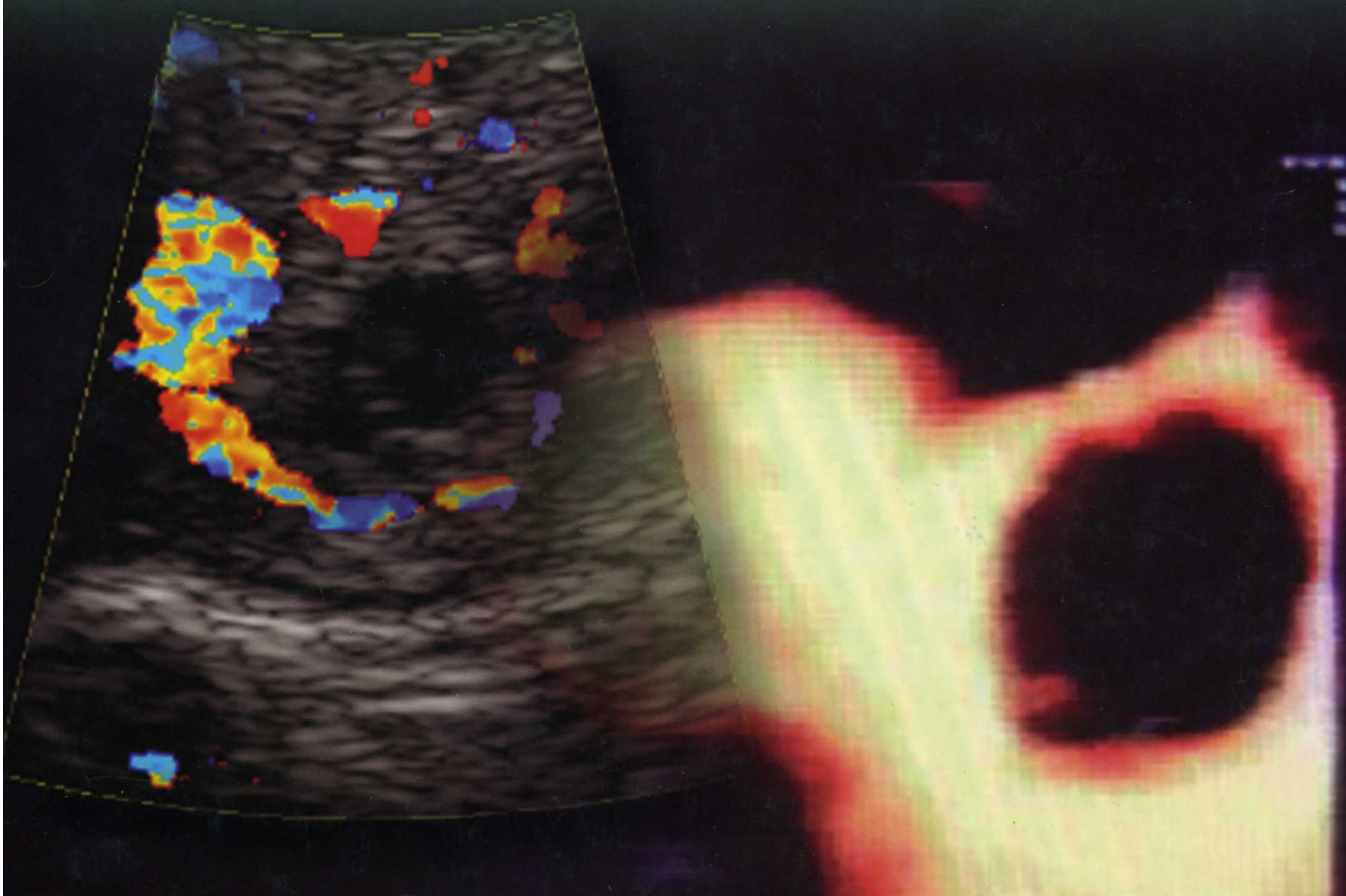
Practical Guide to EMERGENCY ULTRASOUND



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The Aorta

Carrie Tibbles
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Introduction

The timely diagnosis of an abdominal aortic aneurysm (AAA) is one the most important applications of ultrasound in the emergency department (ED). Rupture of an AAA is the 13th leading cause of death in the United States, yet many of these deaths could be prevented by early detection and repair of the aneurysm (1,2). Complications of AAA include rupture, which is often fatal; distal embolism or thrombosis; fistula formation; and dissection (3). Patients with an AAA present with a variety of symptoms, ranging from nonspecific back pain to full cardiac arrest. Unfortunately, the history is not always straightforward because up to 75% of patients are unaware they have an aneurysm before presenting with complications (4). As well, the physical exam has also been shown to be unreliable for the detection of AAA (5). In fact, the triad of hypotension, back pain, and a pulsatile mass is present in less than a third of cases of ruptured AAA (6). In a recent meta-analysis, Lederle and Simel concluded that some form of imaging is required to adequately exclude or diagnose an AAA because history and physical exam are so insensitive (7).

Compared to other imaging tests available to the emergency physician, bedside ultrasound has many advantages for the detection of an AAA. Ultrasound is portable, noninvasive, and readily accessible. ED ultrasound has been shown to be 100% sensitive in the detection of AAA when performed by emergency physicians with limited experience and is comparable or superior to other imaging modalities, such as computed tomography (CT), magnetic resonance imaging (MRI), and operative findings (laparatomy) (8–11).

