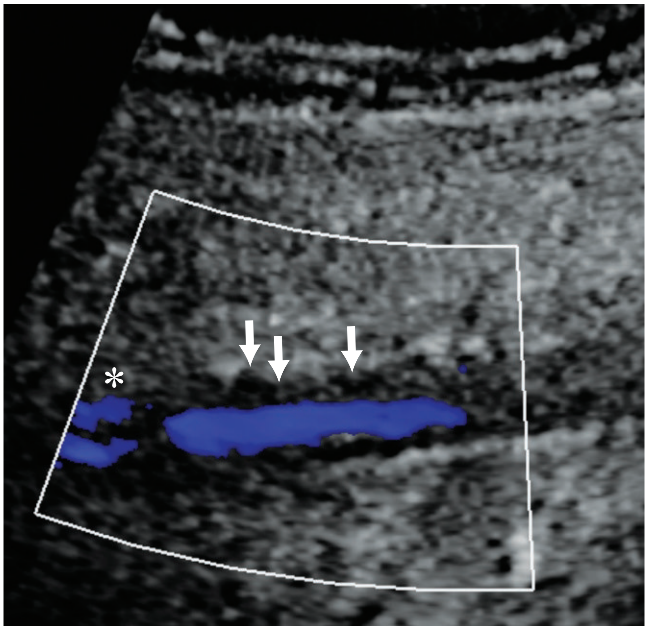


Figure S67-4. In a different patient long axis color Doppler of a popliteal vein with residual venous thrombosis demonstrates the scarring as irregular thickened vein wall (arrows). The majority of the color lumen is central representing recanalization. More proximally, the scarring has left two channels of flow (*).

CASE 68

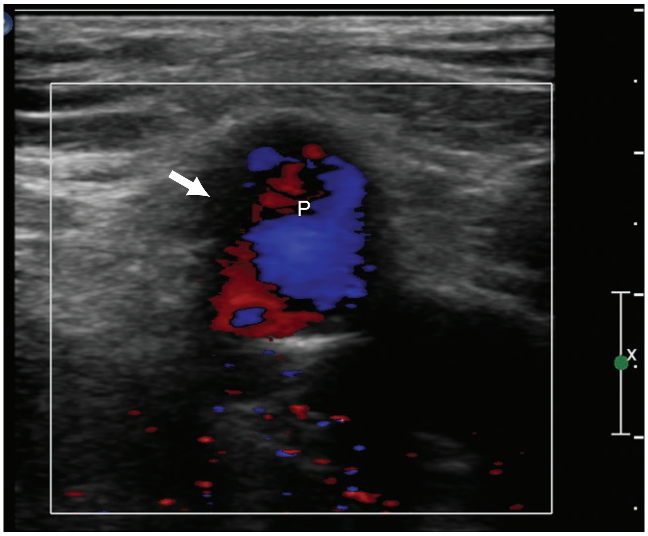


Figure S68-1. Color flow is present in a pseudoaneurysm (P). There is a small amount of thrombus in its wall (arrow).

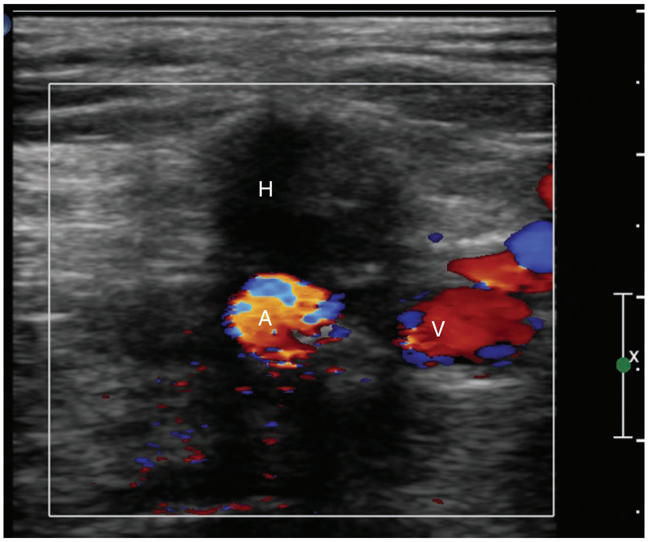


Figure S68-2. Seconds after thrombin injection the pseudoaneurysm has thrombosed leaving a hematoma (H). The common femoral artery (A) and vein (V) are documented to remain patent after the procedure.

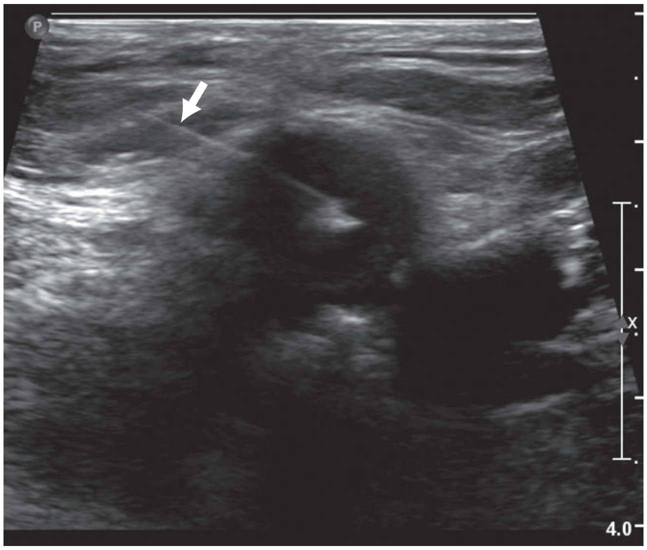


Figure S68-3. During the procedure, a 25-gauge spinal needle (arrow) is placed into the pseudoaneurysm sac and thrombin injection. The echoes at the tip are a combination of the thrombus forming, the thrombin, and a small amount of air that may be present in the needle.

CASE 69

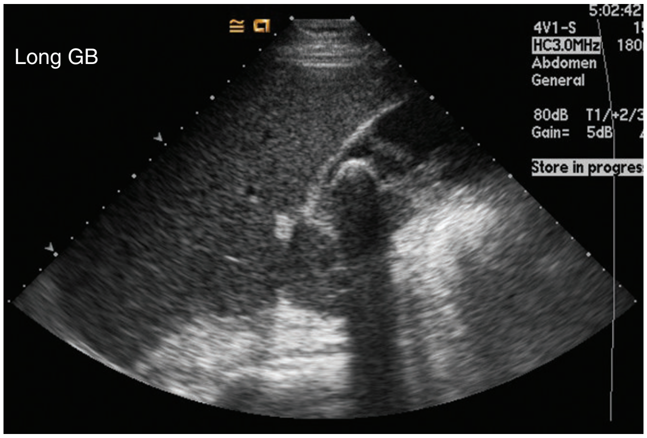


Figure S69-1. Ultrasound image shows classic features of a large gallstone, including highly reflective anterior surface and posterior acoustic shadowing.

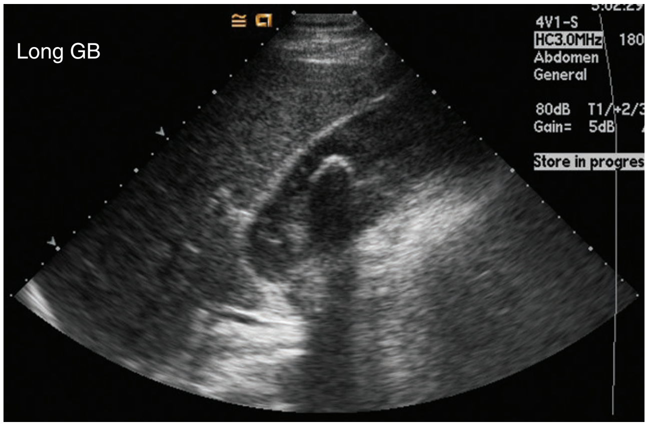


Figure S69-2. Another gallstone in the same patient demonstrates similar features. Note also surrounding low level echoes indicative of biliary sludge, and mild gallbladder wall thickening.

CASE 70

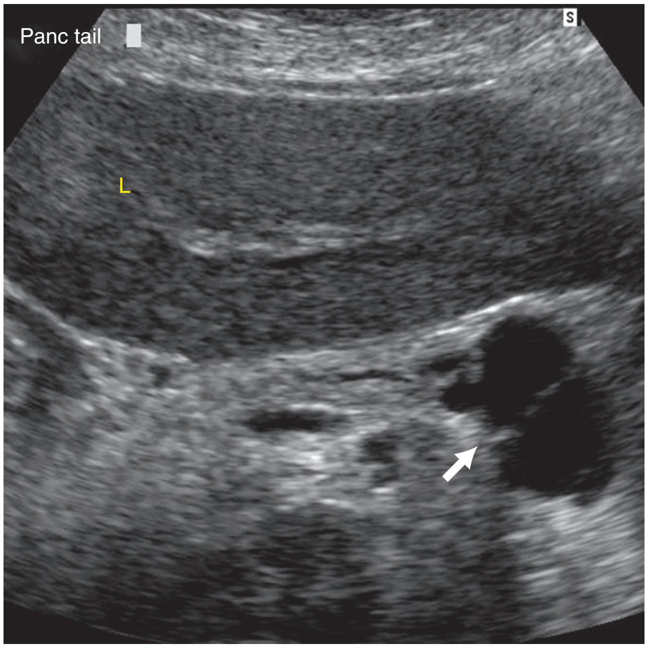


Figure S70-1. Transverse sonogram through liver (L) showing a cystic mass in the body/tail of pancreas (arrow).

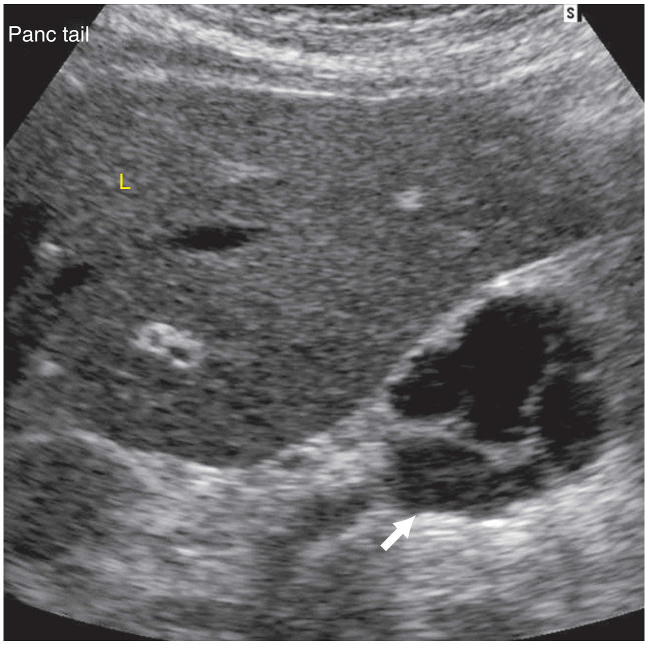


Figure S70-2. Another sonogram showing similar findings of a multi-septated cystic pancreatic mass (arrow). (L=liver.)

CASE 71

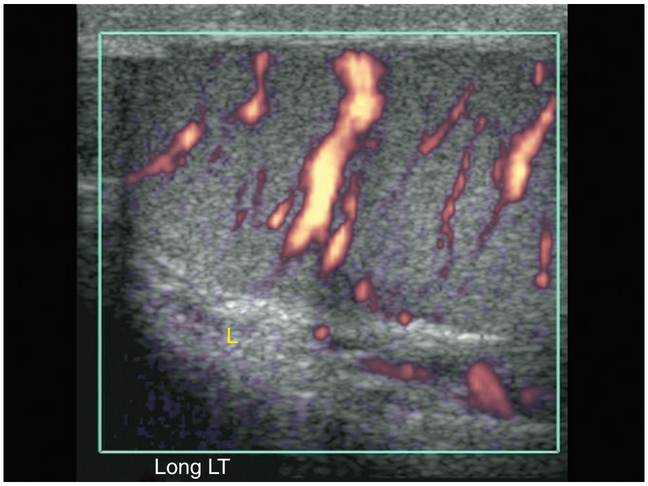


Figure S71-1. Color Doppler ultrasound of the left (L) testis.

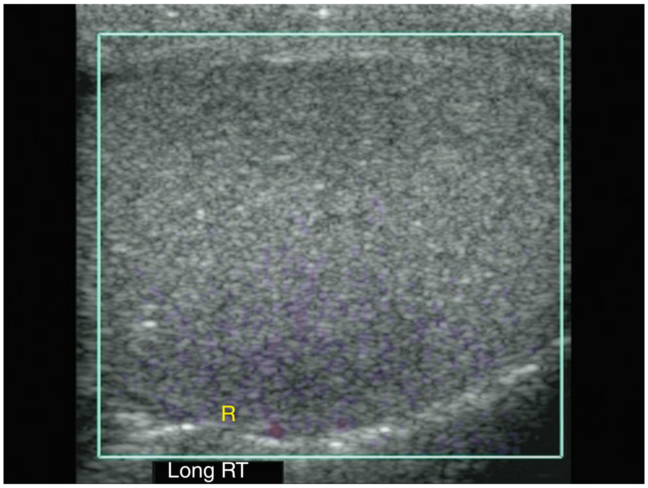


Figure S71-2. Color Doppler ultrasound of the right (R) testis showing absent color flow.

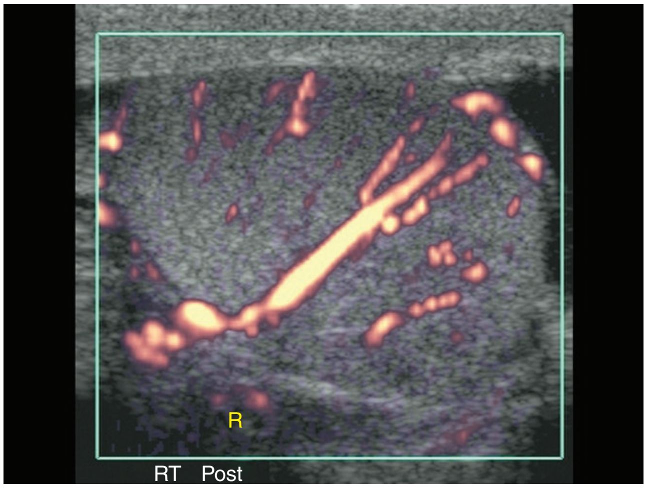


Figure S71-3. Approximately three minutes after obtaining the image in Figure S71-2, there is testicular flow. The patient had manual detorsion of the testis, and the second power Doppler image was obtained showing a return of color flow in the right (R) testis.

CASE 72

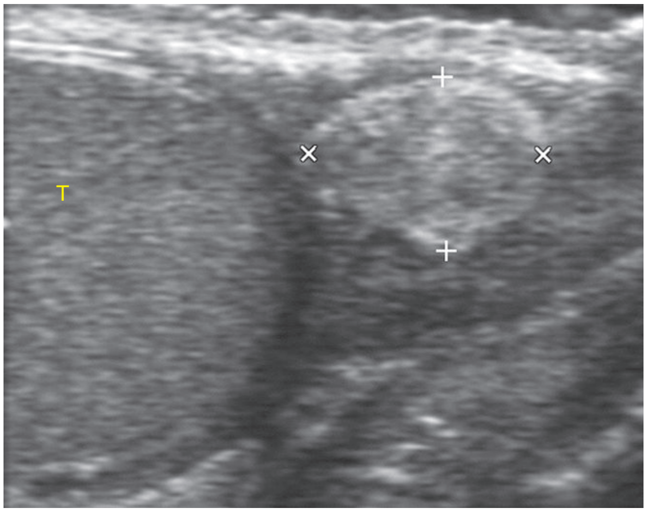


Figure S72-1. Ultrasound of the scrotum shows an echogenic extra-testicular mass (calipers) within the epididymis. (T = testis.)

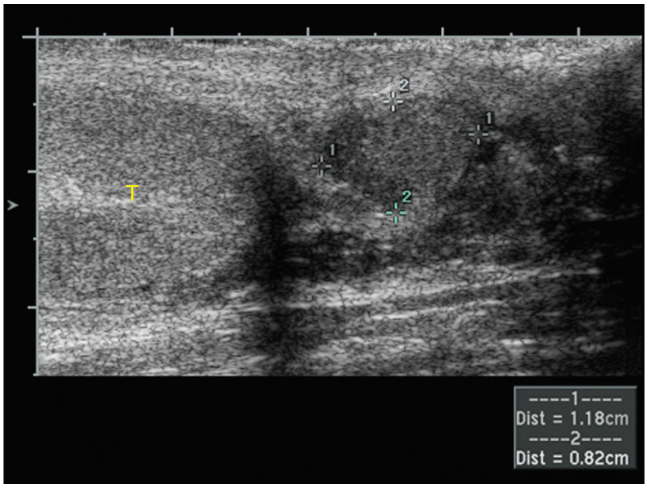


Figure S72-2. Ultrasound of the scrotum in another patient shows an extra-testicular mass (calipers) within the epididymis. (T = testis.)

Figure S73-1. Realtime ultrasound image demonstrates increased echogenicity of the renal pyramids suggestive of medullary nephrocalcinosis.

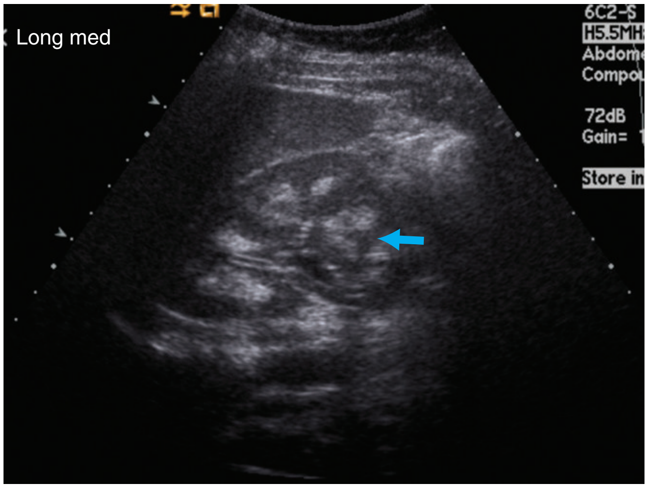


Figure S73-2. Echogenic renal pyramids with some pyramids demonstrating posterior shadowing (arrow), suggestive of advanced disease.

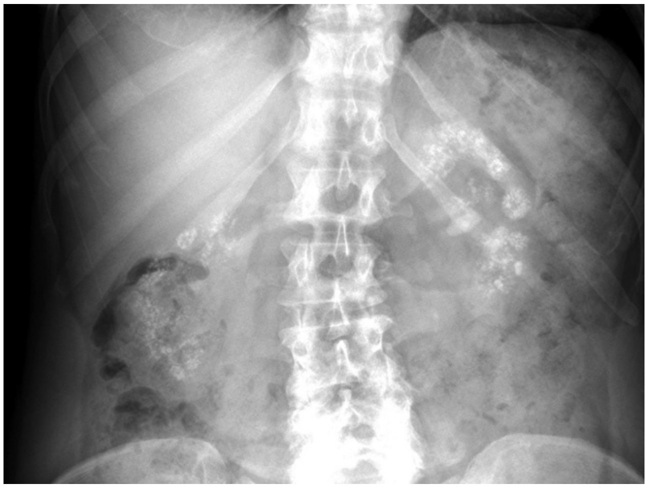


Figure S73-3. Abdomen radiographs demonstrating bilateral renal calcifications outlining the renal pyramids, consistent with medullary nephrocalcinosis.

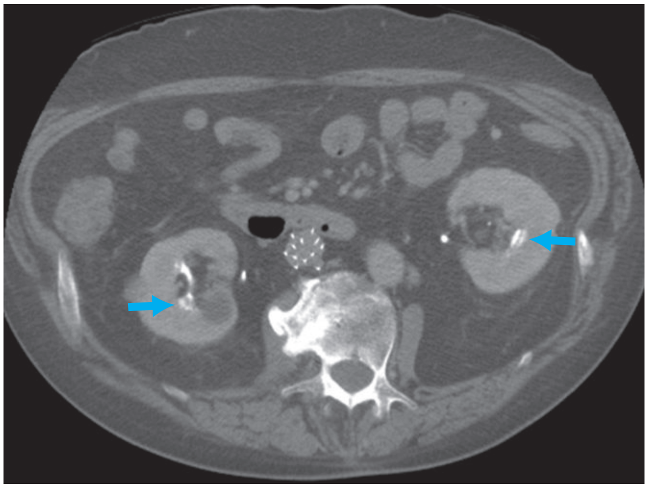


Figure S73-4. Image from CT urogram in a different patient demonstrates "paint brush" appearance of the renal pyramids (arrows) secondary to tubular ectasia seen with medullary sponge kidney.

CASE 74

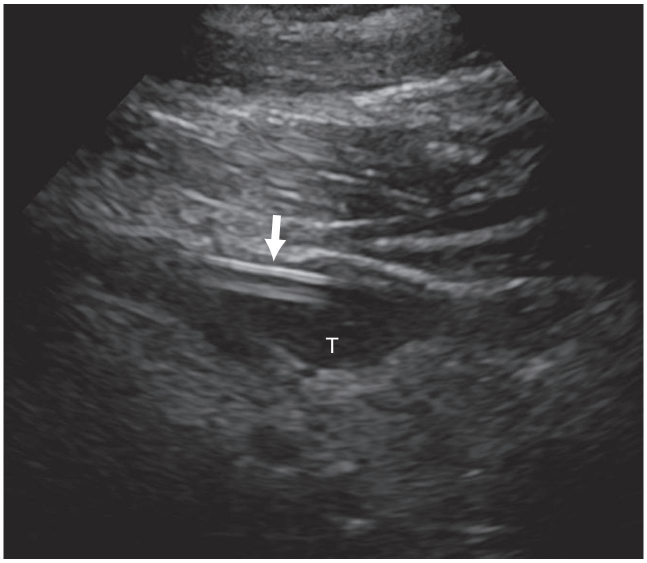


Figure S74-1. Long axis image of the left subclavian vein shows a PICC catheter (arrow). The vein is distended by acute thrombus (T). Compression is not possible in much of the subclavian vein due to overlying bony structures.