Clinical Applications

There are three principle clinical scenarios in which a bedside ultrasound examination of the aorta can be beneficial: (1) adult patients with abdominal pain and hypotension, (2) unexplained abdominal/ flank/ back pain in an adult patient, and (3) screening in adult patients for asymptomatic AAA.

Following rupture or leaking of the aneurysm, patients may present in hypovolemic shock. In these critical patients, the ultrasound exam can be performed rapidly in the ED while the patient is simultaneously being resuscitated. Many patients who present with a ruptured AAA are not stable enough to be transported to the radiology suite. While ultrasound does not usually demonstrate signs of rupture, the detection of an aneurysm in a hypotensive, critically ill patient can facilitate urgent vascular surgery consultation. In the patient who presents in pulseless electrical activity (PEA) arrest, the detection of an AAA directs the physician to a potentially treatable cause (12).

An ultrasound exam establishes the presence of an AAA in the hemodynamically stable patient who presents with flank or back pain, syncope, abdominal pain, or other symptoms suggestive of aortic dilatation. The diagnosis of an AAA may be missed up to 24% of the time. The most common misdiagnosis is renal colic, followed by diverticulitis, and gastrointestinal bleeding (13). The patient may present with atypical symptoms such as altered mental status or focal abdominal pain. The screening bedside ultrasound may pick up both typical and atypical symptomatic AAAs. If an AAA is detected, the physician can then expedite appropriate care and consultation. If an AAA is excluded from consideration by the screening ultrasound, the physician can continue the evaluation for other potential causes of the patient's symptoms.

A third application of ED ultrasound of the aorta is the screening of high-risk patients (14). It is estimated that over 5% of men above the age of 65 have an AAA. The elective repair of an aneurysm has a mortality of less than 5%, compared to over 50% in the patient who survives to surgery following rupture (15). A recent study demonstrated that screening of this high-risk population can be effectively accomplished in the ED (16).

Image Acquisition

The patient is initially and almost exclusively examined in the supine position (Fig. 9.1). For the majority of adults, a 2.5- to 3.5-MHz curved array transducer provides adequate tissue penetration and sufficient resolution to examine the aorta. The depth should be set at 20 cm to begin the exam, but may be adjusted to optimize the image after the aorta is located. If the patient is morbidly obese, a lower-frequency transducer may be needed to adequately visualize the deeper structures in the abdomen, including the aorta. The exam begins with the transducer in the midepigastrium in the transverse plane with the patient in a supine position (Figs. 9.1, 9.2A). This position is similar to the subxiphoid window used to visualize the heart and pericardium (17). Standard transverse abdominal ultrasound orientation has the indicator on the transducer pointing toward the patient's right. The liver is visualized in the upper left corner of the monitor screen and acts as an acoustic window to view other structures (Figs. 9.2B, 9.2C). The anterior aspect of the vertebral body is often the first visible landmark. This appears as a hyperechoic, shadow-casting arch (Fig. 9.3). The aorta lies just anterior to the vertebral body, and appears as an anechoic cylinder. The inferior vena cava (IVC) lies just to the right of the aorta (Fig. 9.4). Once a midline view is obtained, the identity of the aorta should be confirmed by visualizing either the celiac trunk or the superior mesenteric artery, and the IVC should be located to confirm its identity. Once the aorta has been identified in the epigastrium, it can be traced caudad most easily in the longitudinal orientation. The longitudinal orientation is obtained by rotating the transducer to move the indicator to a 12-o'clock position; this projects the head of the patient toward the left of the monitor screen (Fig. 9.5). Whenever possible, it is ideal to maintain the transducer at the epigastrium in order to take full advantage of the liver as an acoustic window. It can then be projected caudad without actually moving the transducer from the epigastrium, and the aorta can be followed as inferiorly as possible. Because 95% of AAAs are distal to the renal arteries, it is important to visualize the abdominal aorta in its entirety from the diaphragm to the bifurcation (Fig. 9.6)(18).

Bowel gas or obesity may obscure images of the aorta (Fig. 9.7A). Gentle, constant pressure with the transducer may displace the bowel gas (Fig. 9.7B). In fact, one of the pitfalls in imaging the aorta is moving the transducer away from an area of bowel gas too quickly. Usually, peristalsis combined with gentle pressure from the transducer will dissipate most problematic bowel gas. Other techniques to improve visualization include modifying the angle of the transducer, and displacing the panniculus away from the area that is being imaged.

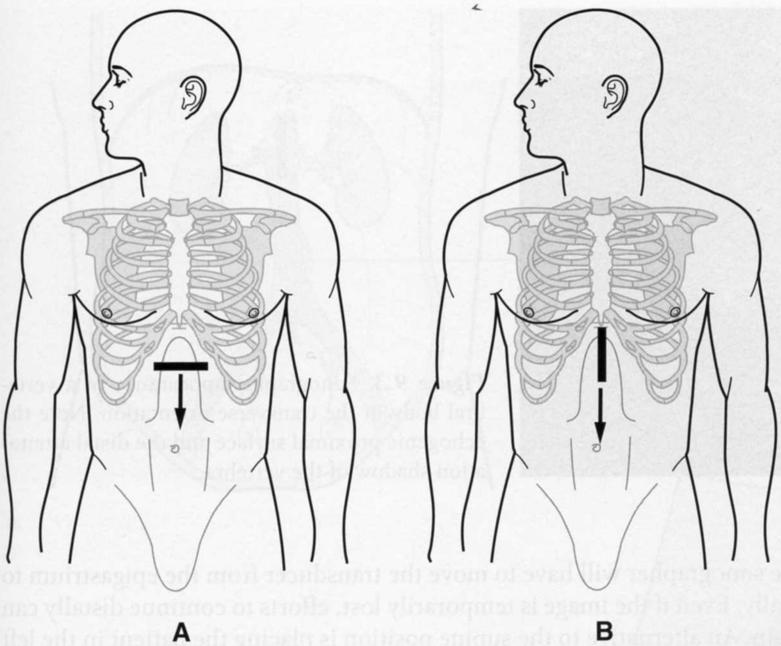


Figure 9.1. Guide to Image Acquisition: The Aorta. Begin in the midline of the epigastrium and scan down the abdomen to the umbilicus in both transverse (A) and longitudinal (B) orientations.

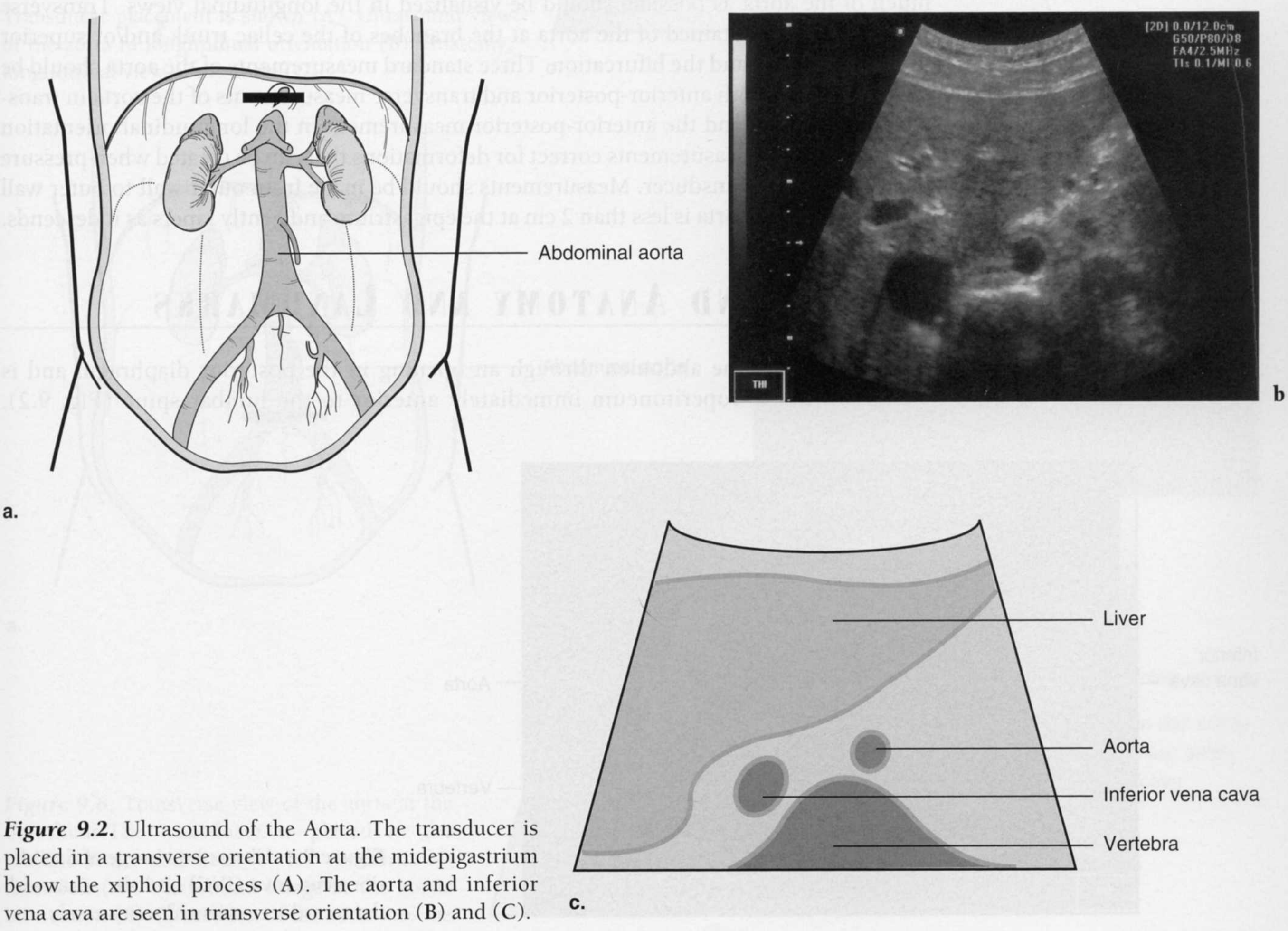


Figure 9.2. Ultrasound of the Aorta. The transducer is placed in a transverse orientation at the midepigastrium below the xiphoid process (A). The aorta and inferior vena cava are seen in transverse orientation (B) and (C).