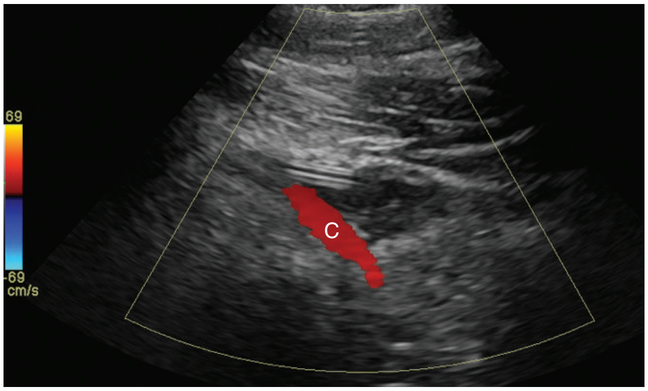


Figure S74-2. Long axis color Doppler of the subclavian vein. There is occlusion of the vein at the site of thrombosis. A collateral vein (C) is flowing toward the midline. It is a collateral vein since it does not have the expected course paralleling the subclavian artery.

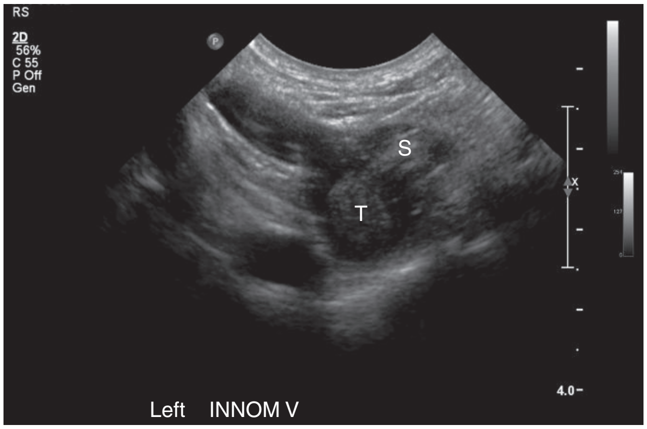


Figure S74-3. In another patient, a coronal image of the left innominate vein shows an echogenic acute thrombus (T) freely floating in the lumen. The attachment is in the subclavian vein (S).

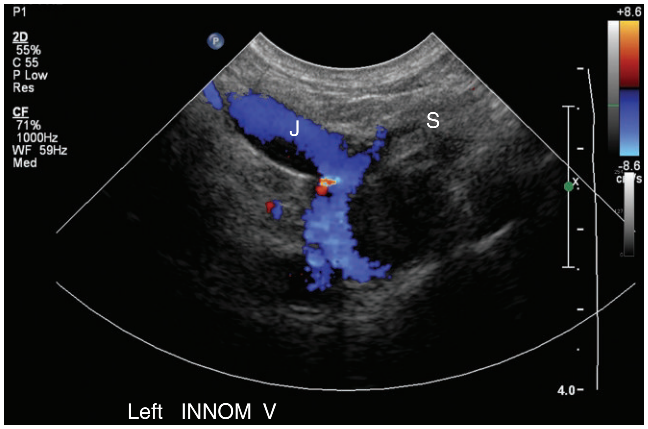


Figure S74-4. Color Doppler obtained in the same plane as Figure S74-3. The thrombus appears as a color filling defect in the innominate vein. The subclavian vein (S) is obstructed and the jugular vein (J) is patent. Note the echogenicity of the thrombus is less when the color Doppler is active.

CASE 75

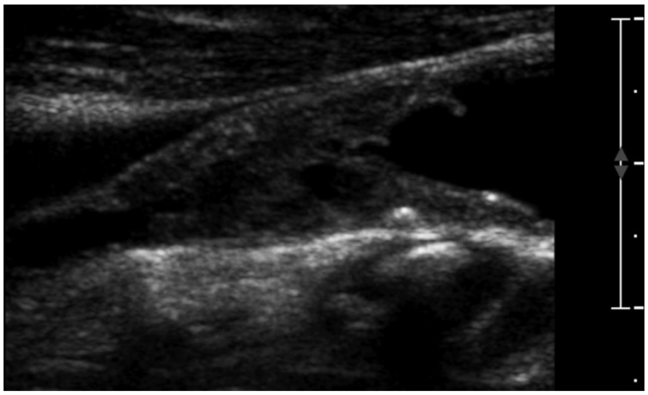


Figure S75-1. Gray scale ultrasound of the right ICA demonstrates irregular plaque narrowing the lumen.

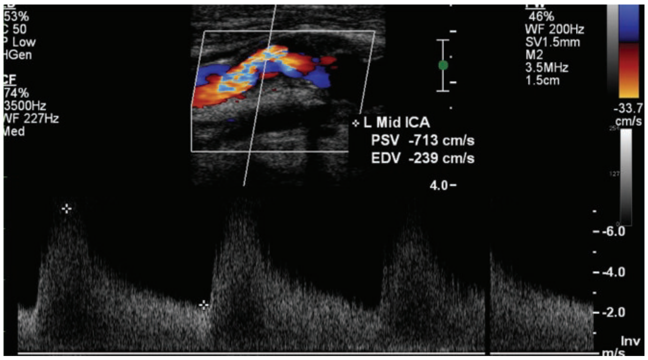


Figure S75-2. Spectral duplex Doppler at the site of maximal ICA velocity demonstrates plaque, color narrowing and aliasing, and elevated ICA velocities. The peak systolic velocity is 713 cm/s and the end-diastolic velocity is 239 cm/s.

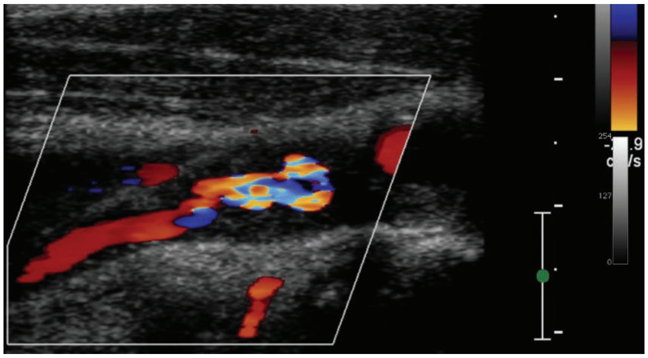


Figure S75-3. Color Doppler of the ICA stenosis shows narrowing of the color lumen. This is an approximate size of the lumen since the ultrasound is a two-dimensional representation of a three-dimensional object. In the area of narrowing proximally, the mixtures of colors is due to color aliasing from high velocity. More distally the velocity decreases and the color of the ICA flow velocity is red.

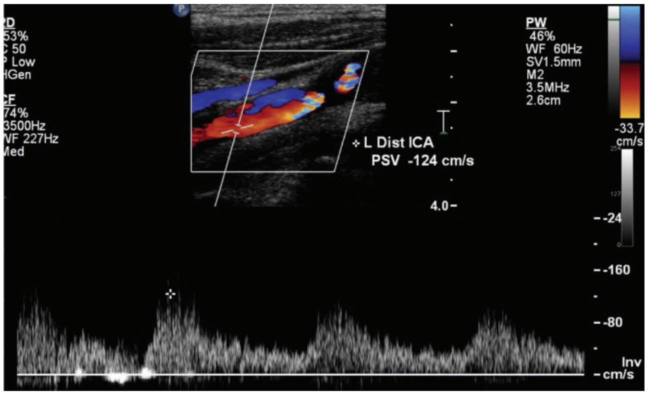


Figure S75-4. Spectral duplex Doppler beyond the site of narrowing shows a red color indicating a lower velocity. This is confirmed by the spectral Doppler that shows a PSV of 124 cm/s. The edge of the waveform has numerous spikes. This is termed a picket fence appearance and it is produced by turbulent poststenotic flow.

CASE 76

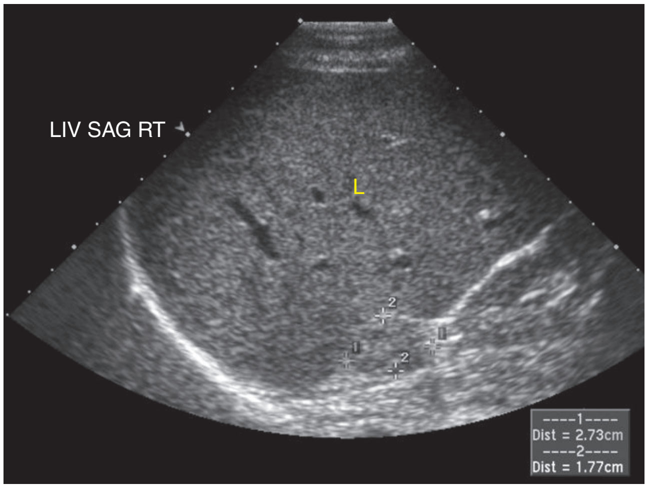


Figure S76-1. Longitudinal image of the hepatorenal fossa demonstrates a well-circumscribed, isoechoic rounded mass (calipers) in the expected location of the right adrenal gland. (L = liver.)

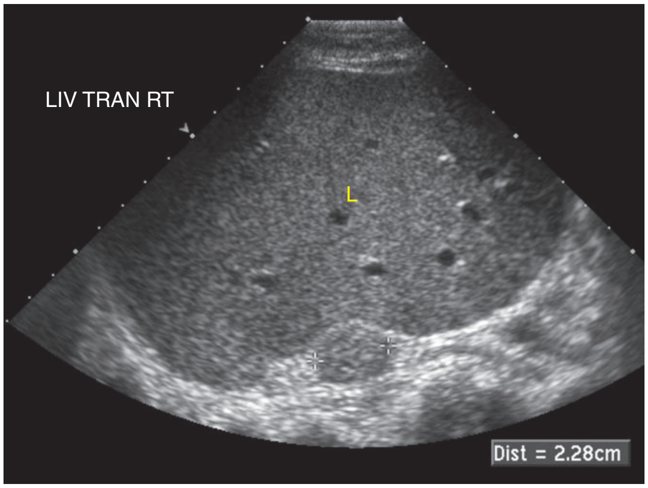


Figure S76-2. Transverse image of the hepatorenal fossa that demonstrates the mass (calipers) is separate from both the liver (L) and kidney, verifying its location within the adrenal gland.

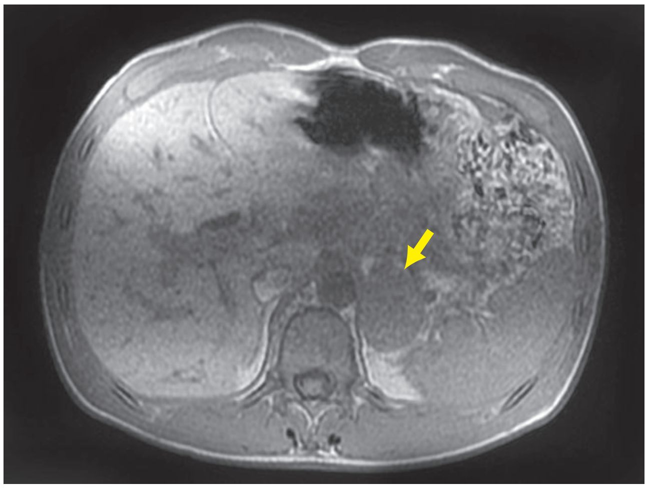


Figure S76-3. In-phase MRI of left adrenal in another patient (arrow).

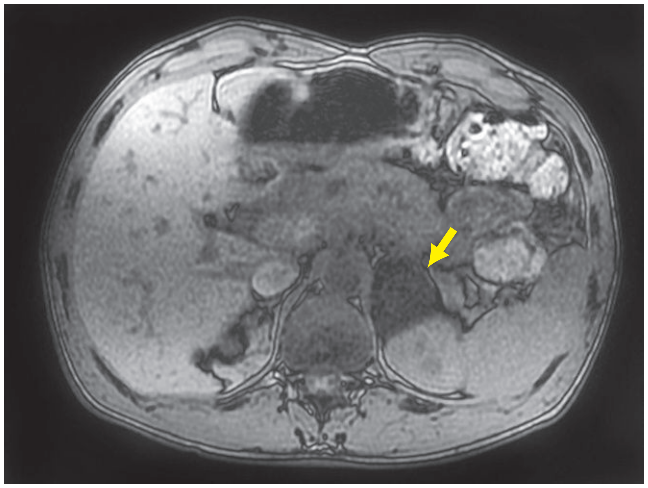


Figure S76-4. Out-of-phase MRI of left adrenal with signal dropout (arrow), which is seen with adrenal adenomas.

CASE 77

Figure S77-1. Complex mass noted within the right lobe of the liver (calipers) with stippled echogenic regions that may represent small collections of gas.

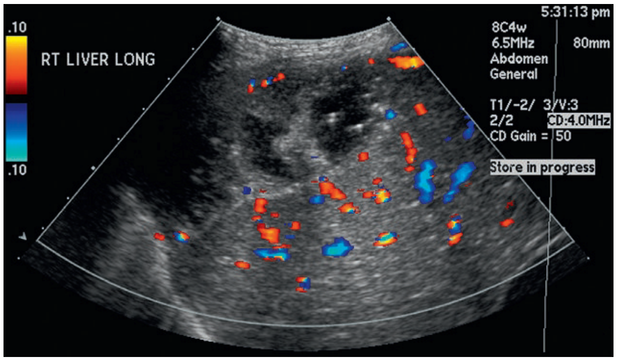


Figure S77-2. Color Doppler ultrasound demonstrates little color within the complex mass.

CASE 78

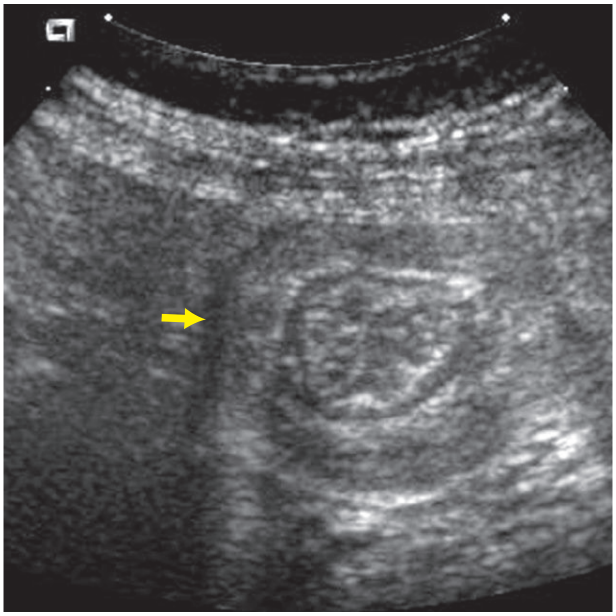


Figure S78-1. Transverse ultrasound of structure on RLQ of the abdomen in area of pain. Demonstrates target appearances of intussusception (arrow).

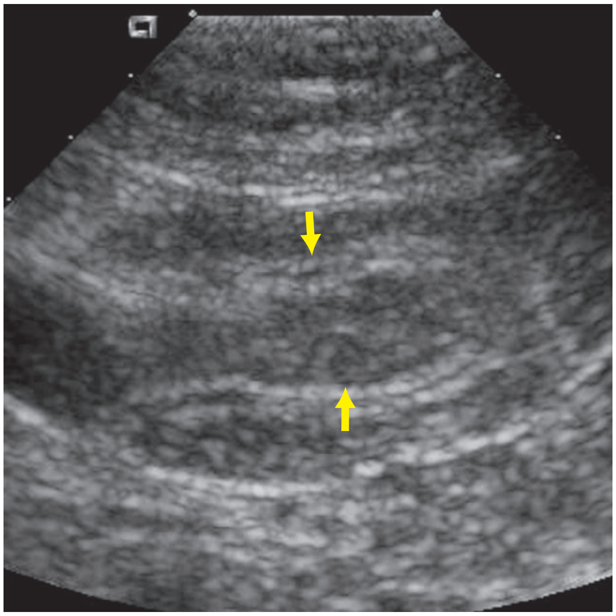


Figure S78-2. Longitudinal ultrasound of structure in RLQ of the abdomen in area of pain show the intussusceptum (arrow) inside the intussuscipiens.

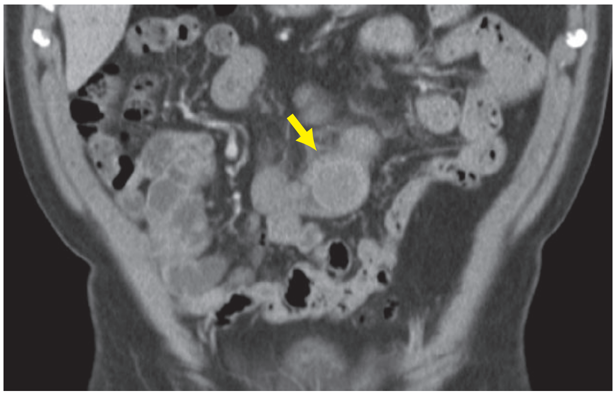


Figure S78-3. CT of a different patient shows intussusceptions secondary to a small bowel mass (arrow) in an adult patient.

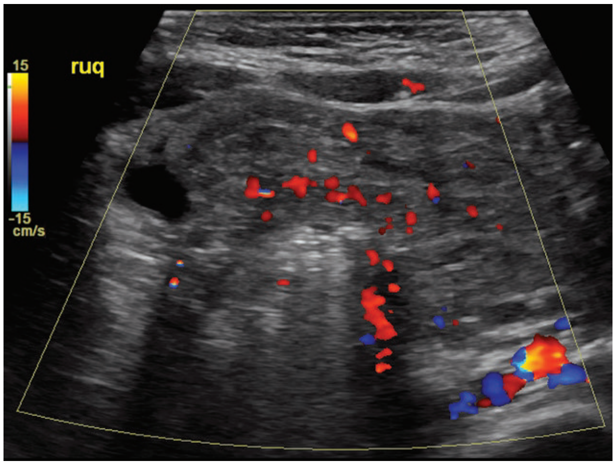


Figure S78-4. Color Doppler demonstrates flow in the bowel in this case of intussusceptions.

CASE 79

Figure S79-1. The longitudinal gray scale sonographic image of the testis shows a solid, heterogeneous mass with a small calcification nearly replacing the testis.

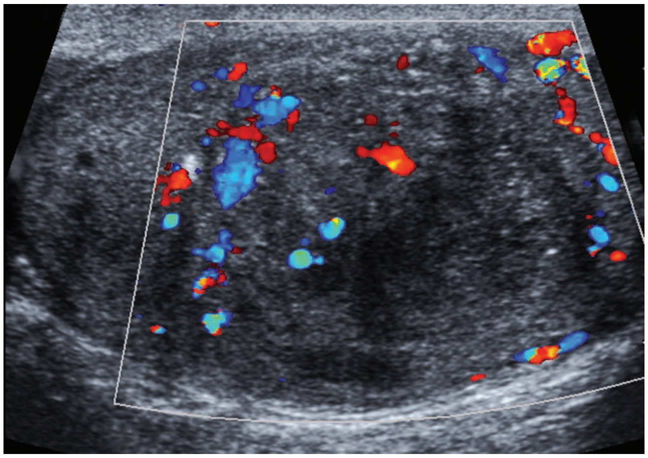


Figure S79-2. The longitudinal color Doppler sonographic image of the testis shows internal vascularity in the mass.

CASE 80

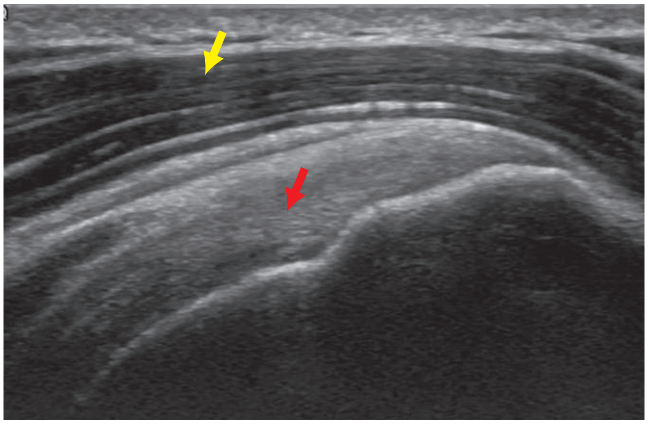


Figure S80-1. The long axis view (medial to lateral) of the rotator cuff shows the cuff (red arrow) and overlying deltoid muscle (yellow arrow). The cuff is normal in thickness and echogenicity.

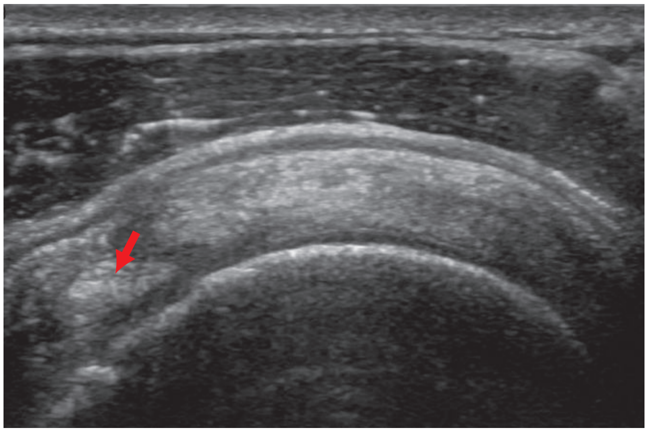


Figure S80-2. The short axis view (anterior to posterior) of the rotator cuff shows the intra-articular portion of the biceps tendon (arrow). The cuff is normal in thickness and echogenicity.

CASE 81

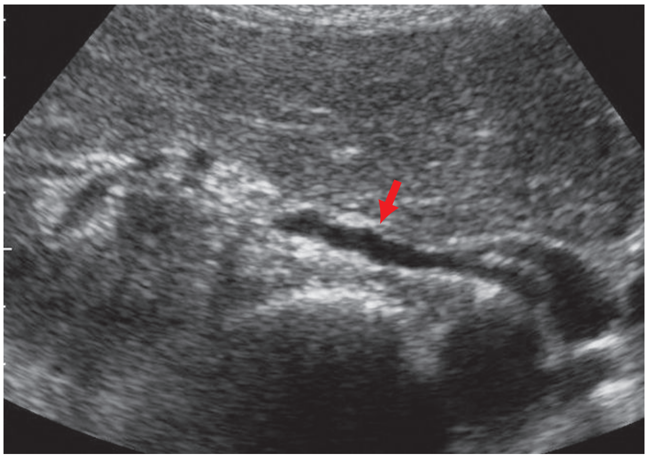


Figure S81-1. The gray scale image of the right renal artery shows irregularity of the vessel wall (arrow) and subtle focal areas of narrowing and dilatation in the mid to distal artery.

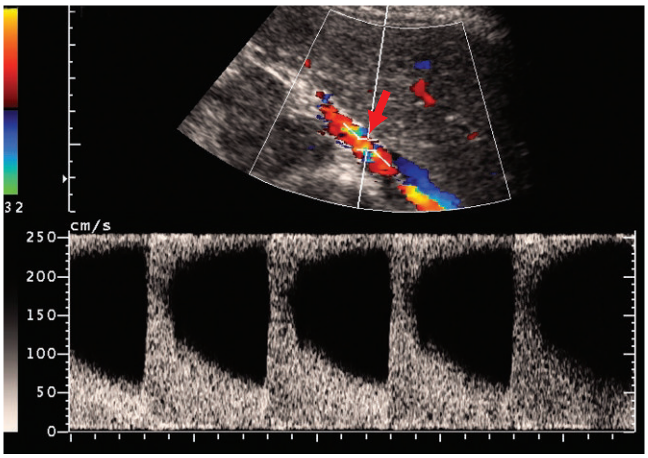


Figure S81-2. The color Doppler image shows aliasing (arrow) in the mid portion (retrocaval) of the right renal artery, and the waveform shows elevated arterial velocities greater than 200 cm/second.

CASE 82

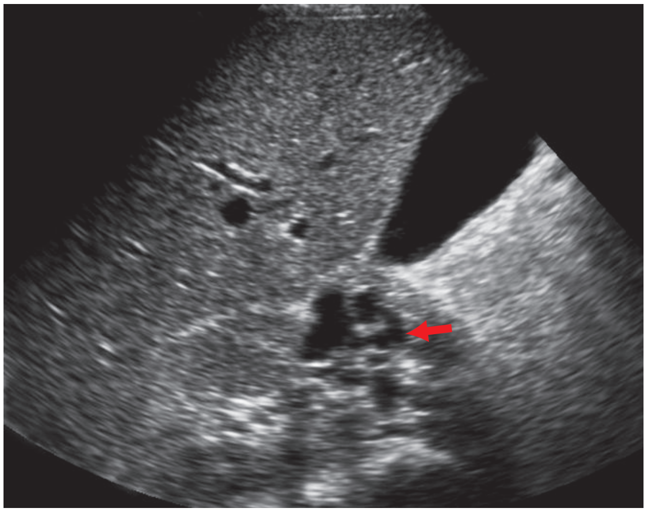


Figure S82-1. The transverse gray scale sonographic image shows multiple tortuous, tubular channels in the vicinity of the main right renal vein (arrow). The normal renal vein cannot be visualized.

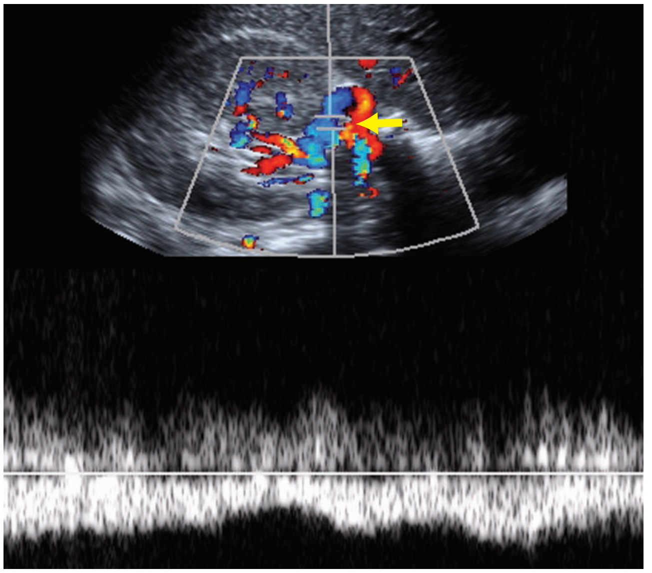


Figure S82-2. The transverse duplex and color Doppler image shows multiple tortuous, tubular channels in the vicinity of the main right renal vein on color Doppler (arrow). A venous waveform was obtained in one of these venous collaterals.

CASE 83

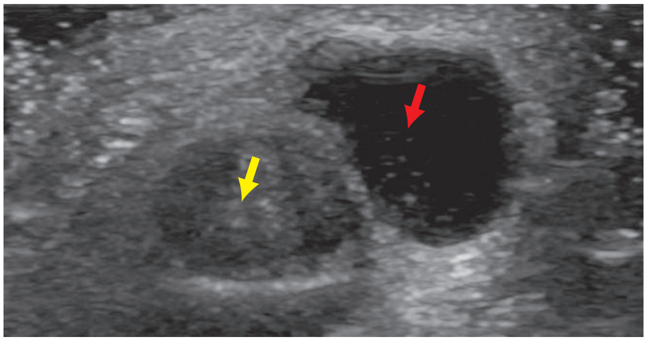


Figure S83-1. The transverse image shows the anechoic ganglion with a few internal echoes (red arrow) due to mucin. The ganglion is adjacent to a flexor tendon (yellow arrow).

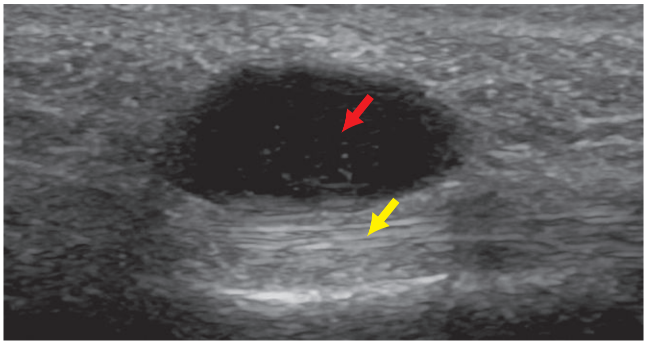


Figure S83-2. The sagittal image shows the anechoic ganglion with a few internal echoes (red arrow) due to mucin. The ganglion is adjacent to a flexor tendon (yellow arrow).

CASE 84

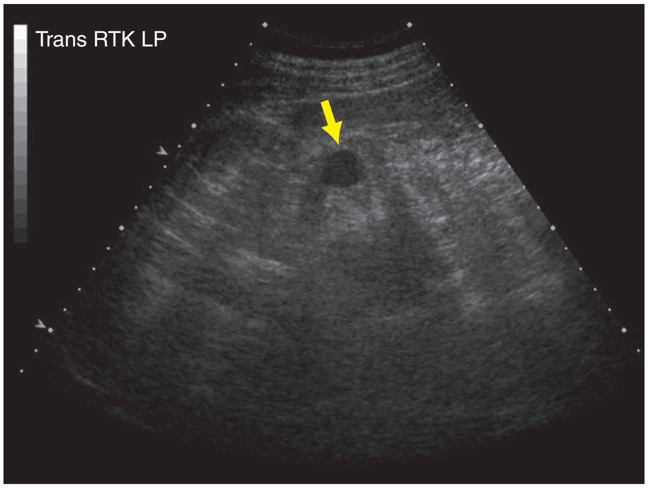


Figure S84-1. Real-time ultrasound performed through the mass (arrow) demonstrates it is very hypoechoic compared to surrounding peritoneal fat.

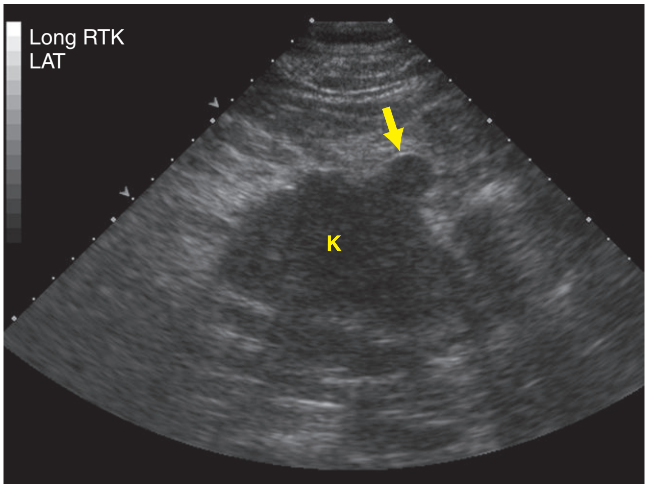


Figure S84-2. Real-time ultrasound of the right kidney (K) demonstrates circumscribed hypoechoic mass (arrow) with slightly echogenic margins.

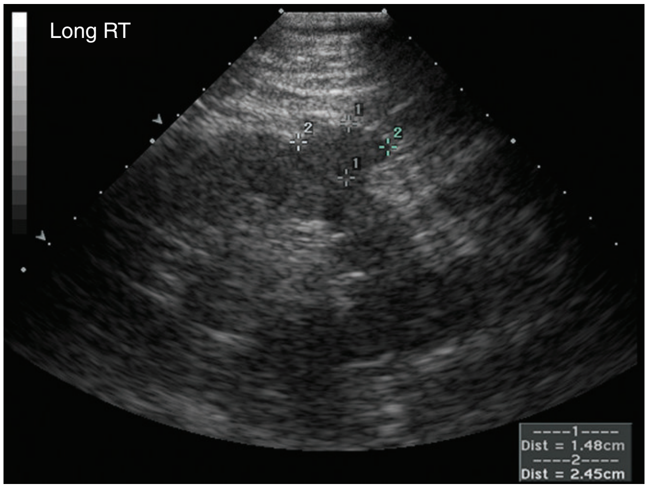


Figure S84-3. Follow-up ultrasound in three months demonstrates the mass (calipers), which appears exophytic and isoechoic to the rest of the parenchyma.

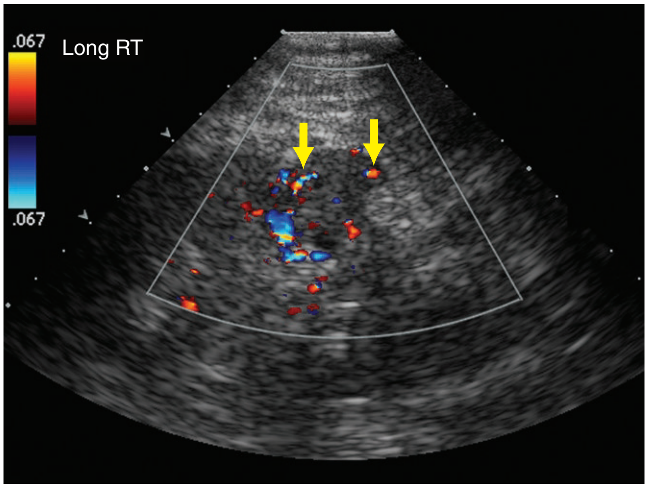


Figure S84-4. Color Doppler ultrasound demonstrates the mass with color flow (arrows) in the mass. Biopsy was performed to demonstrate a low-grade clear cell carcinoma.

CASE 85

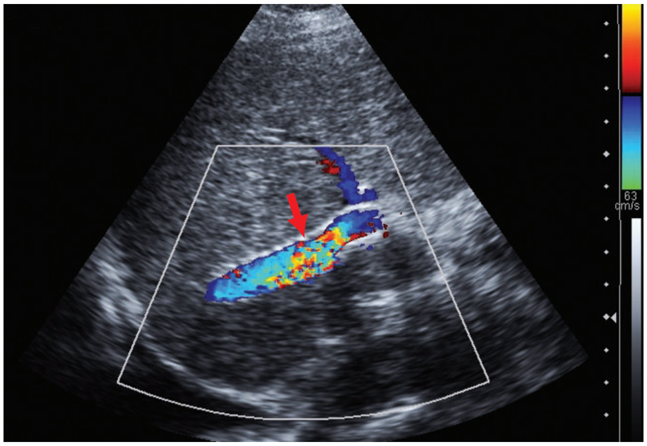


Figure S85-1. The longitudinal color Doppler image of the stent graft shows focal aliasing in the mid aspect of the stent graft (arrow) suggestive of a stenosis.

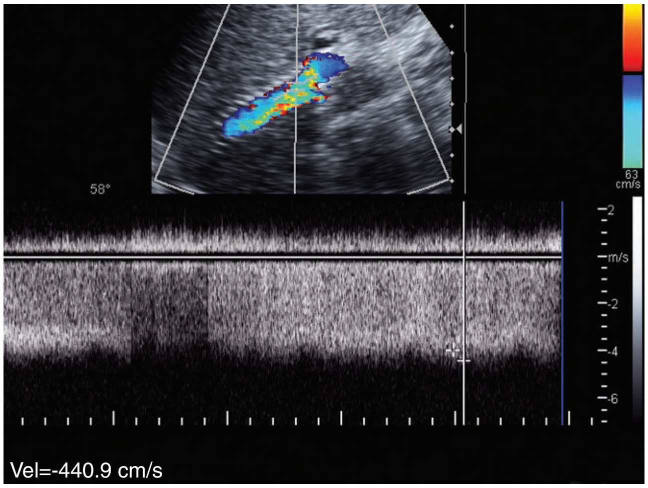


Figure S85-2. The longitudinal duplex and color Doppler image of the stent graft shows an elevated velocity of 441 cm/second in the area of aliasing indicative of a stenosis. The normal range for stent graft velocity is 90-190 cm/second.

CASE 86

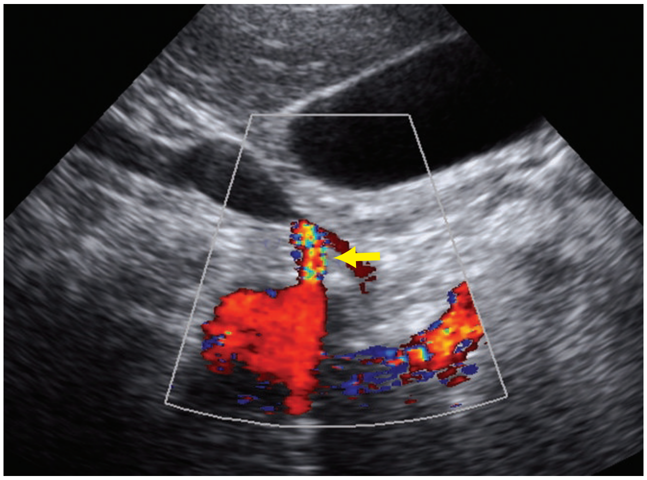


Figure S86-1. The sonographic image shows aliasing (arrow) at the origin of the right renal artery.

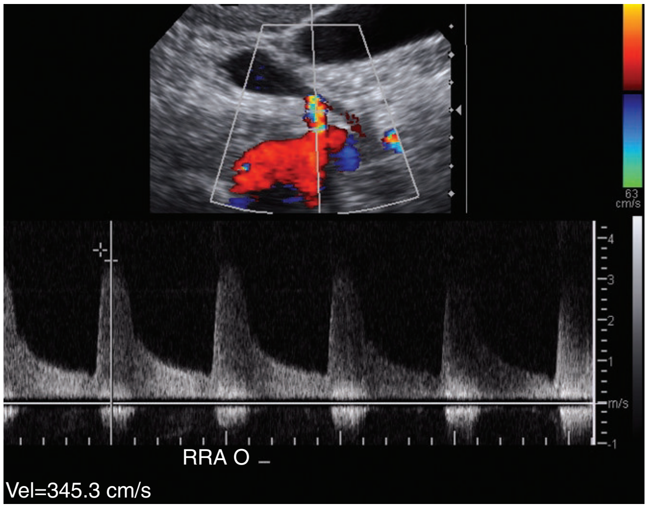


Figure S86-2. The sonographic image shows an elevated peak systolic velocity (345.3 cm/second – lower left corner) at the origin of the right renal artery.

CASE 87

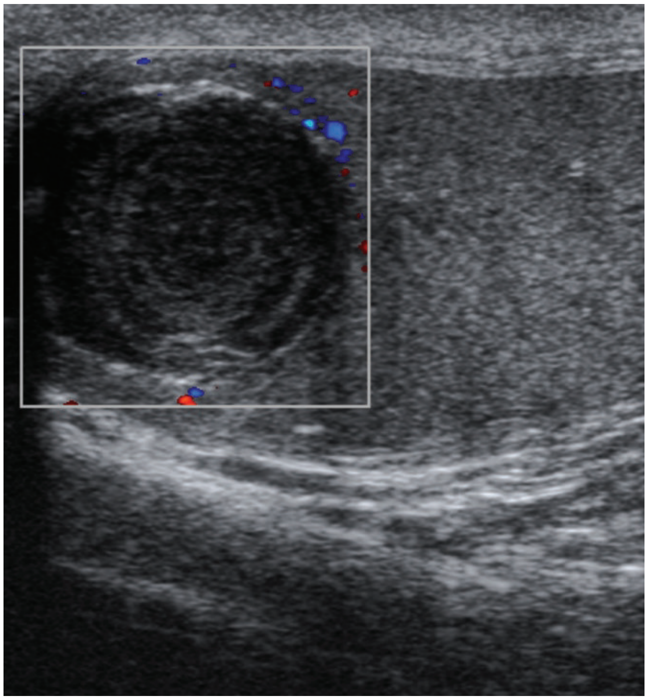


Figure S87-1. Longitudinal image of the left testicle demonstrates a well circumscribed heterogeneous isoechoic mass within the testicle measuring 17 mm in longitudinal axis. The cyst features multiple alternating hypoechoic and hyperechoic layers. The center of the cyst is hyperechoic without appreciable shadowing.

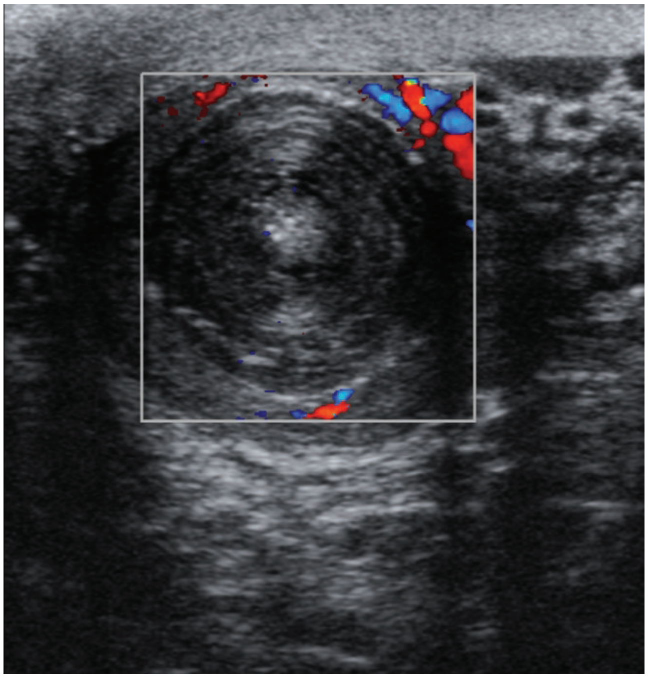


Figure S87-2. Transverse image of the left testicle with Doppler demonstrates no internal vascularity and minimal peripheral vascularity.

CASE 88

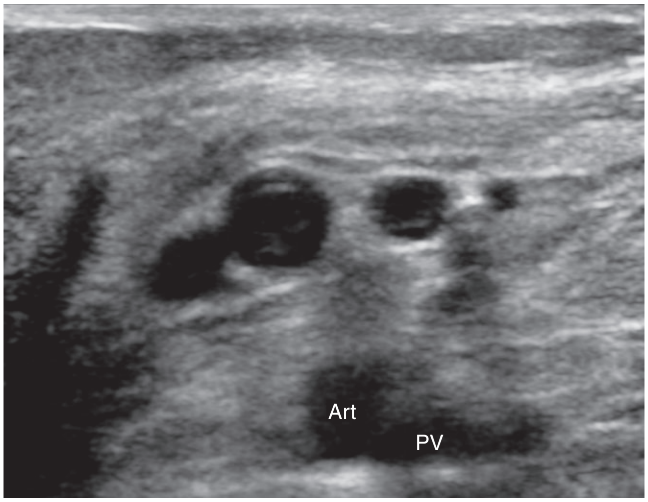


Figure S88-1. The popliteal artery (Art) and popliteal vein (PV) are in the far field. Four circular structures representing smaller vessels are in the near field within the upper calf muscle and are gastrocnemius veins. There are some low level echoes in the two more medial veins and one vein is clearly larger than the others.