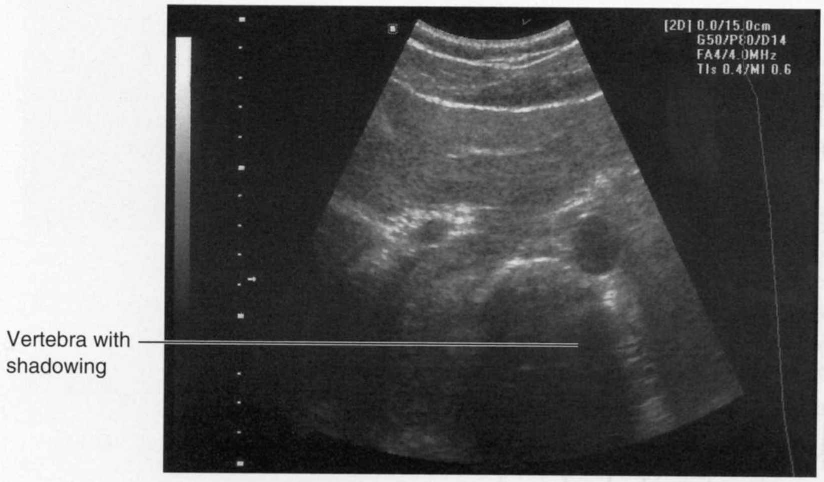


Figure 9.3. Sonographic appearance of a vertebral body in the transverse orientation. Note the echogenic proximal surface and the distal attenuation shadow of the vertebra.

Eventually, the sonographer will have to move the transducer from the epigastrium to trace the aorta distally. Even if the image is temporarily lost, efforts to continue distally can often pick it up again. An alternative to the supine position is placing the patient in the left lateral decubitus position and scanning in the midaxillary line. This approach takes advantage of the liver as an acoustic window and provides a longitudinal image of the aorta (Fig. 9.8).

The aorta should be visualized in both the transverse and longitudinal orientations. As much of the aorta as possible should be visualized in the longitudinal views. Transverse views should be obtained of the aorta at the branches of the celiac trunk and/or superior mesenteric artery and the bifurcation. Three standard measurements of the aorta should be made including both anterior-posterior and transverse measurements of the aorta in transverse orientation, and the anterior-posterior measurement in the longitudinal orientation (Fig. 9.9). These measurements correct for deformations that can be created when pressure is applied by the transducer. Measurements should be made from outer wall to outer wall (12). The normal aorta is less than 2 cm at the epigastrium and gently tapers as it descends.

Ultrasound Anatomy and Landmarks

The aorta enters the abdomen through an opening in the posterior diaphragm and is located in the retroperitoneum immediately anterior to the lumbar spine (Fig. 9.2).

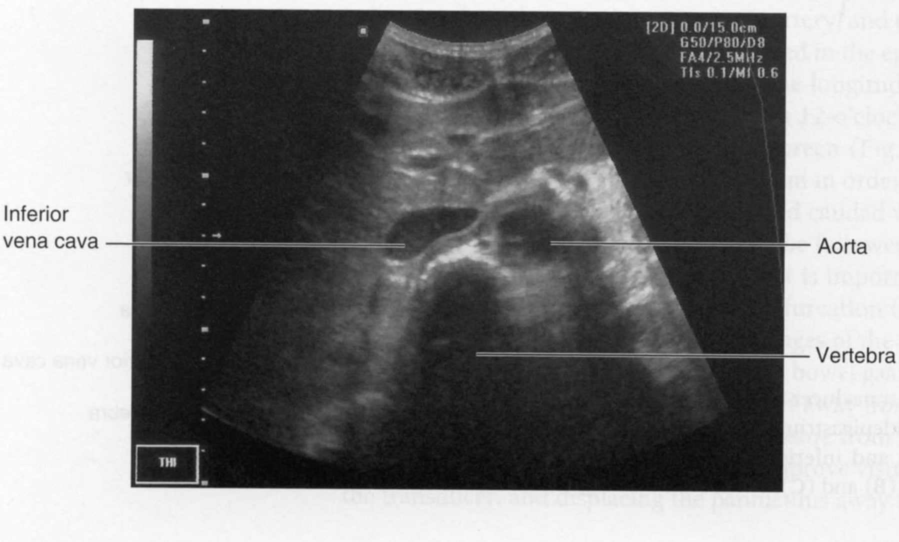
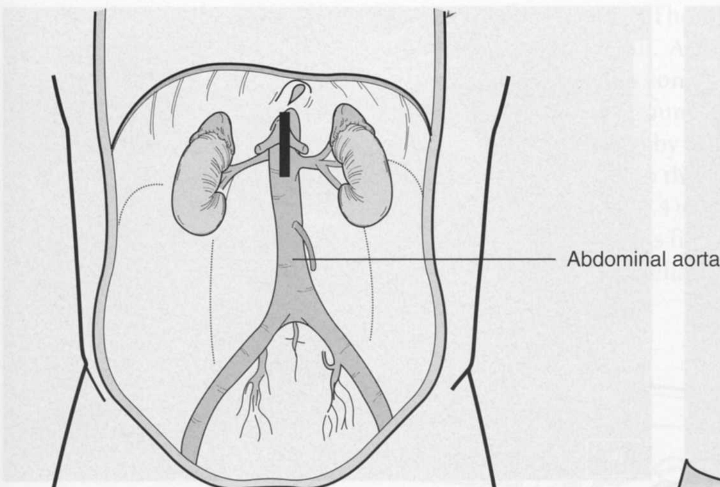
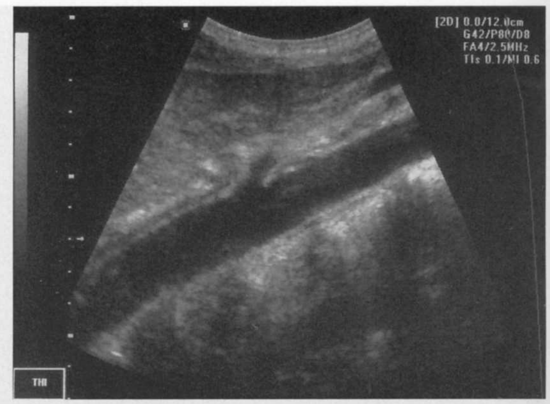


Figure 9.4. Ultrasound image of the inferior vena cava (IVC) and the aorta with the transducer oriented transversely.



a.



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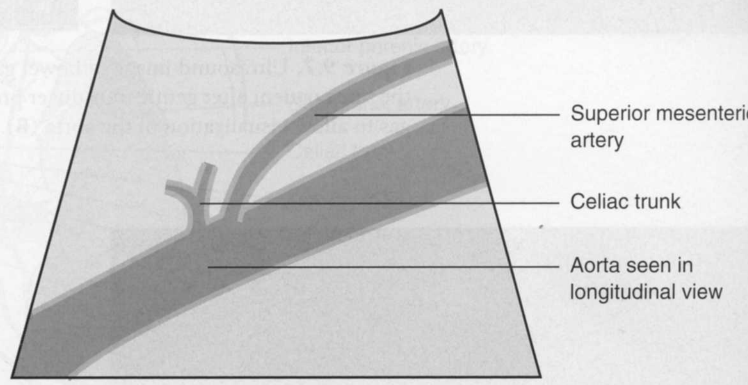
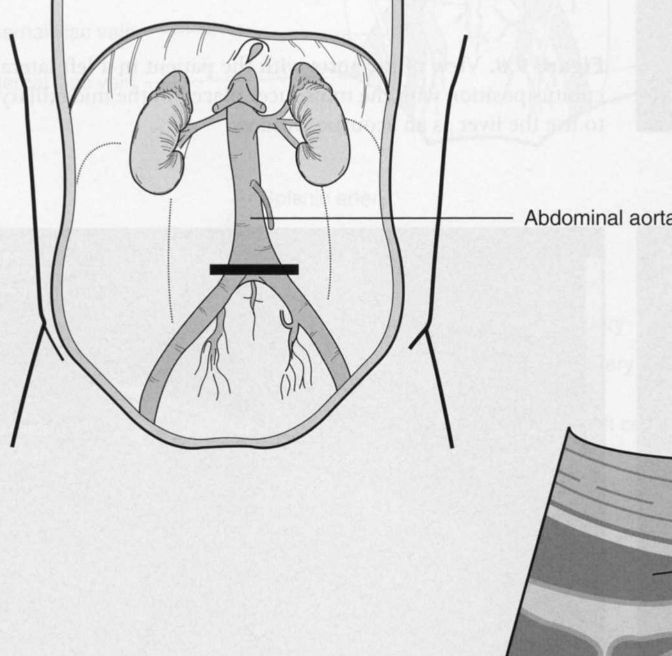
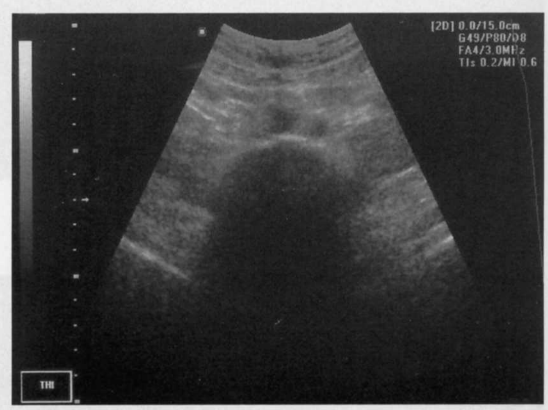


c.

Figure 9.5. Transducer placement for longitudinal orientation. The transducer is placed in the midline between the epigastrium and umbilicus to obtain a longitudinal view of the aorta and inferior vena cava (IVC). Transducer placement is shown (A). Ultrasound view of the aorta in longitudinal orientation (B). Anatomy, longitudinal view of the aorta (C).



a.