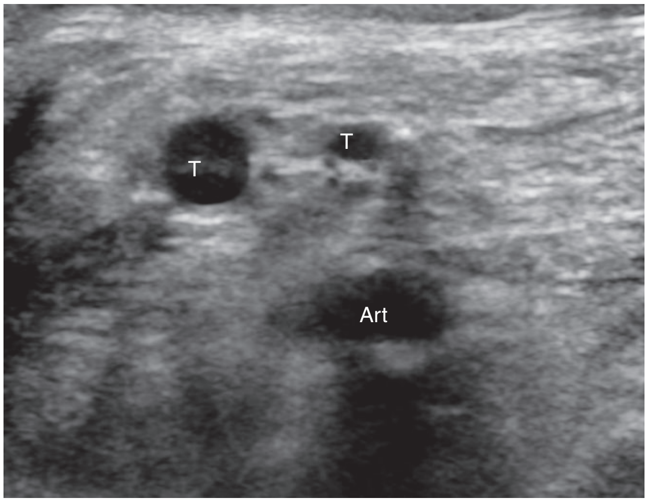


Figure S88-2. With compression, the normal popliteal vein compresses completely and it is free of deep venous thrombosis (DVT). Two of the gastrocnemius veins do not compress (including the largest vein), indicating acute DVT (T). The other two compress completely and are free of DVT.

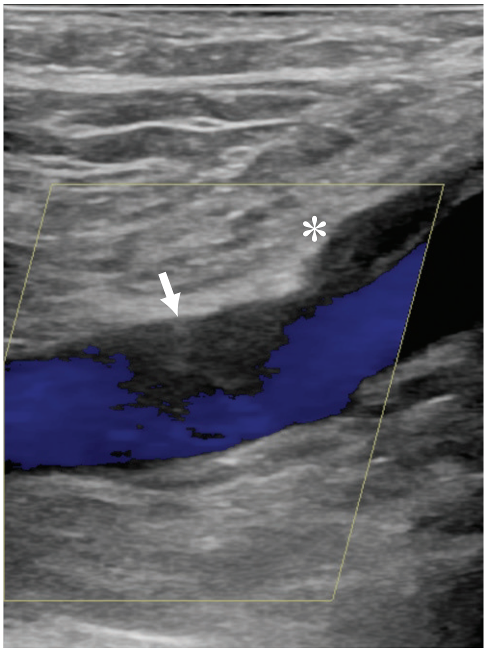


Figure S88-3. Gastrocnemius and central DVT. In a related case, a long axis color image of a gastrocnemius vein and popliteal vein demonstrate, the calf DVT fills the gastrocnemius vein (*) and extends centrally to involve the popliteal vein (arrow). The gastrocnemius has no color and is occluded. The popliteal DVT is a filling defect on the color column. On compression images (not shown) the material is smooth and deformable indicating acute DVT.

CASE 89

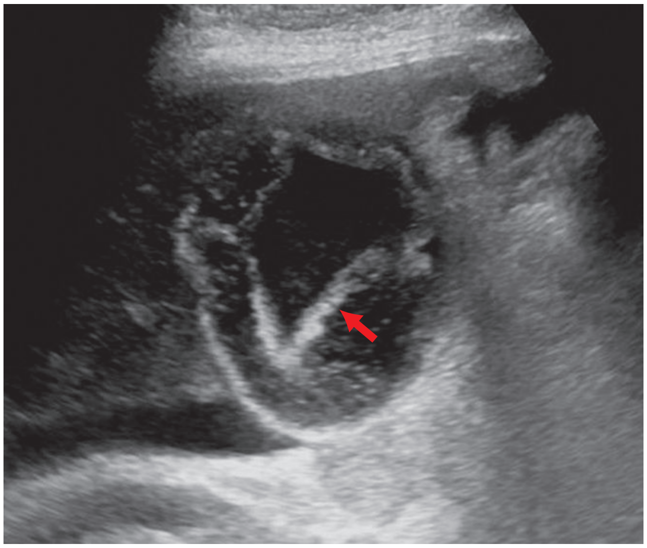


Figure S89-1. The transverse sonographic image of the gallbladder shows intraluminal membranes (arrow) consistent with sloughed mucosa.

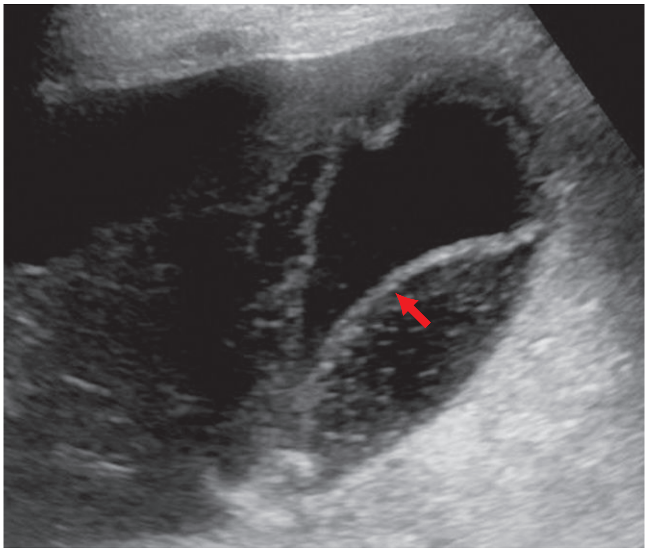


Figure S89-2. The sagittal sonographic image of the gallbladder again shows intraluminal membranes that are parallel to the gallbladder wall (arrow) indicative of sloughed mucosa.

CASE 90

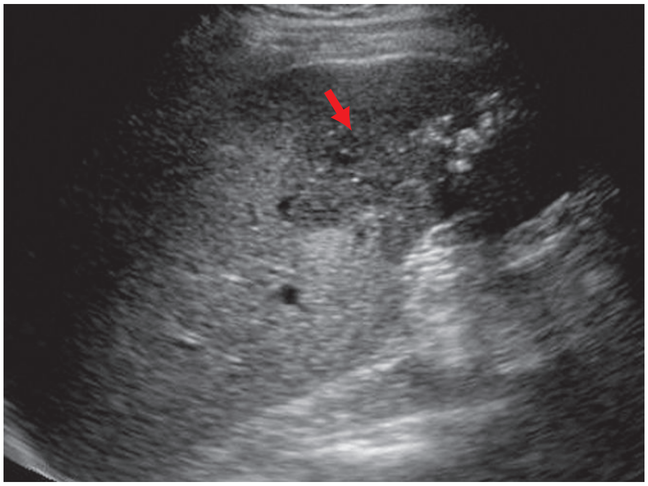


Figure S90-1. The gray scale image shows a distended gallbladder with cholelithiasis and an ill-defined thickened wall (hepatic surface) with invasion into the liver (arrow). The invading mass is hypoechoic.

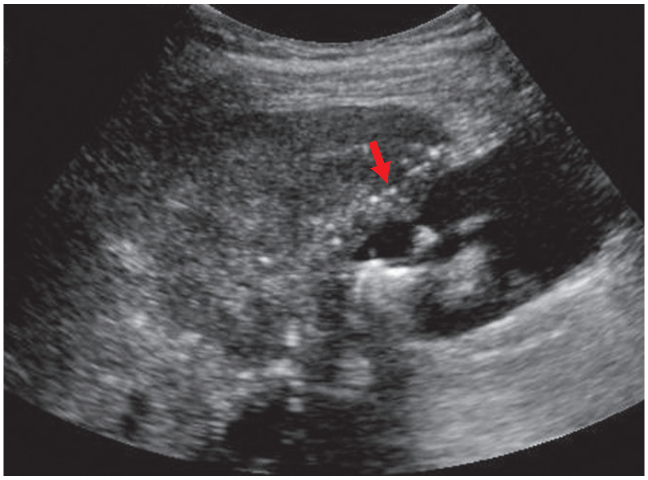


Figure S90-2. The magnified image better shows the ill-defined focally thickened gallbladder wall (arrow) with invasion of tumor into the liver.

CASE 91

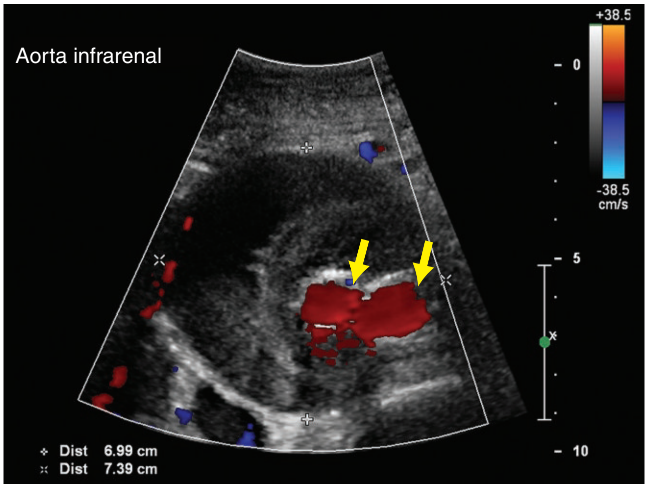


Figure S91-1. Color flow of the endo-abdominal aorta which measures 7.4 cm in diameter. Note the two branches of the endograft that will supply the common iliac arteries (arrows).

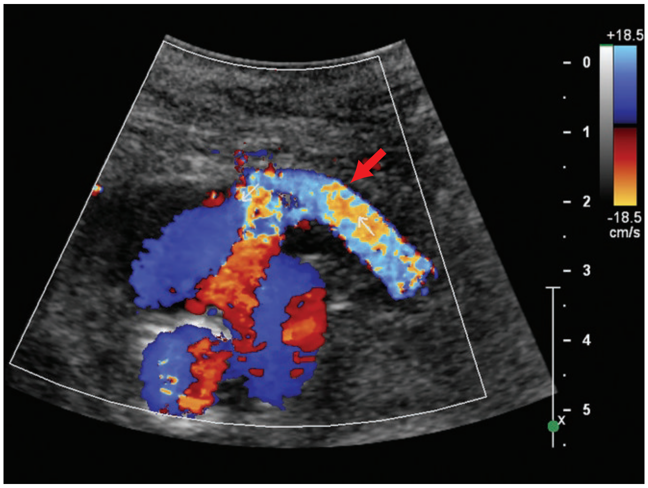


Figure S91-2. In a slightly different portion of the endograft, both the common iliac artery stents are observed posteriorly, but also there is retrograde supply of the aneurismal sac via the inferior mesenteric artery (arrow).

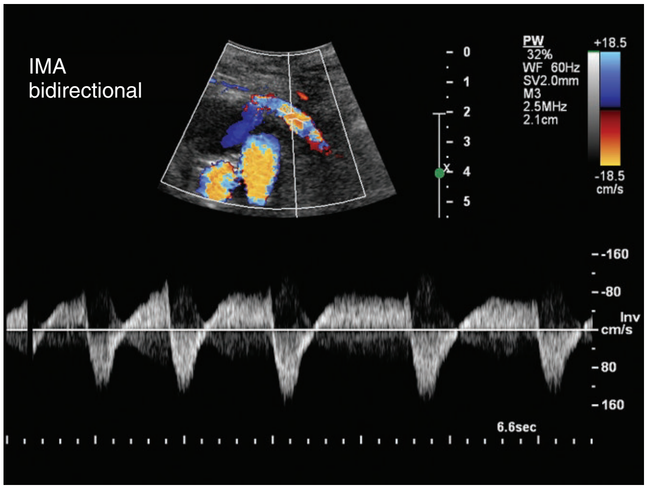


Figure S91-3. Doppler ultrasound of the inferior mesenteric artery demonstrates bidirectional flow within that artery that supplies the abdominal aortic sac.

CASE 92

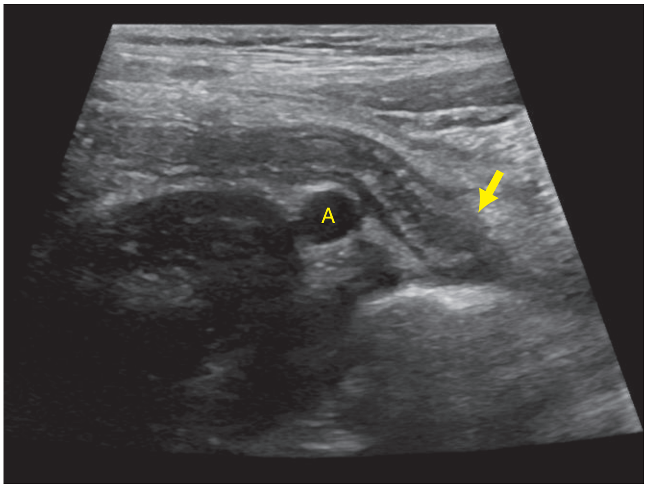


Figure S92-1. Ultrasound of the right lower quadrant of the abdomen revealed a blind ending tubular structure (arrow) that was compressible and corresponds to the appendix. (A = external iliac artery.)

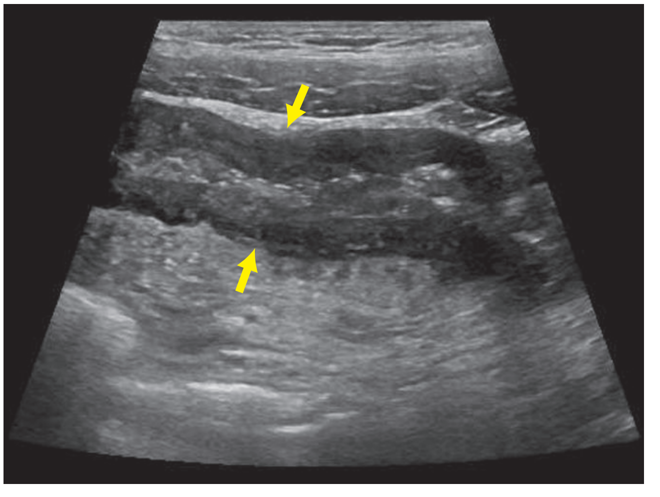


Figure S92-2. Longitudinal scan of the terminal ileum demonstrates marked thickening of the small bowel wall (arrows).

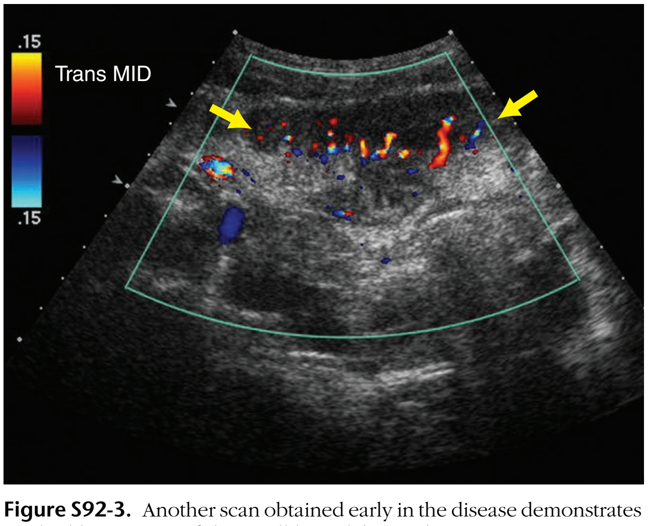


Figure S92-3. Another scan obtained early in the disease demonstrates marked hyperemia of the small bowel (arrows).

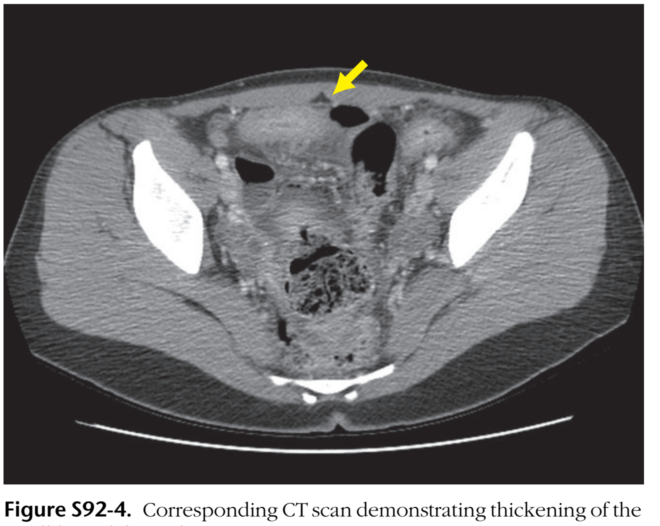


Figure S92-4. Corresponding CT scan demonstrating thickening of the small bowel (arrow).

CASE 93

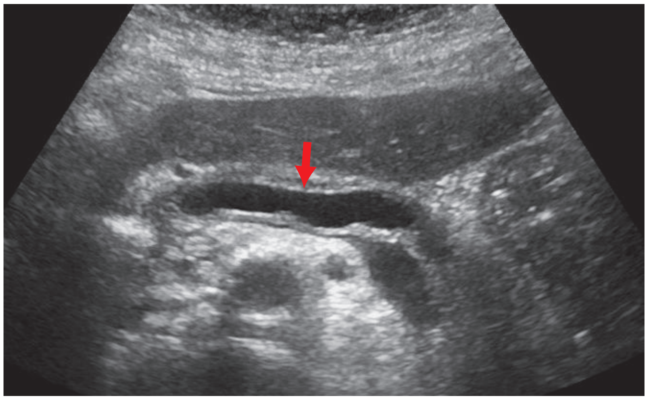


Figure S93-1. The transverse gray scale image shows a dilated pancreatic duct (arrow) and marked atrophy of the pancreatic parenchyma.

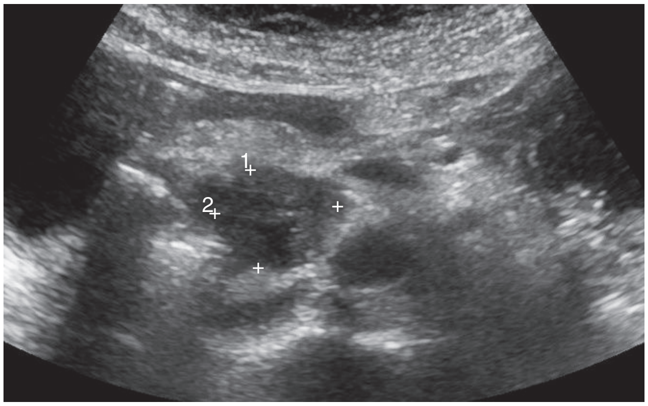


Figure S93-2. The transverse gray scale image shows a hypoechoic, solid mass in the pancreatic head (surrounded by calipers).

CASE 94

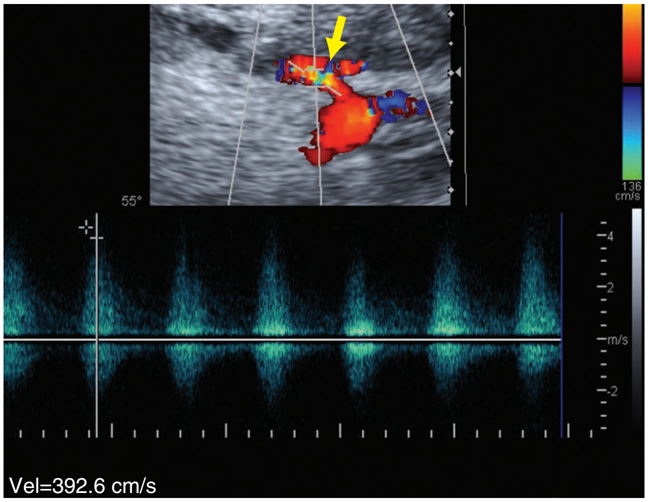


Figure S94-1. The color Doppler image immediately distal to the origin of the transplant renal artery shows aliasing (arrow) and a markedly elevated peak systolic velocity (393 cm/second).

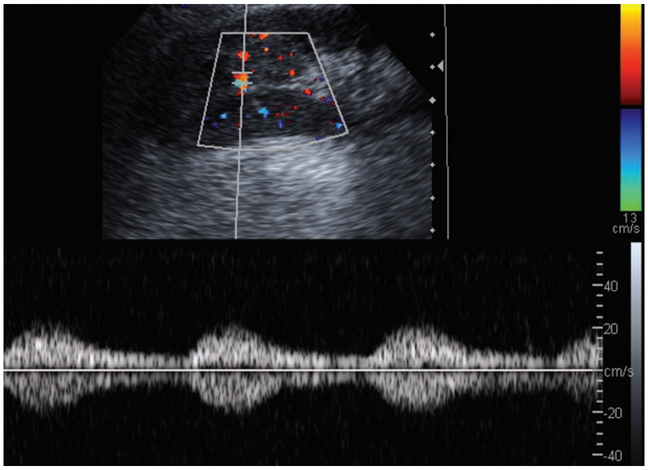


Figure S94-2. The Doppler waveform was obtained in an upper pole segmental renal transplant artery branch and has a tardus parvus appearance indicative of a more proximal stenosis.