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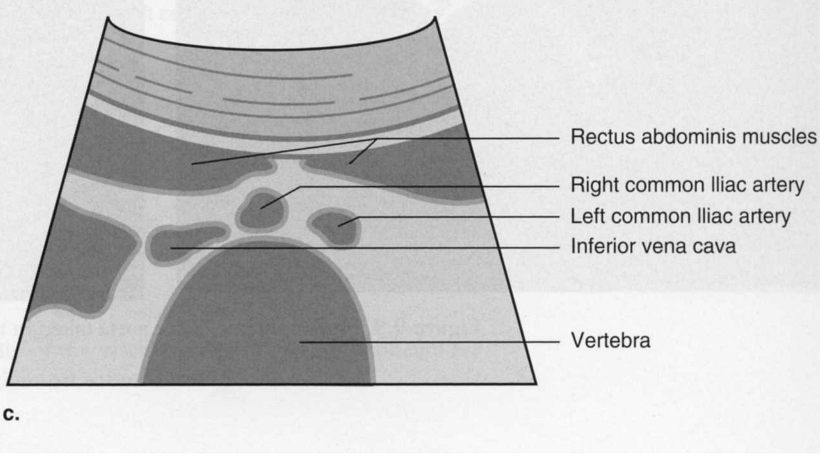


c.

Figure 9.6. Transverse view of the aorta at the umbilicus.The transducer is placed in the midline at the umbilicus to view the aortic bifurcation (A). Ultrasound image at the aortic bifurcation (B). Bifurcation of the aorta into the common iliac arteries (C).

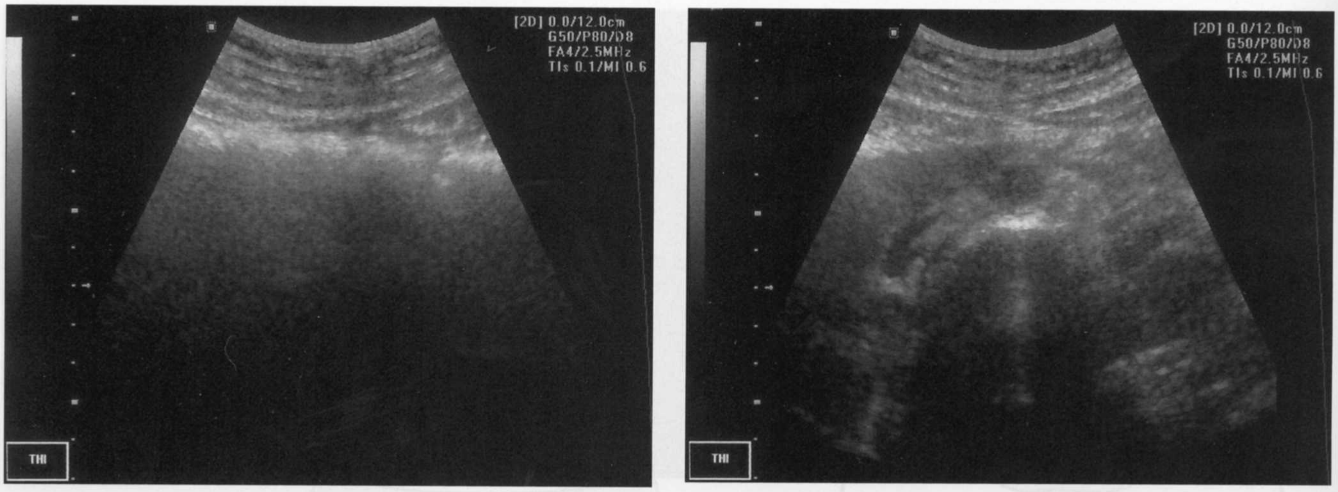


Figure 9.7. Ultrasound image of bowel gas obstructing views of the aorta (A). Ultrasound image of the same patient after gentle transducer pressure and peristalsis has decreased shadowing from bowel gas to allow visualization of the aorta (B).

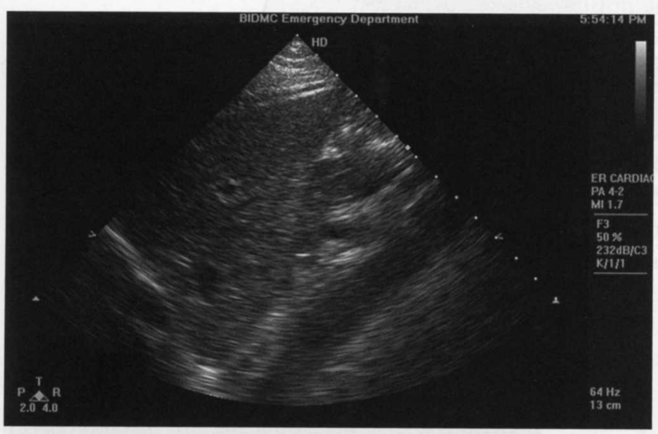


Figure 9.8. View of the aorta with the patient in a left lateral decubitus position with the transducer placed in the midaxillary line to use the liver as an acoustic window.

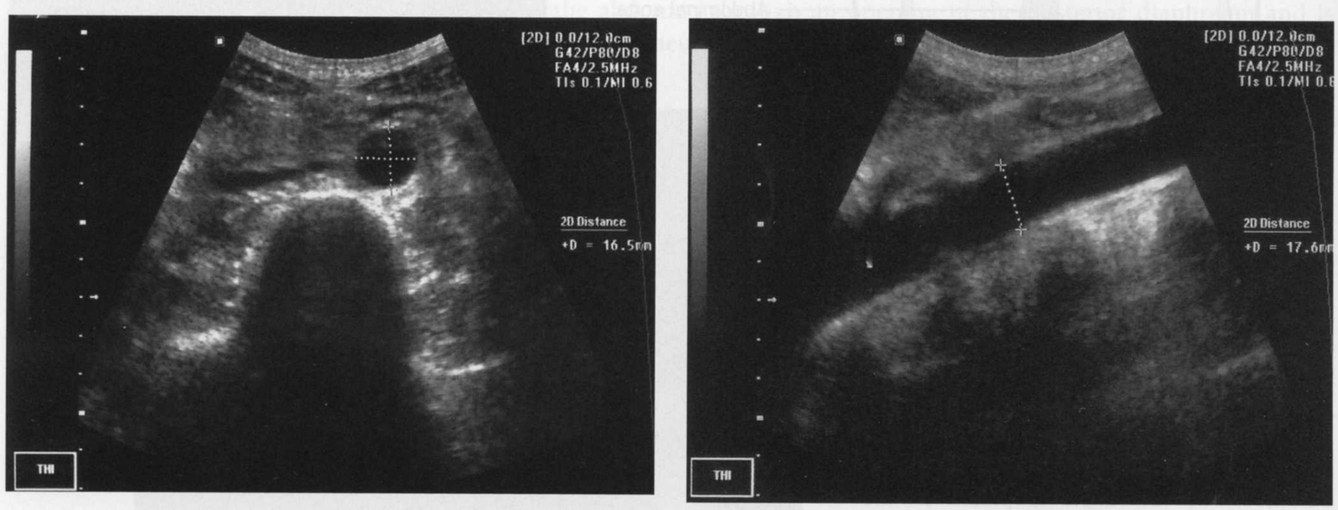


Figure 9.9. Measurements of the aorta taken in transverse (A) and longitudinal (B) views.

It is important to distinguish between the aorta and the IVC. The aorta lies in the midline and has a thickened, echogenic, and sometimes irregular wall. An atherosclerotic aorta may contain plaque and calcium and often creates shadows. In contrast, the IVC lies just to the right of midline and has a smooth, regular wall. The ultrasound appearance of the IVC depends largely upon the degree of hydration and is effected by volume and blood pressure. The normal IVC takes on a tear shape and tends to lie just to the right of the midline; sometimes it appears to drape over the vertebral column (Fig. 9.4). The IVC is the most posterior vascular structure in the retroperitoneum. The aorta has five major branches in the abdomen prior to its bifurcation (Fig. 9.10). The first is the celiac trunk.

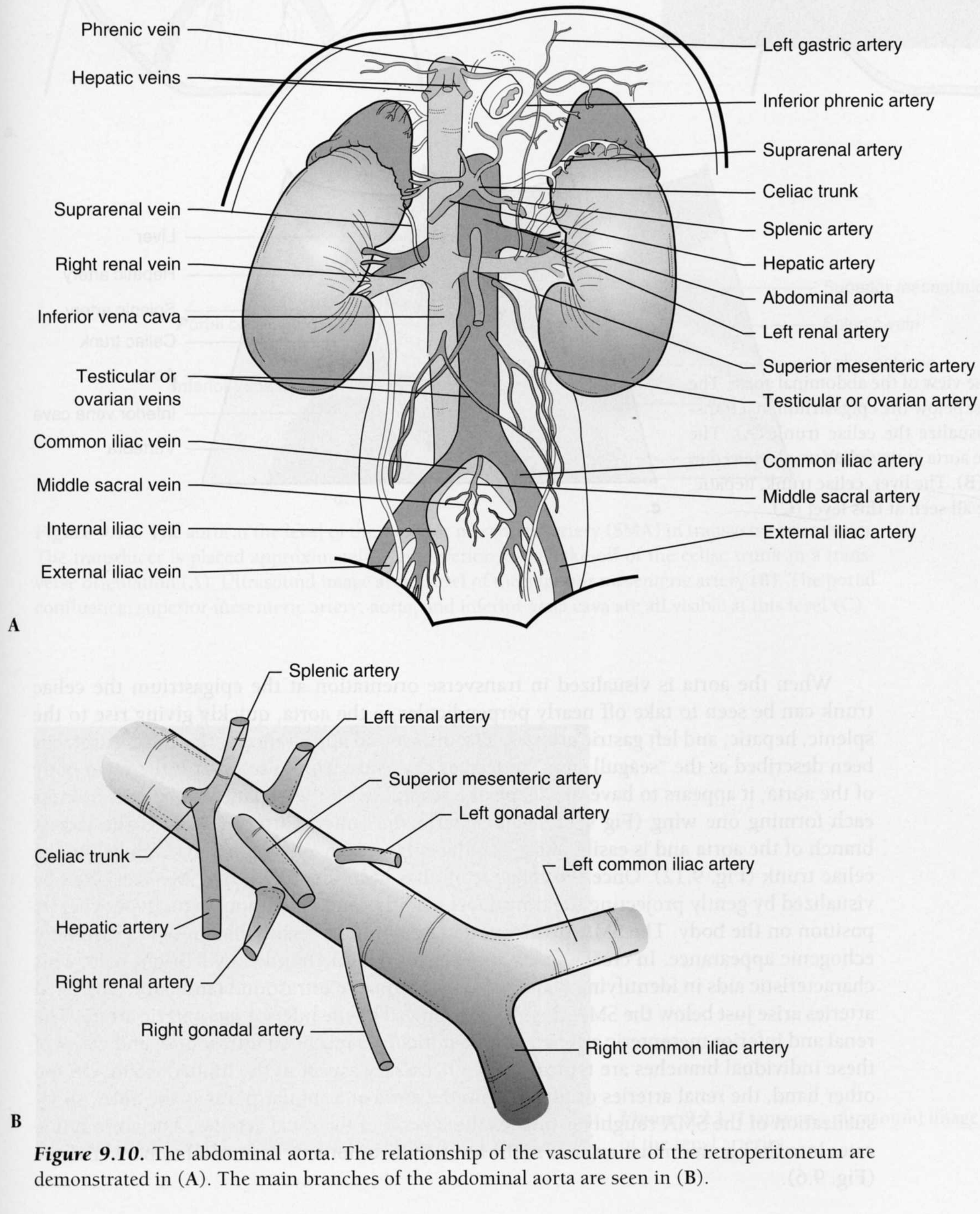
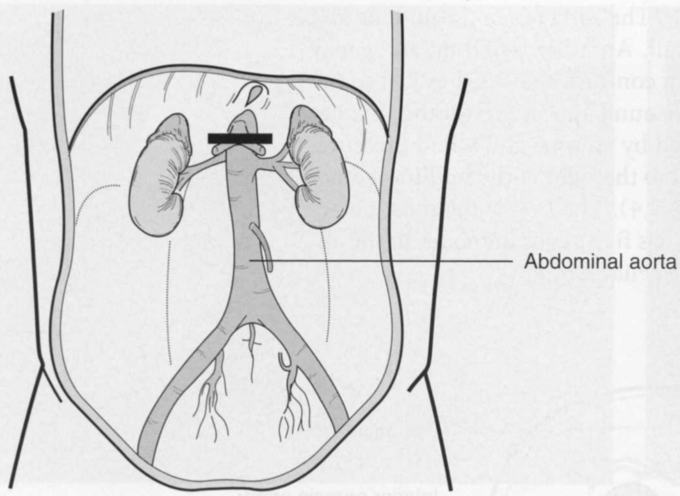