CASE 95

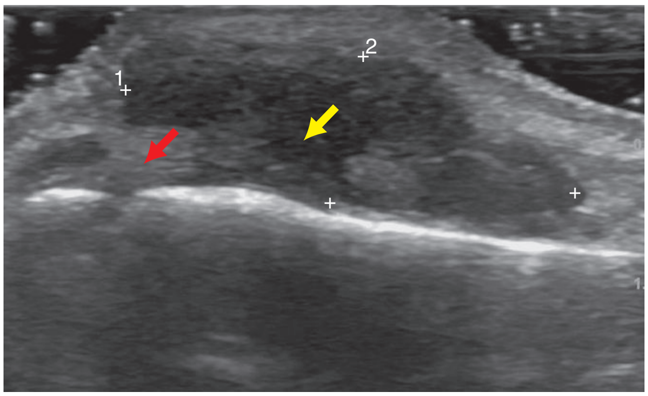


Figure S95-1. The sagittal image of the flexor side of the thumb shows the flexor tendon (red arrow) and the giant cell tumor (yellow arrow). The tumor is hypoechoic relative to the surrounding soft tissues.

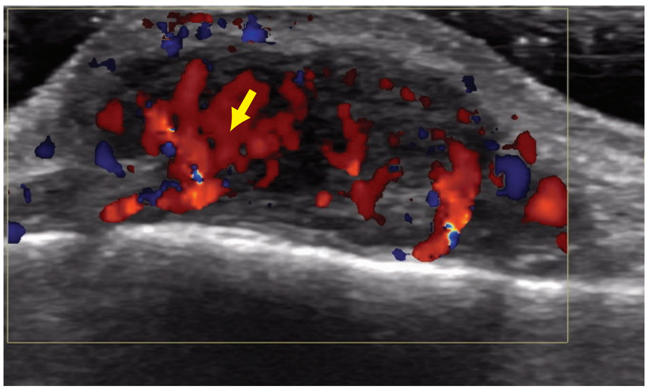


Figure S95-2. The sagittal image of the flexor side of the thumb shows increased color Doppler flow within the giant cell tumor (arrow).

CASE 96

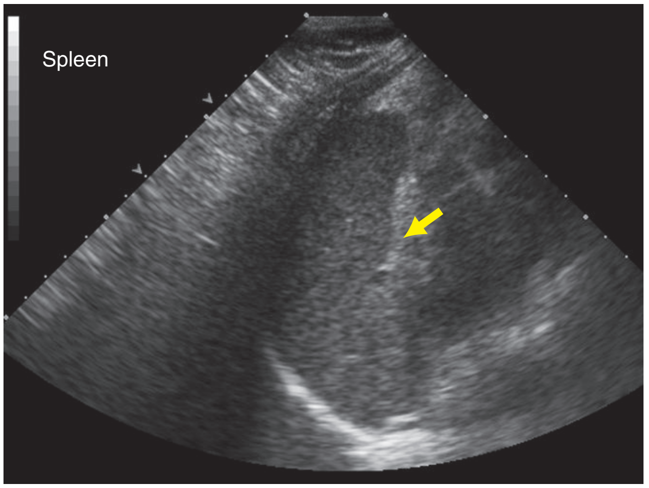


Figure S96-1. Ultrasound of the spleen (arrow) was obtained.

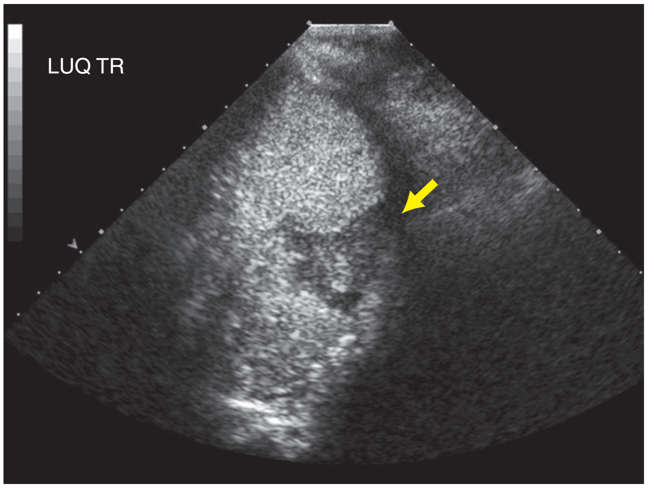


Figure S96-2. Using ultrasound contrast another repeat ultrasound of the spleen was performed demonstrating normal echogenicity of the spleen, with a non-perfused, hypoechoic region (arrow) corresponding to splenic laceration.

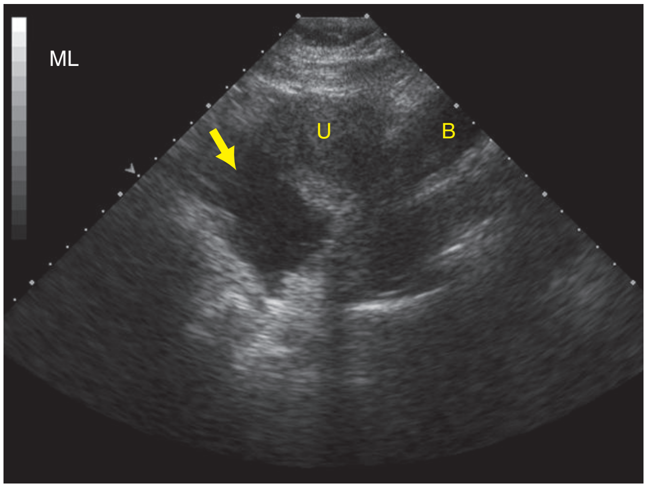


Figure S96-3. Ultrasound of the pelvis is obtained demonstrating free fluid (U=uterus and B=bladder).

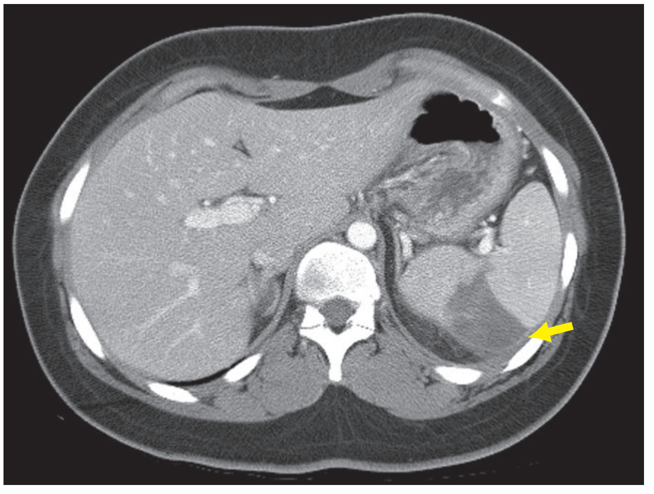


Figure S96-4. Corresponding CT demonstrating splenic laceration (arrow).

CASE 97

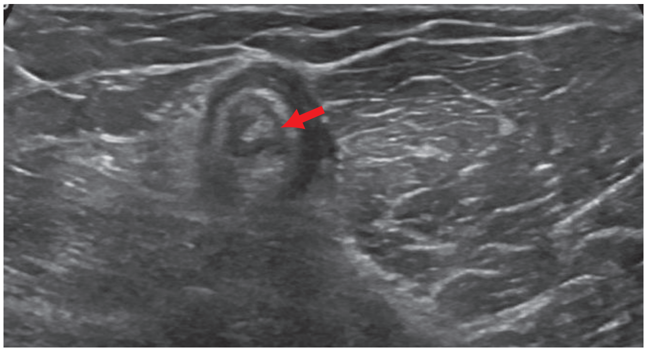


Figure S97-1. The transverse image at the level of the musculotendinous junction of the biceps shows a ruptured tendon (arrow) that has retracted to the level of the muscle.

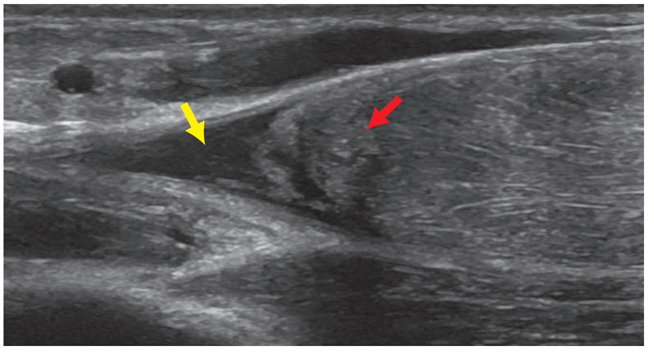


Figure S97-2. The longitudinal image is at the level of the biceps muscle and shows a contracted muscle (red arrow). The proximal portion of the muscle is surrounded by fluid (yellow arrow).

CASE 98

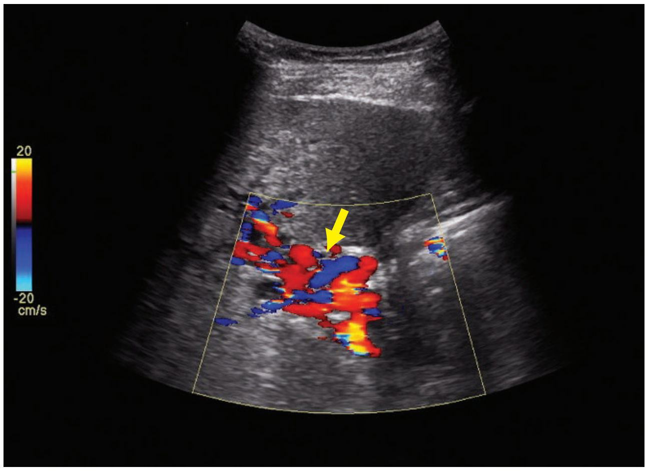


Figure S98-1. The color Doppler image of the porta shows multiple tubular channels (arrow) extending into the liver along the course of the thrombosed right portal vein. These tubular channels are red and blue because of the tortuosity of the venous collaterals, however, the overall direction of blood flow is toward (hepatopetal) the liver.

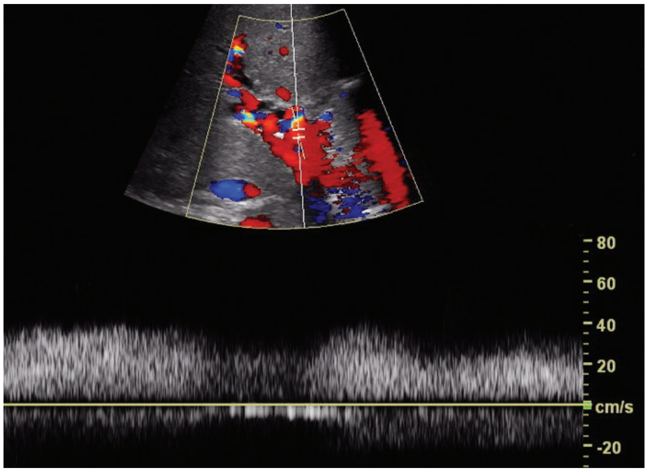


Figure S98-2. The Doppler waveform confirms that the tubular collaterals in the porta have venous flow.

CASE 99

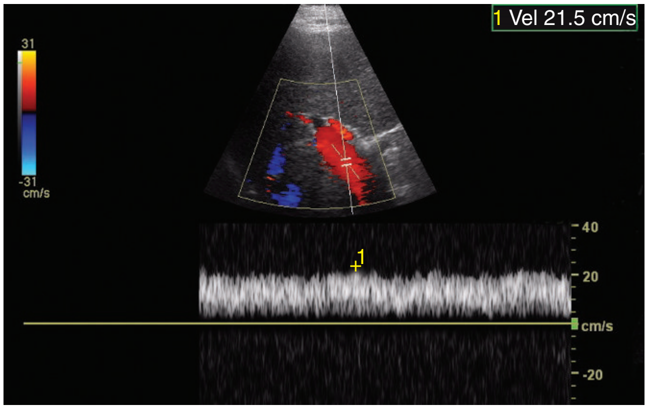


Figure S99-1. The duplex and color Doppler image shows a low velocity in the main portal vein of 22 cm/second, which is below the lower limits of normal (30 cm/second) and suggestive of a downstream stenosis in the stent graft.

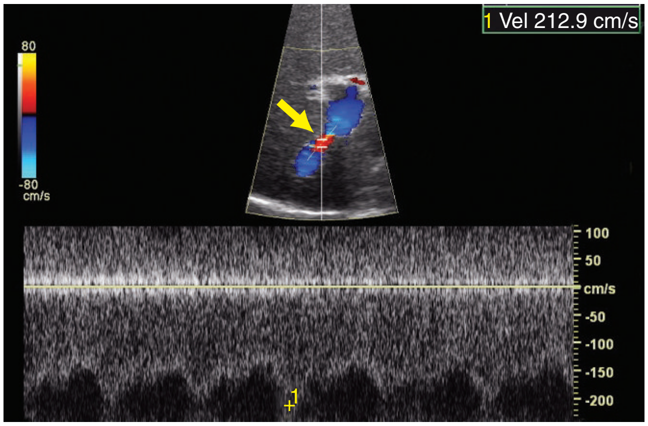


Figure S99-2. The duplex and color Doppler image shows an elevated velocity of 213 cm/sec in the stent graft at a site of focal aliasing (arrow) indicating a stenosis. Normal stent graft velocities range between 90 and 190 cm per second.

CASE 100

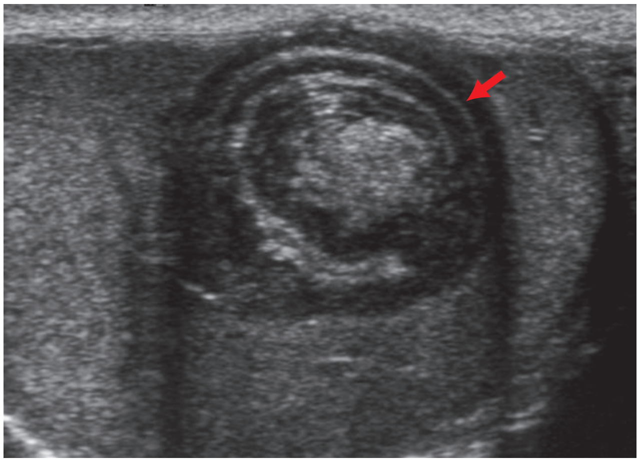


Figure S100-1. The longitudinal sonographic image of the testis shows a solid lesion with alternating hyperechoic and hypoechoic concentric rings (arrow) with an echogenic center.

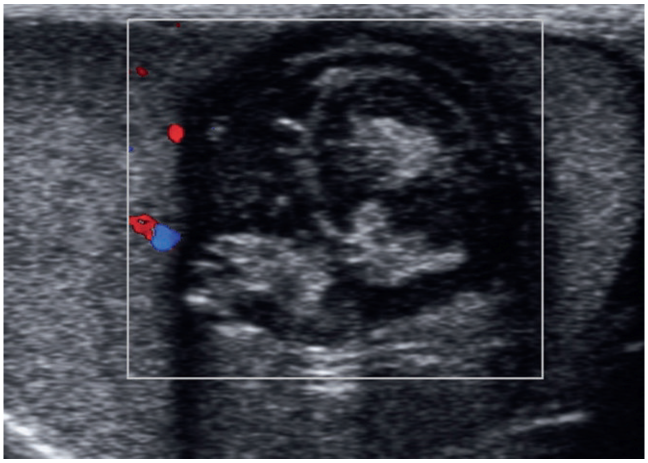


Figure S100-2. The longitudinal image of the testis shows that there is no color Doppler flow in the lesion.

CASE 101

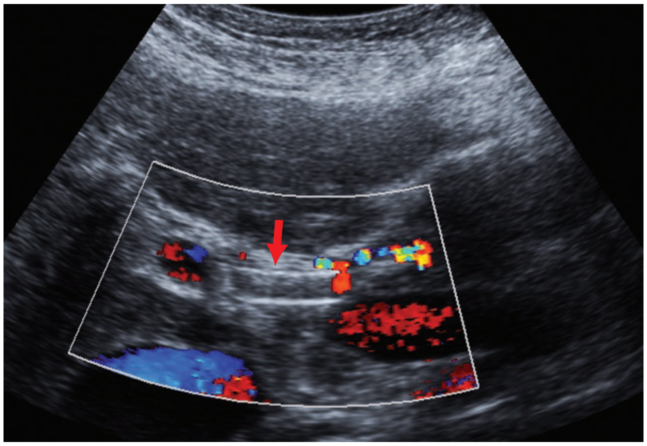


Figure S101-1. The color Doppler image of the porta shows lack of blood flow in the hepatic arterial stent (arrow) indicating stent thrombosis.

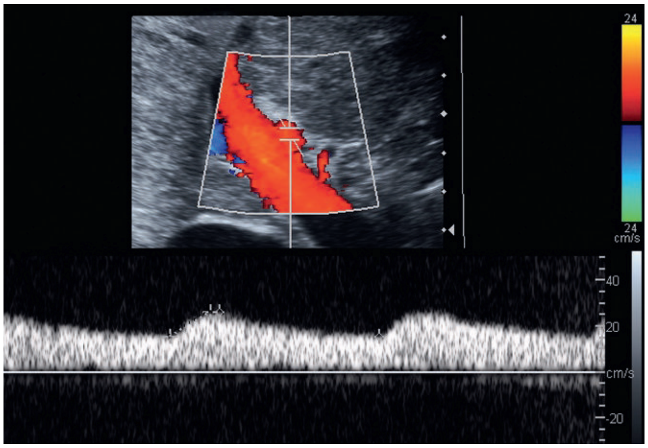


Figure S101-2. The color Doppler image of the porta shows an arterial waveform obtained from a right hepatic artery branch with tardus parvus changes. The right hepatic artery is being supplied by collaterals that developed in the setting of hepatic artery stent thrombosis.

CASE 102

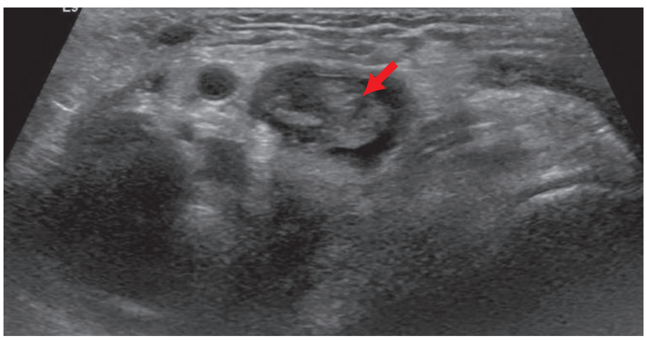


Figure S102-1. The transverse image of the distal arm shows the torn distal retracted biceps tendon surrounded by fluid (arrow).

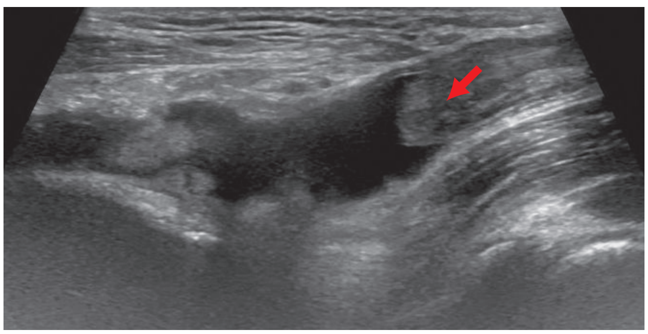


Figure S102-2. The longitudinal image of the distal arm shows the torn distal retracted biceps tendon surrounded by fluid (arrow).

CASE 103

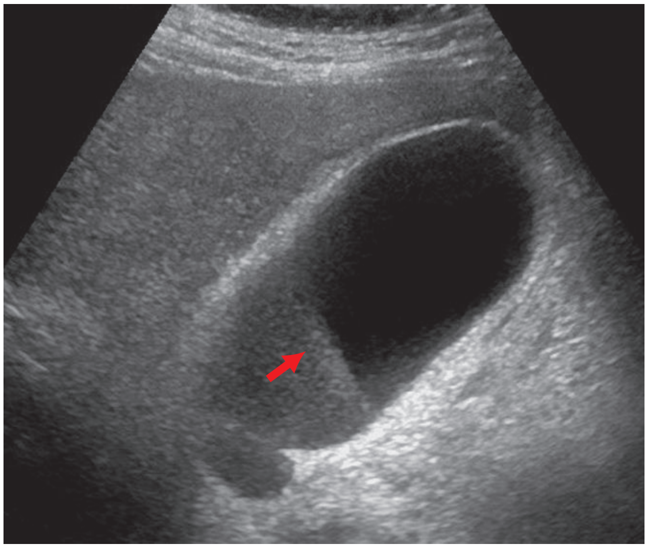


Figure S103-1. The sagittal sonographic image of the gallbladder shows a distended lumen, layering sludge (arrow), and a normal wall thickness.

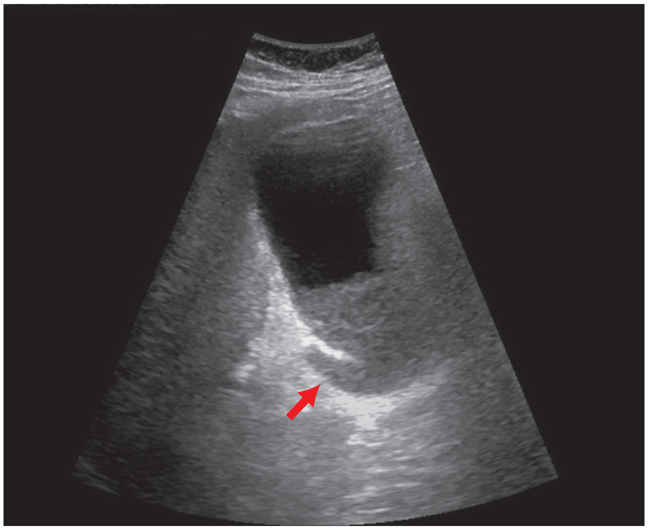


Figure S103-2. The sonographic image of the distended gallbladder shows the neck (arrow) filled with sludge. There are no gallstones.

CASE 104

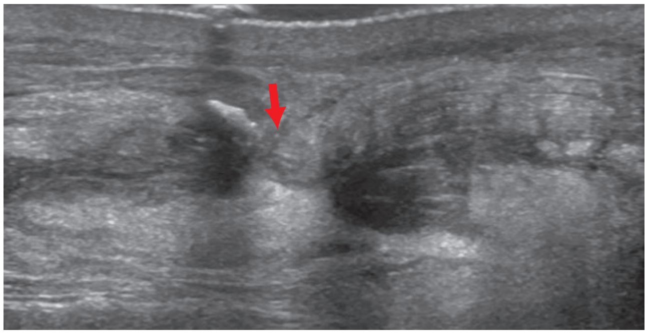


Figure S104-1. The longitudinal image shows rupture of the Achilles tendon; the gap between the torn tendon ends (arrow) is likely filled with fat and hematoma.

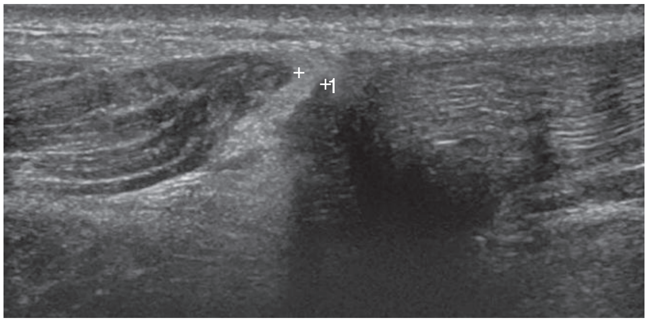


Figure S104-2. The longitudinal image of another patient shows rupture of the Achilles tendon; the calipers measure the distance between the torn tendon ends.

CASE 105

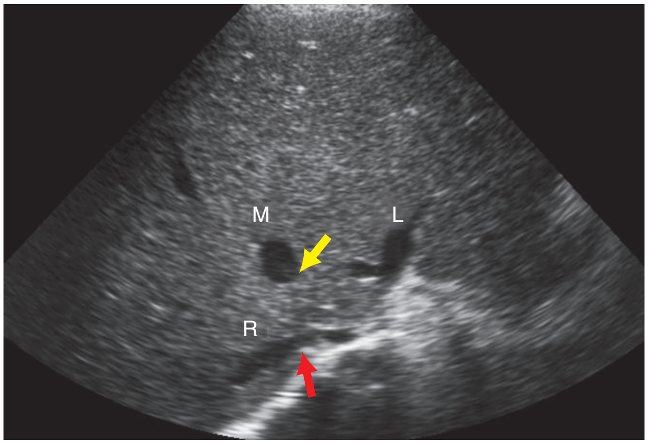


Figure S105-1. The transverse sonographic image of the liver shows a very narrowed right hepatic vein (R, red arrow) and distal thrombosis/occlusion of the middle (M, yellow arrow) and left (L) hepatic veins near where they normally communicate with the IVC.

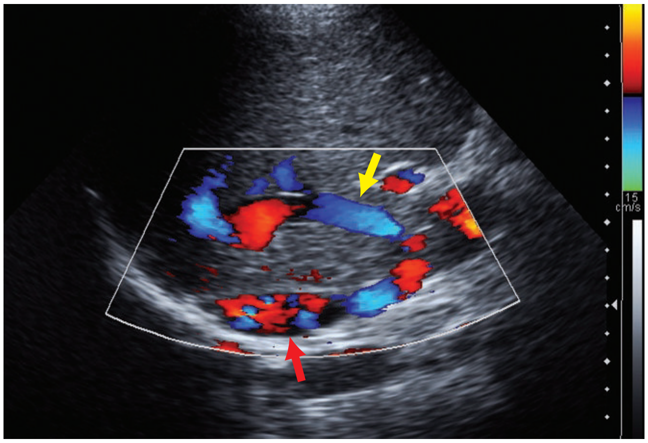


Figure S105-2. The sagittal color Doppler image of the liver shows a dilated caudate vein (yellow arrow) draining into the IVC (red arrow).

CASE 106

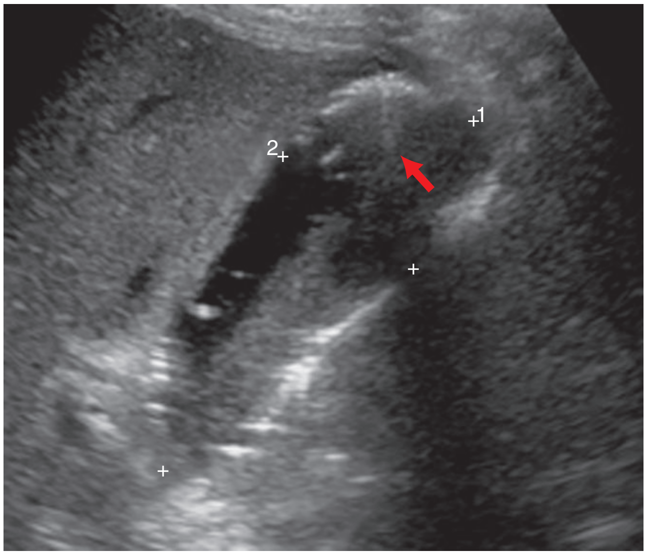


Figure S106-1. The sagittal sonographic image of the gallbladder shows an echogenic gallbladder wall with dirty shadowing posteriorly (arrow). There are also a few echogenic foci within the lumen consistent with intraluminal air and there is sludge.

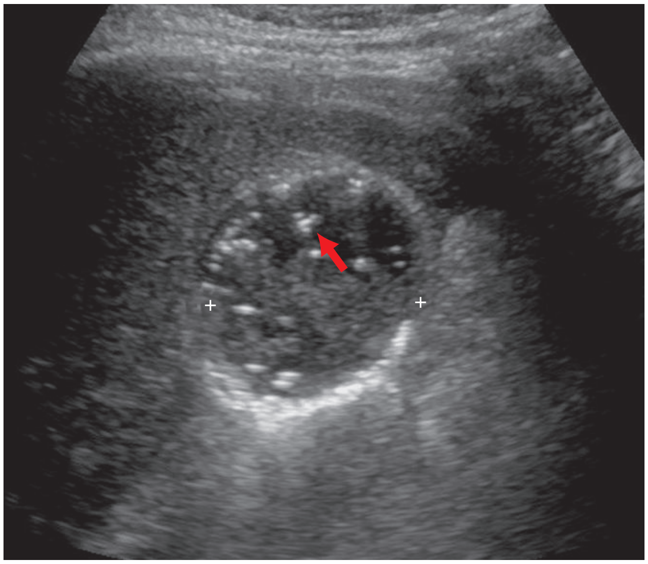


Figure S106-2. The transverse sonographic image of the gallbladder shows air within the wall and multiple echogenic foci (arrow) consistent with air within the lumen.

CASE 107

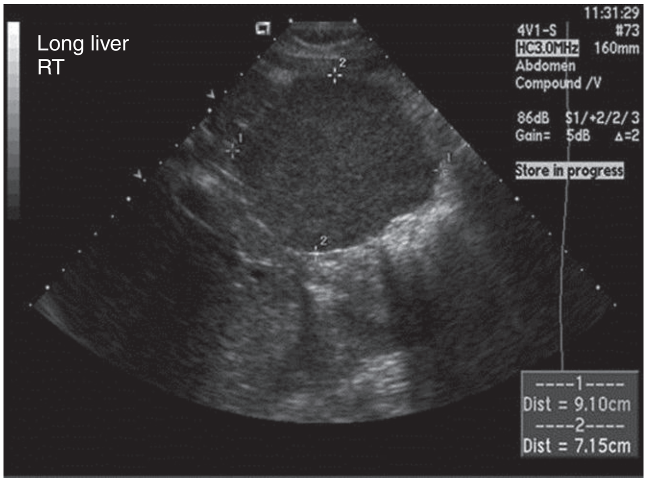


Figure S107-1. Isoechoic, well-circumscribed lesion in the liver (calipers).

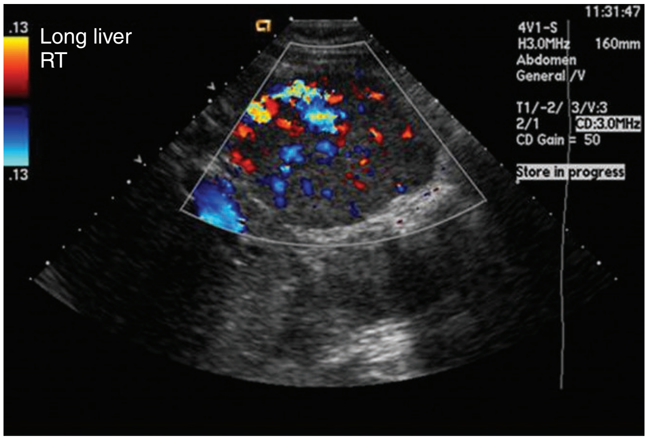


Figure S107-2. Hypervascular lesion on color Doppler interrogation.

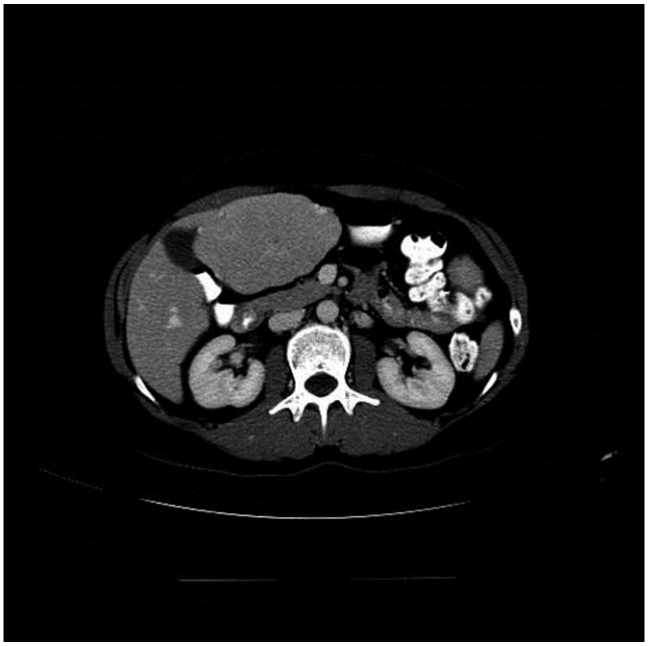


Figure S107-3. Isodense lesion on non-contrast CT. Faint central scar is identified.

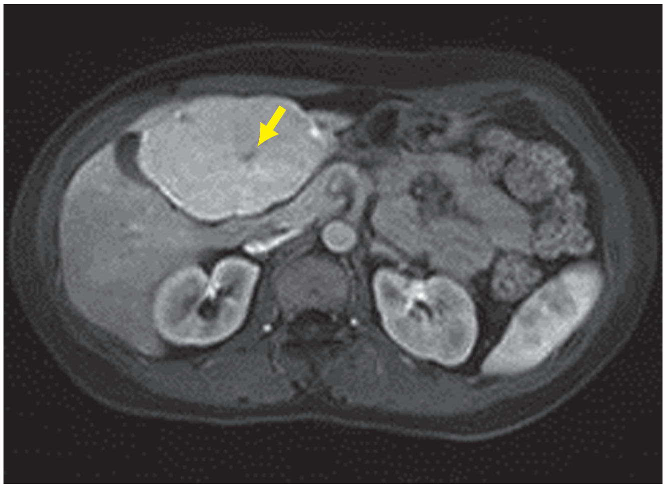


Figure S107-4. Enhancing lesion on arterial phase MRI. Central scar (arrow) is non-enhancing on this phase.

CASE 108

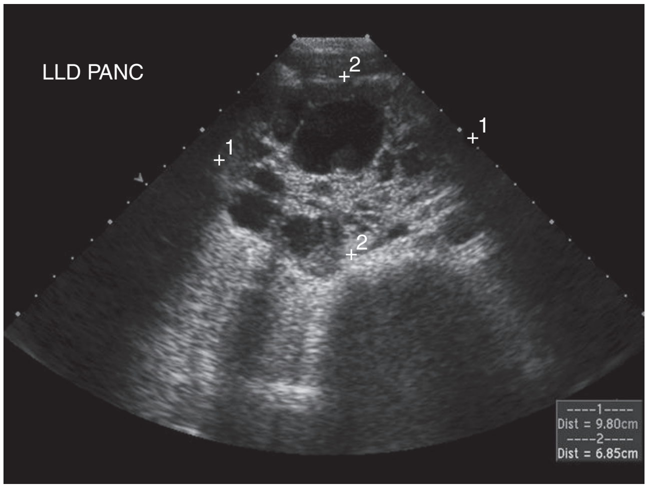


Figure S108-1. Transverse image of the pancreas noted by calipers.

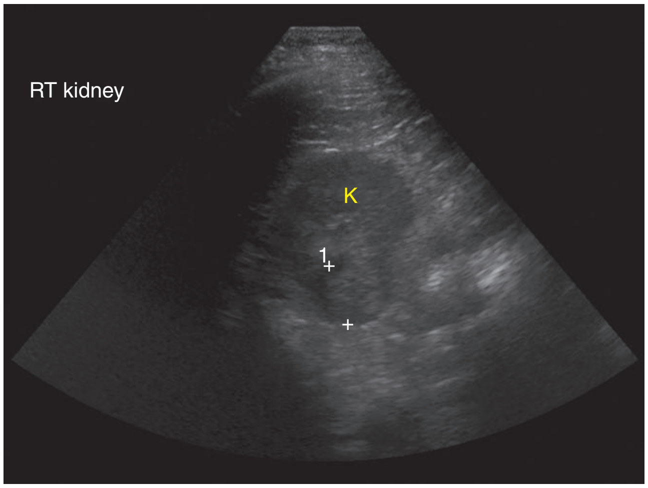


Figure S108-2. Ultrasound of the lower pole of the right kidney (K) demonstrating subtle 2.3-cm mass, outlined by calipers.

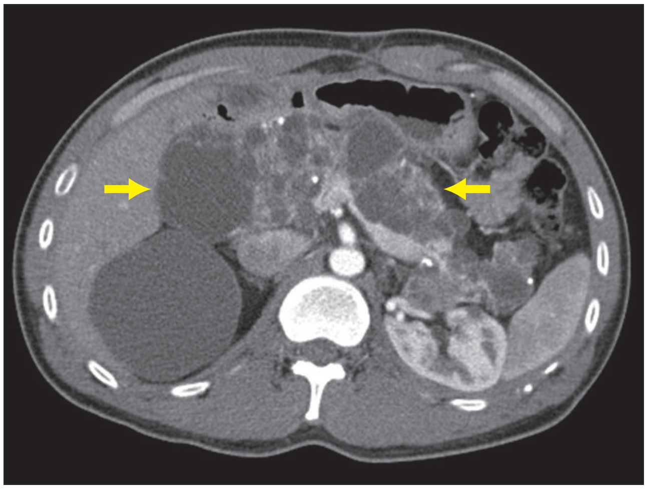


Figure S108-3. CT scan demonstrating multiple cysts within the pancreas (arrows) as well as upper pole right renal cyst. Other scans demonstrated a solid right renal mass.

CASE 109

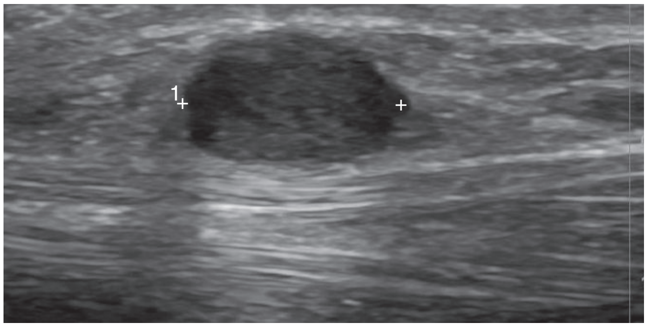


Figure S109-1. The sagittal image of the volar aspect of the forearm shows a hypoechoic mass in the subcutaneous tissues (between calipers).

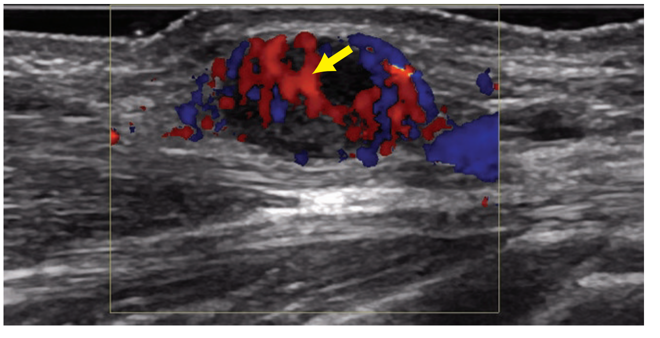


Figure S109-2. The sagittal image of the volar aspect of the forearm shows a hypoechoic mass in the subcutaneous tissues with marked internal vascularity (arrow) on color Doppler.

CASE 110

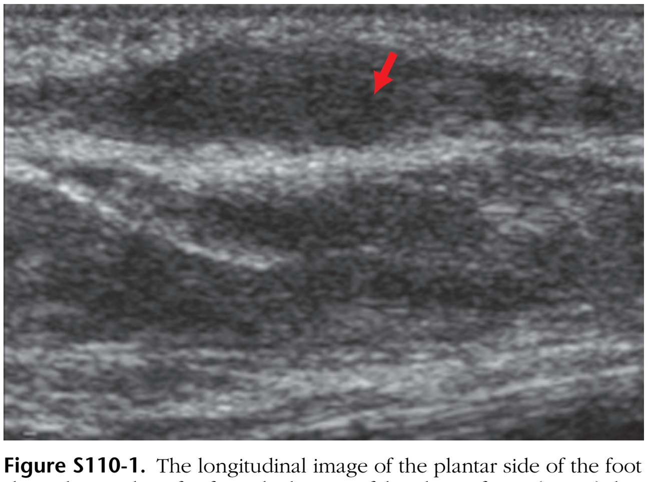


Figure S110-1. The longitudinal image of the plantar side of the foot shows hypoechoic fusiform thickening of the plantar fascia (arrow) that is located in the more central area of the fascia consistent with plantar fibromatosis. The underlying musculature is intact.

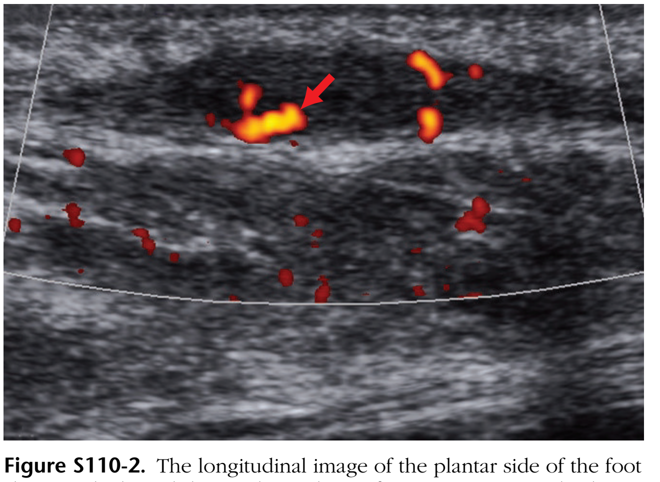


Figure S110-2. The longitudinal image of the plantar side of the foot shows a thickened, hypoechoic plantar fascia consistent with plantar fibromatosis; there is increased color Doppler flow within the area of fibromatosis (arrow).

CASE 111

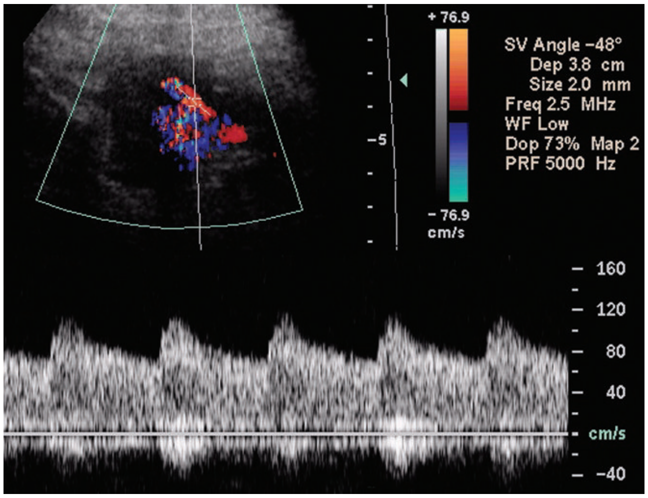


Figure S111-1. The transverse duplex and color Doppler sonogram of the right kidney shows a low resistance waveform in the artery feeding the arteriovenous fistula (AVF).

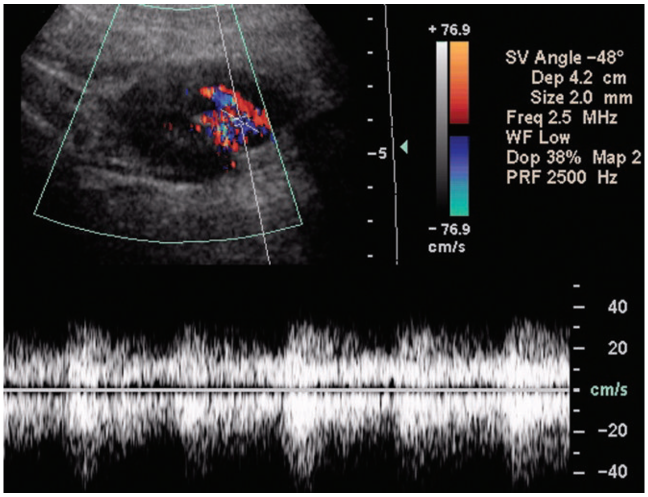


Figure S111-2. The transverse duplex and color Doppler sonogram of the right kidney shows an arterialized waveform in the vein draining the AVF.

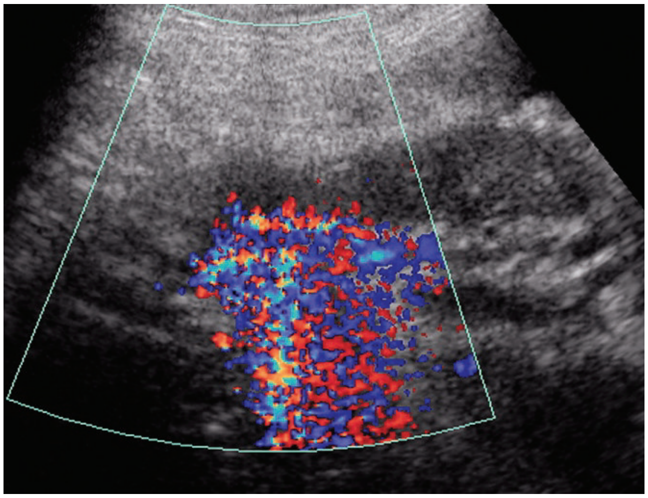


Figure S111-3. The longitudinal color Doppler image shows perivascular tissue vibration in the upper hilar region of the right kidney.

CASE 112

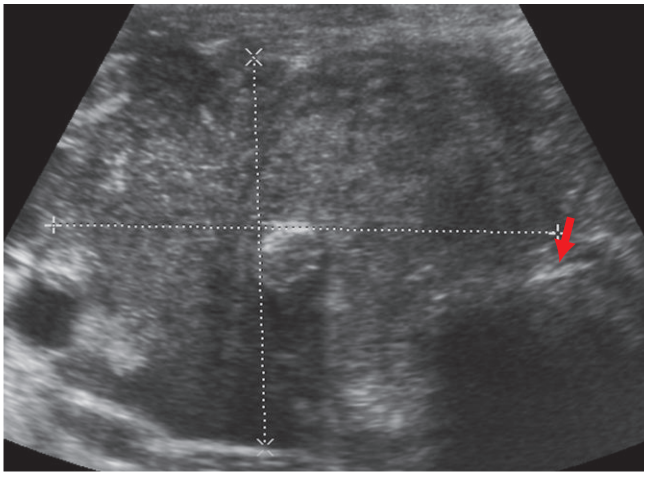


Figure S112-1. The transverse gray scale sonographic images show a large, solid, hypoechoic/heterogeneous thyroid mass in the right lobe with chunky calcification that abuts the trachea (arrow) and surrounds the carotid artery.

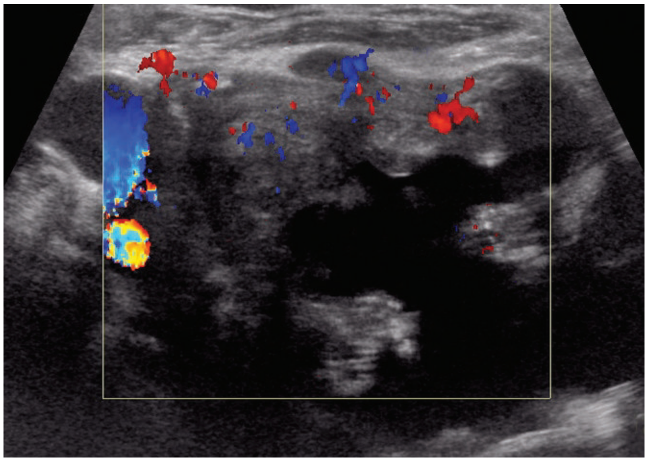


Figure S112-2. The transverse color Doppler sonographic image of a different patient shows a large, solid, hypoechoic/heterogeneous thyroid mass in the right lobe with a large area of cystic change. There is some internal vascularity.

CASE 113

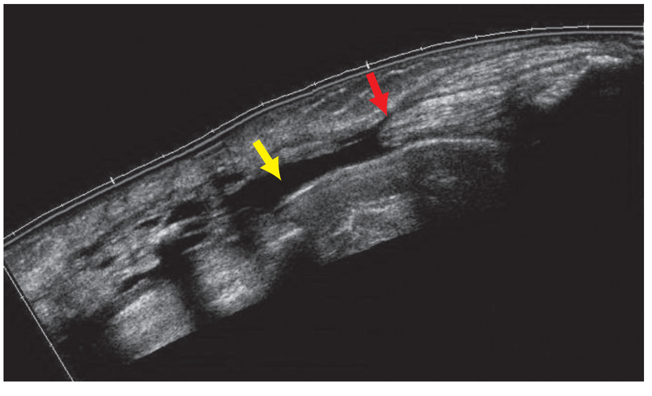


Figure S113-1. The extended field of view image of the region of the quadriceps tendon shows a large fluid collection (yellow arrow) due to rupture of the quadriceps tendon. The red arrow points to the distal torn tendon end.

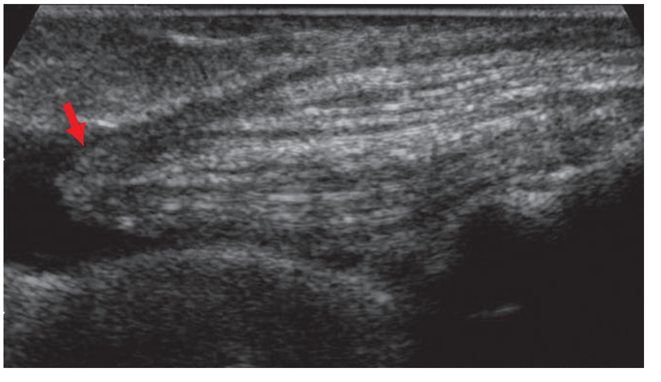


Figure S113-2. The magnified image of the region of the quadriceps tendon shows the distal torn quadriceps tendon end (arrow).

CASE 114

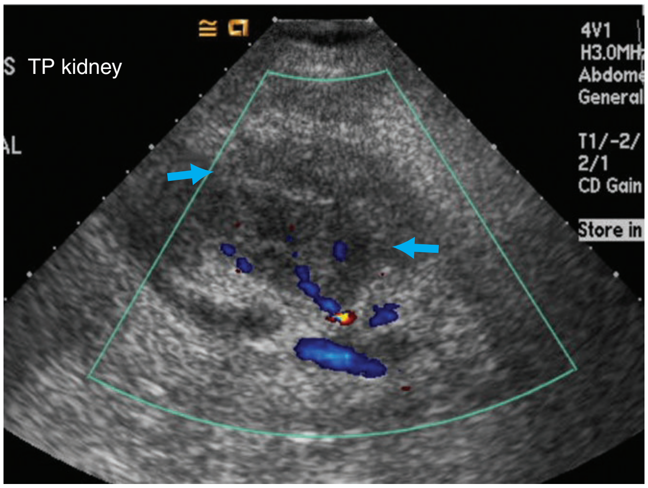


Figure S114-1. Color Doppler ultrasound image demonstrates an echogenic collection superior to the kidney. Poorly vascularized kidney can be identified separately from the avascular hematoma. An interface between the hematoma and the underlying kidney is demonstrated (arrows).

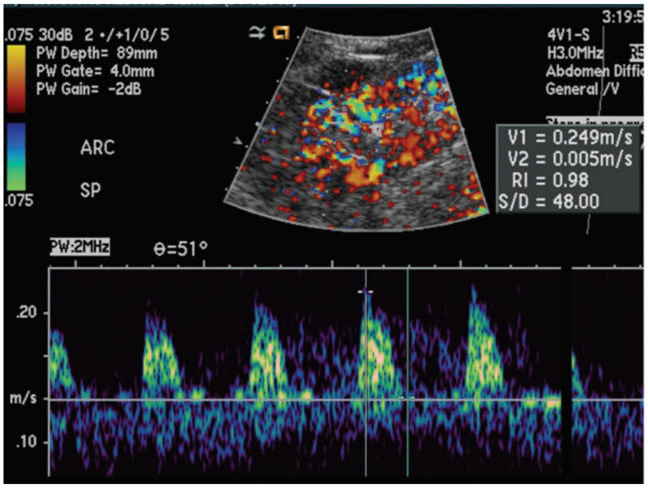


Figure S114-2. Intrarenal Doppler waveform demonstrates high resistance waveform with absent diastolic flow reflective. High resistive index of 0.98 is calculated, but in reality is probably 1.0.

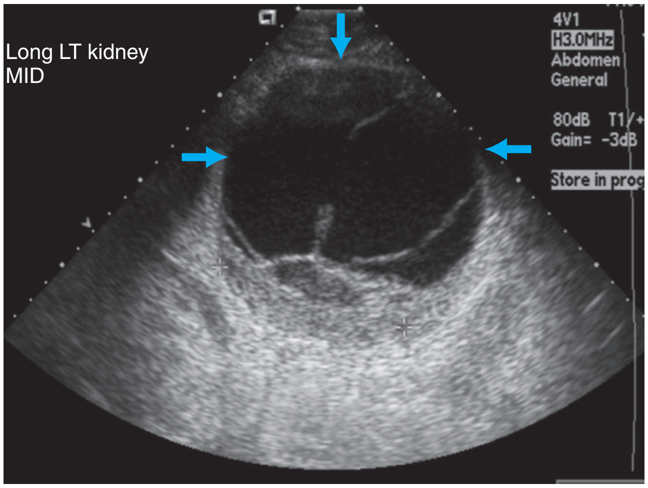


Figure S114-3. Ultrasound images demonstrate a subcapsular anechoic fluid collection (arrows) with septations causing mass effect on the underlying kidney in this patient with chronic subcapsular hematoma, which has now completely liquefied.

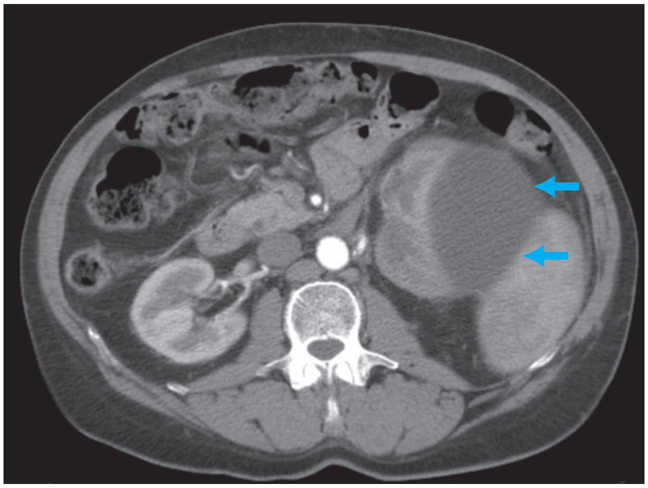


Figure S114-4. CT images from the same patient redemonstrate the subcapsular collection (arrows) and associated mass effect distorting the underlying native kidney.

CASE 115

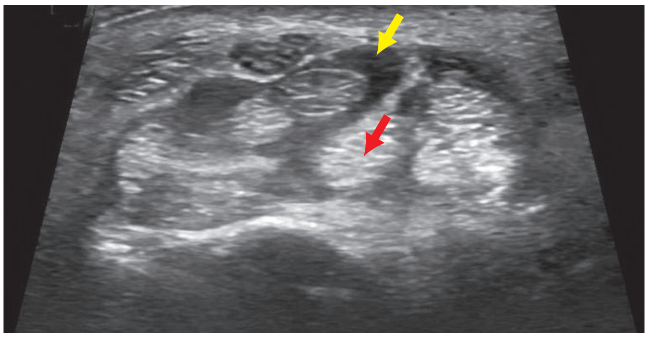


Figure S115-1. The transverse images of extensor compartment four on the dorsum of the wrist show the extensor tendons (red arrow) and hypoechoic thickened synovium (yellow arrow).

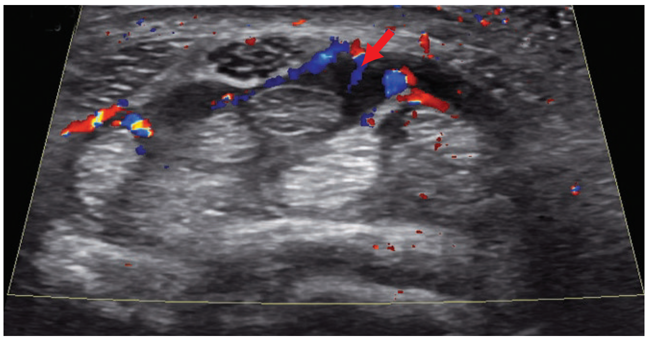


Figure S115-2. The transverse image of extensor compartment four on the dorsum of the wrist shows increased color Doppler flow of the thickened synovium (arrow) indicating tenosynovitis.

CASE 116

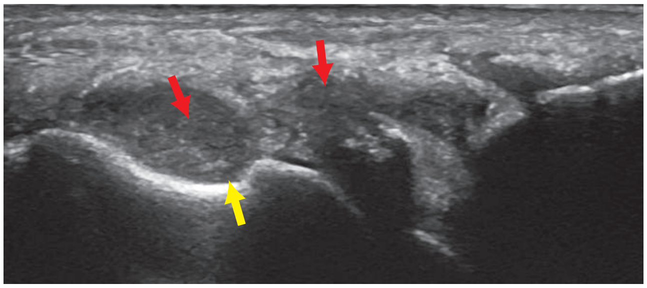


Figure S116-1. The longitudinal image of the dorsum of the wrist shows marked hypoechoic synovial thickening (red arrows). The yellow arrow points to the surface of the capitate, which indicates the mid carpal row.

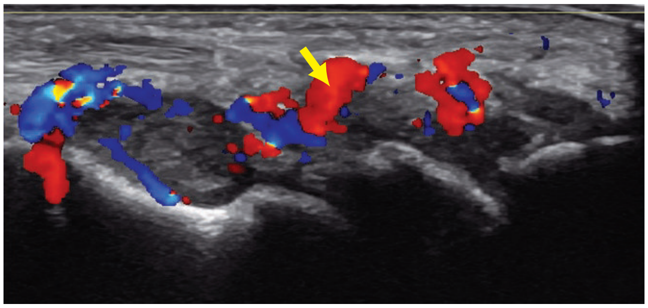


Figure S116-2. The longitudinal image of the dorsum of the wrist shows marked hypoechoic synovial thickening and increased color Doppler flow (arrow), which indicates synovitis.

CASE 117

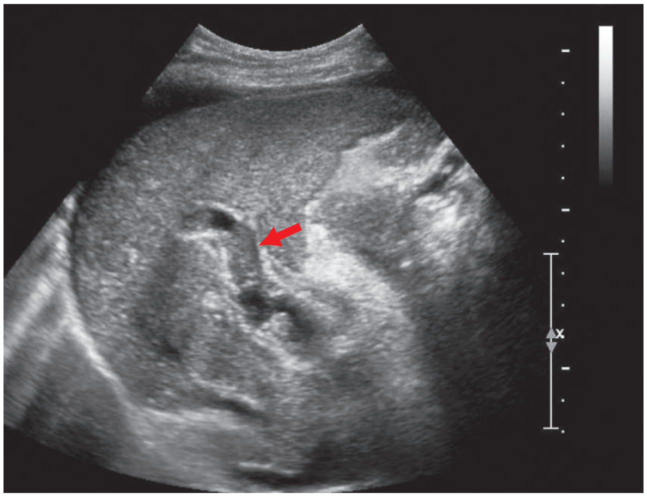


Figure S117-1. The gray scale sonographic image of the liver shows non-occlusive isoechoic thrombus in the main and right portal vein (arrow).

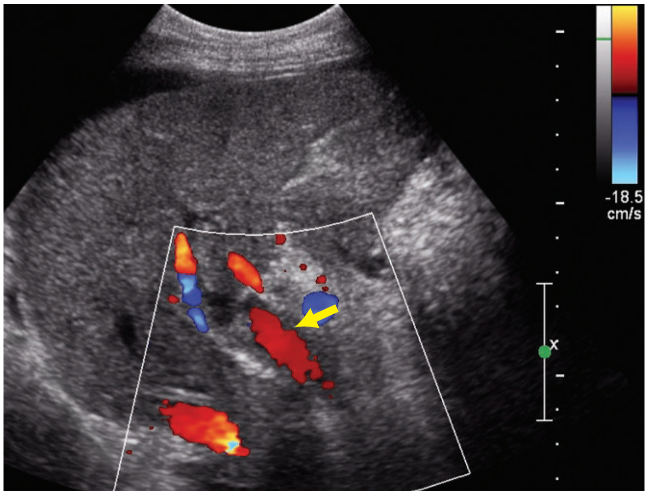


Figure S117-2. The color Doppler sonographic image of the liver shows color Doppler flow (arrow) around the isoechoic thrombus indicating that is it non-occlusive.

CASE 118

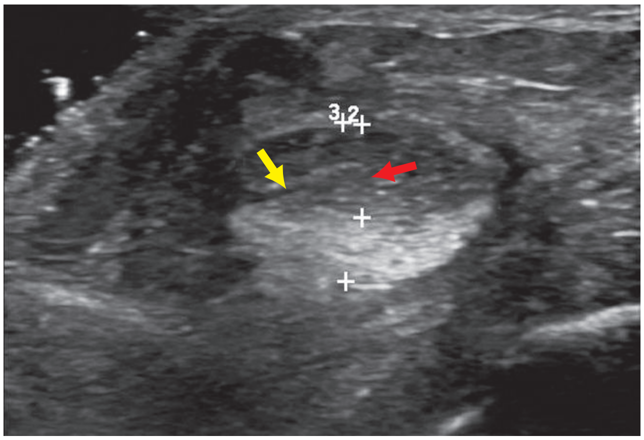


Figure S118-1. The transverse image of the tibialis posterior tendon shows a hypoechoic area (red arrow) consistent with tendinopathy. There are subtle anechoic defects consistent with intrasubstance tears (yellow arrow). The 2 sets of calipers measure the thickness of the hypoechoic area and the entire tendon (longer set of calipers).

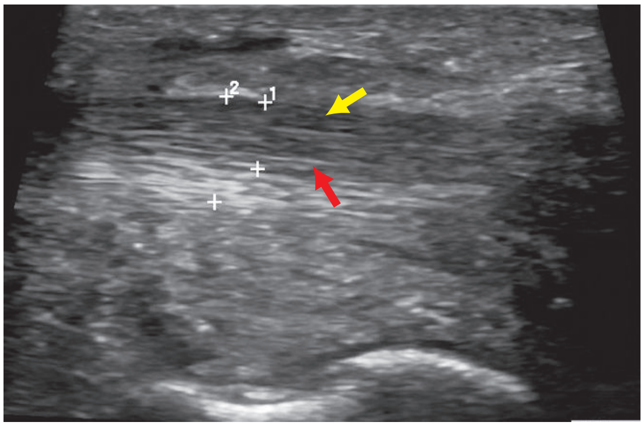


Figure S118-2. The longitudinal image of the tibialis posterior tendon shows a hypoechoic area (red arrow) consistent with tendinopathy. There are subtle anechoic defects consistent with intrasubstance tears (yellow arrow). The 2 sets of calipers measure the thickness of the hypoechoic area and the entire tendon (longer set of calipers).

CASE 119

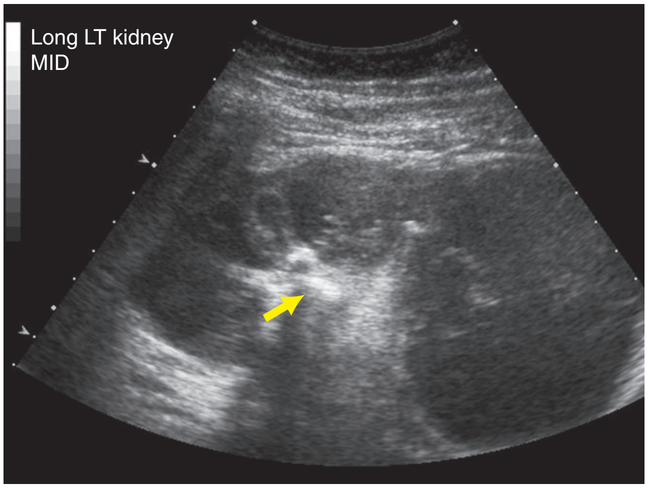


Figure S119-1. Longitudinal scan of the left kidney demonstrating enlarged left kidney with a diffuse hypoechoic appearance with focal bulge noted in the left lower pole. Note: Central echogenicity with acoustic shadowing (arrow).

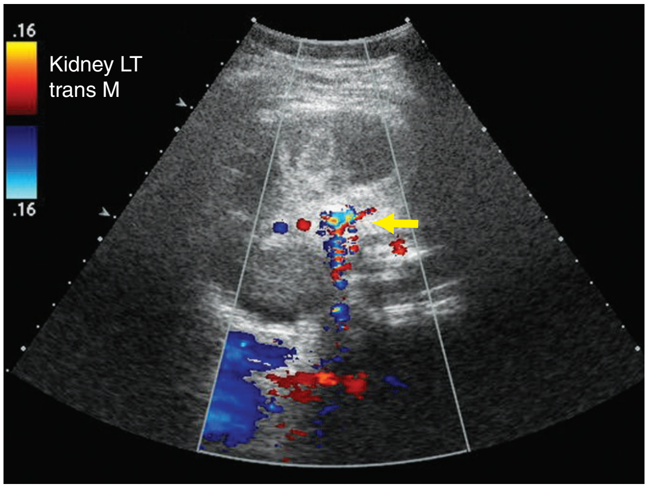


Figure S119-2. Color Doppler ultrasound demonstrated the kidney with fairly avascular but with focal echogenicity having ring-down artifact (arrow) posterior to the echogenic stone.

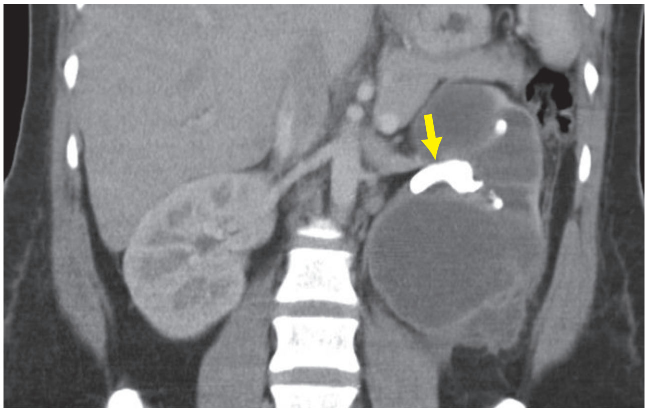


Figure S119-3. Correlative CT scan demonstrates the very thin renal cortex with replaced renal parenchyma. Note: Central staghorn calculi (arrow). Also note the more focal bulge of the left lower pole.

CASE 120

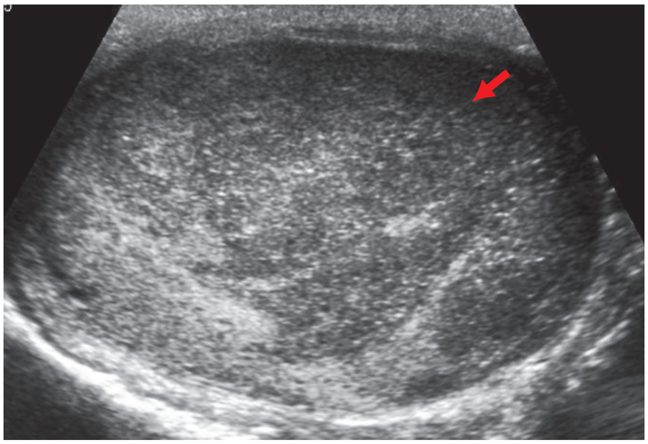


Figure S120-1. The longitudinal sonographic image of the testis shows a large, solid, hypoechoic mass that nearly replaced the testis (arrow).

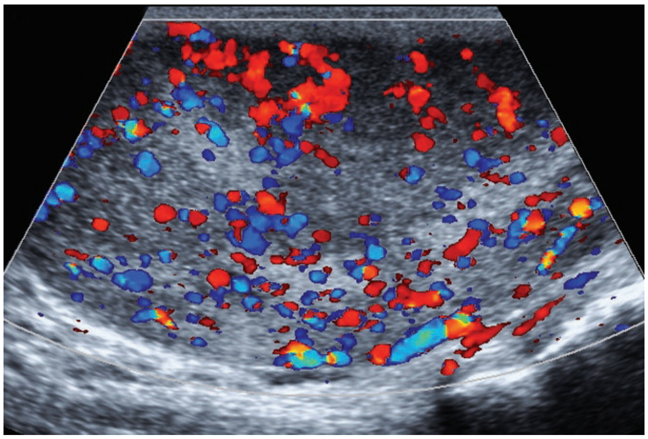


Figure S120-2. The longitudinal color Doppler sonographic image of the testis shows marked hypervascularity of the tumor.

CASE 121

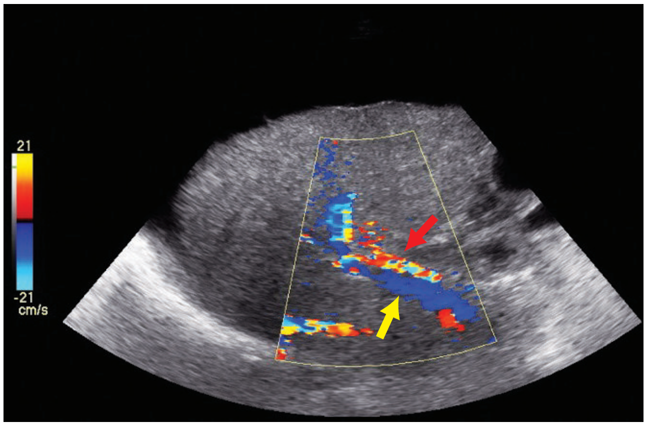


Figure S121-1. The color Doppler sonographic image of the liver shows hepatofugal flow in the right and main portal vein (yellow arrow) and aliasing in the hepatic artery (red arrow) indicating high velocities.

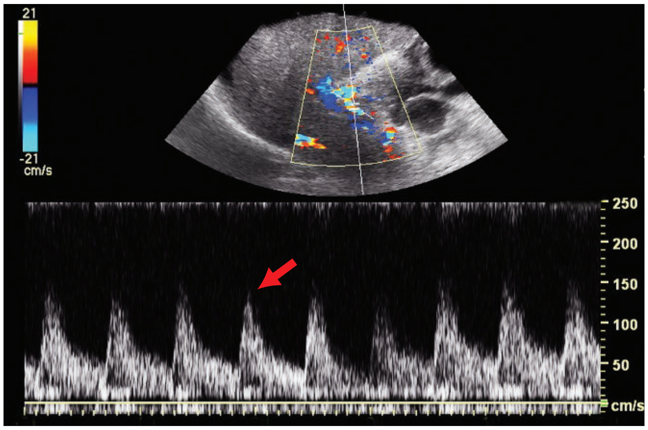


Figure S121-2. The duplex and color Doppler sonographic image of the liver shows aliasing in the hepatic artery indicating a high velocity as evidenced by the high peak systolic velocity of the arterial waveform (arrow).

CASE 122

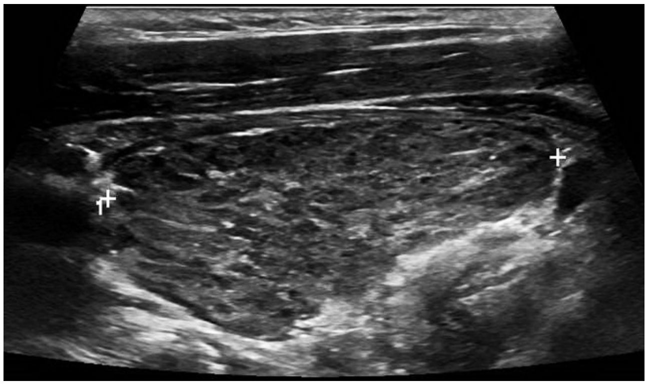


Figure S122-1. The longitudinal gray scale image of the right lobe of the thyroid shows innumerable hypoechoic micronodules with echogenic septae throughout both lobes of the thyroid.

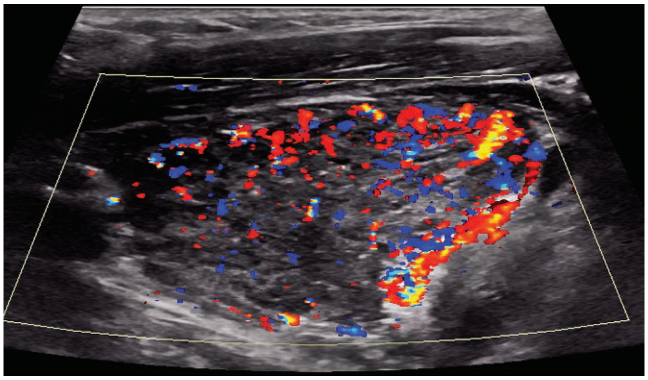


Figure S122-2. The longitudinal color Doppler image of the right lobe of the thyroid shows hypervascularity.

CASE 123

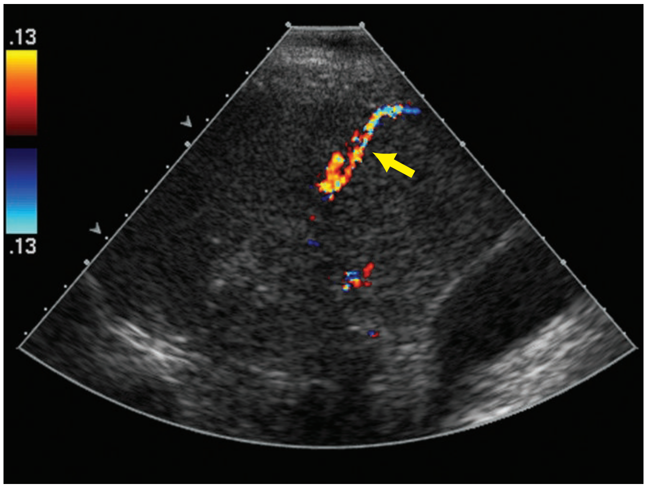


Figure S123-1. In this patient, after radiofrequency ablation of the liver, the color "line sign" (arrow) is seen with the line extending to the surface of the liver.

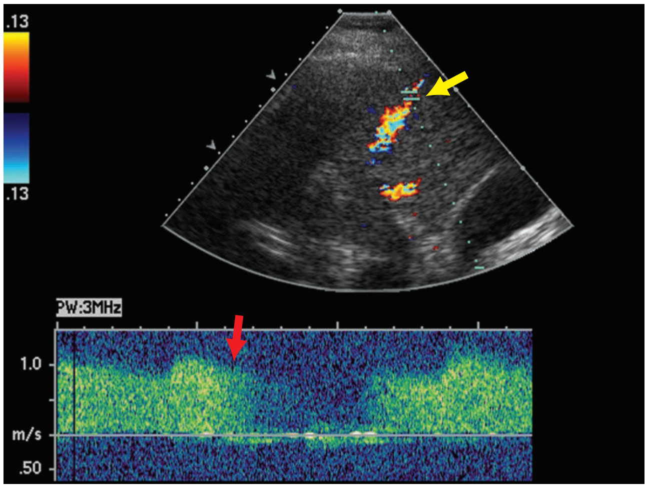


Figure S123-2. Doppler cursor (arrow) placed on color line. This color "line sign" (yellow arrow) revealed Doppler of a low resistance arterial wave form (red arrow).

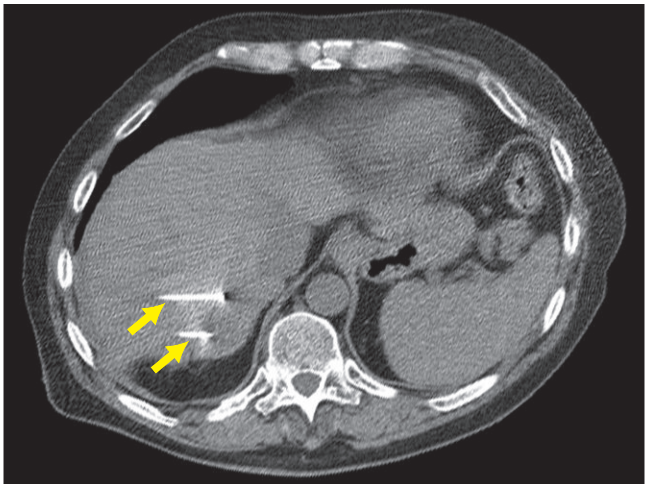


Figure S123-3. CT scan performed showing radiofrequency electrodes (arrows) during ablation.

CASE 124

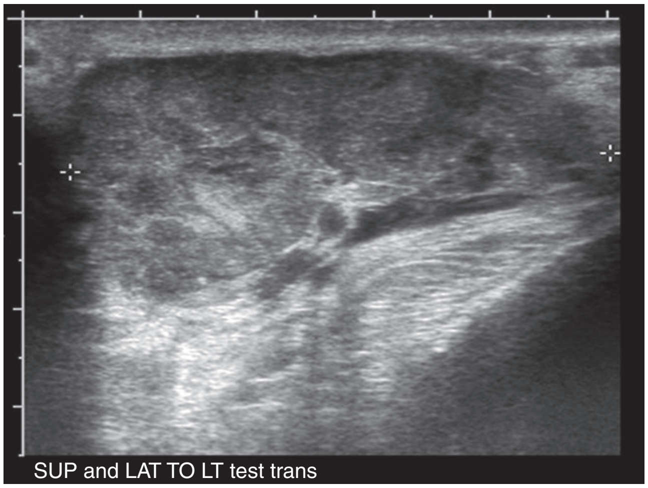


Figure S124-1. Ultrasound of the left inguinal region demonstrating this 2 cm × 3 cm × 4 cm mass-like lesion separate from the left testis.

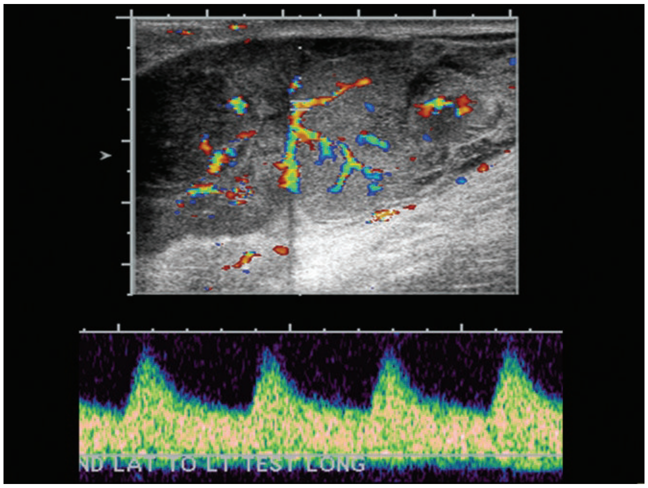


Figure S124-2. Color Doppler ultrasound was performed demonstrating increased color flow within this extratesticular mass.

Figure S124-3. Gross pathologic specimen of this extratesticular mass showed a high-grade myxoid liposarcoma.

CASE 125

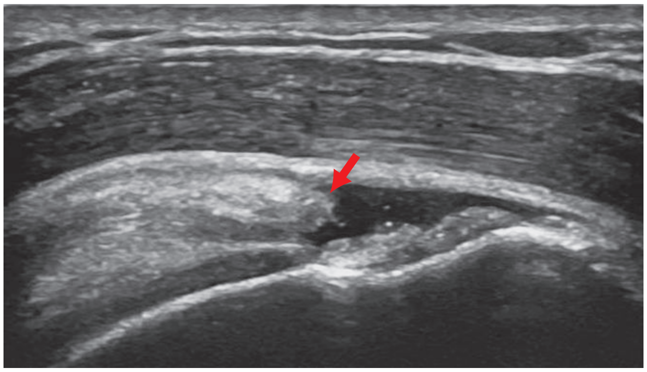


Figure S125-1. The sagittal image shows a retracted full thickness rotator cuff tear. Fluid surrounds the torn tendon end (arrow).

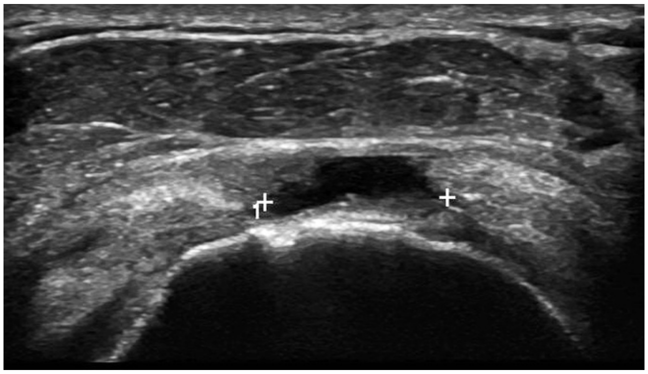


Figure S125-2. The transverse image shows the full thickness rotator cuff tear. The calipers are placed so as to measure the width of the tear.

CASE 126

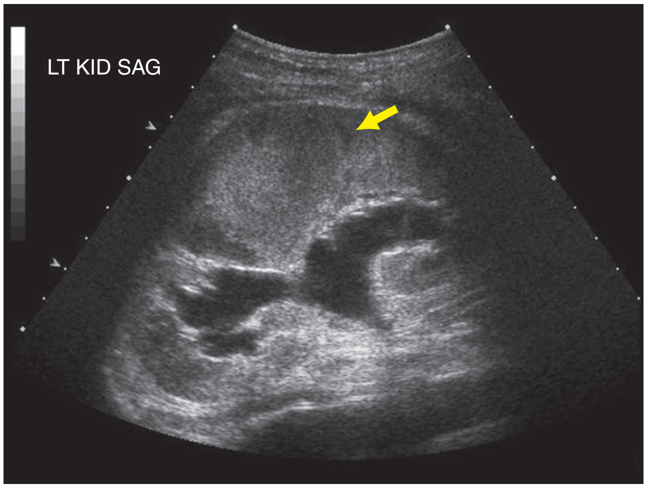


Figure S126-1. Ultrasound of the left kidney demonstrates hydronephrosis and hypoechoic mass involving the mid portion of the left kidney (arrow).

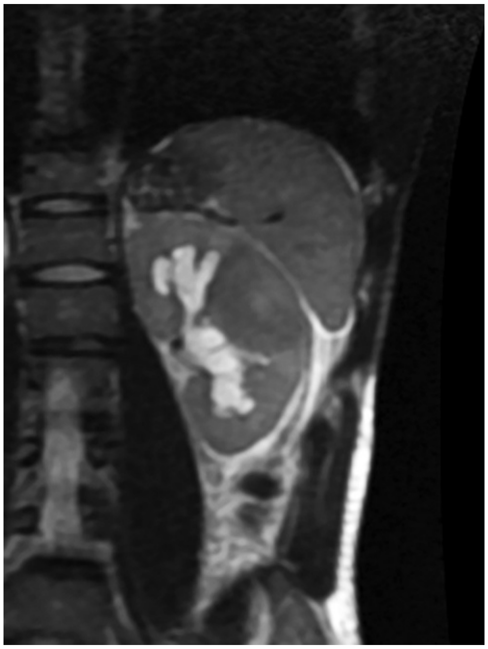


Figure S126-2. Single shot fast spin echo MRI of the left kidney demonstrates the hydronephosis as well as the focal region of the decreased signal intensity noted in the mid pole of the left kidney.

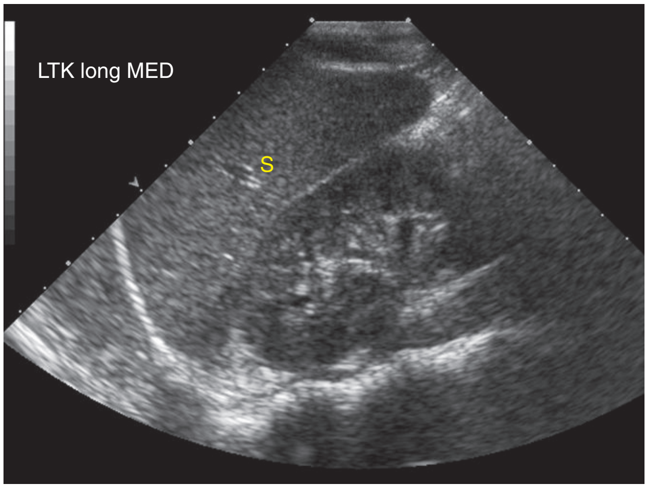


Figure S126-3. Three-month follow-up ultrasound after therapy demonstrates a more normal appearance to the left kidney. (S = Spleen.)

CASE 127

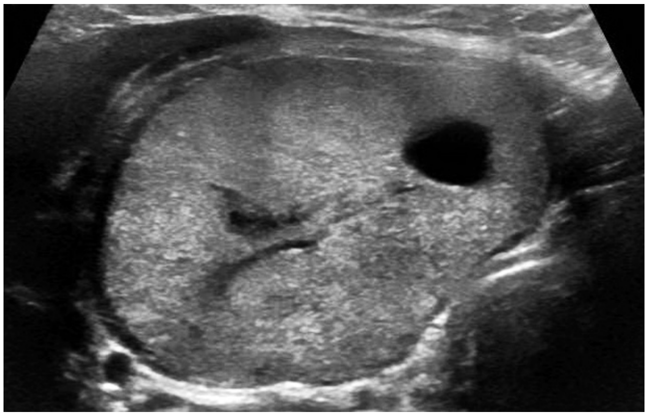


Figure S127-1. The transverse gray scale sonographic image of the right thyroid lobe shows a large, solid, isoechoic nodule with an anechoic (cystic) center and a thin hypoechoic rim that nearly replaces the lobe.

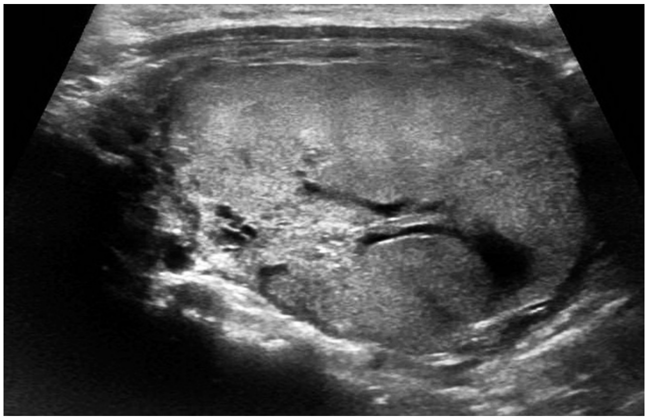


Figure S127-2. The longitudinal gray scale sonographic image of the right thyroid lobe shows a large, solid, isoechoic nodule with a thin hypoechoic rim that nearly replaces the lobe.

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