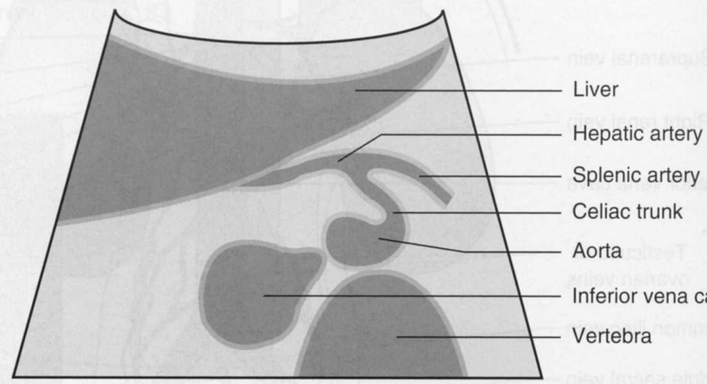
Figure 9.10. The abdominal aorta. The relationship of the vasculature of the retroperitoneum are demonstrated in (A). The main branches of the abdominal aorta are seen in (B).



a.

b

Figure 9.11. Transverse view of the abdominal aorta. The transducer is placed just below the epigastrium in a transverse orientation to visualize the celiac trunk (A). The ultrasound image of the aorta at the celiac trunk viewed in transverse orientation (B). The liver, celiac trunk, hepatic, and splenic arteries are all seen at this level (C).



c.

When the aorta is visualized in transverse orientation at the epigastrium the celiac trunk can be seen to take off nearly perpendicular to the aorta, quickly giving rise to the splenic, hepatic, and left gastric arteries. The ultrasound appearance of the celiac trunk has been described as the "seagull sign;" indeed as the celiac trunk projects off the main body of the aorta, it appears to have the shape of a seagull, with the hepatic and splenic arteries each forming one wing (Fig 9.11). The superior mesenteric artery (SMA) is the largest branch of the aorta and is easily imaged in the epigastrium approximately 2 cm below the celiac trunk (Fig. 9.12). Once the celiac trunk has been identified, the SMA can often be visualized by gently projecting the transducer slightly caudad, without actually moving its position on the body. The SMA is surrounded by fibrofatty tissue that gives it a distinctly echogenic appearance. In cross section it appears to be surrounded by a bright halo. This characteristic aids in identifying it and makes it a valuable ultrasound landmark. The renal arteries arise just below the SMA (Fig. 9.13) followed by the inferior mesenteric artery. The renal and inferior mesenteric arteries may be difficult to image on ultrasound, and views of these individual branches are typically not a necessary aspect of the limited exam. On the other hand, the renal arteries originate from the aorta at a similar point as the SMA, so visualization of the SMA roughly estimates the takeoff of the renal arteries. The aorta bifurcates into the common iliac arteries at the level of the umbilicus or fourth lumbar vertebrae (Fig. 9.6).

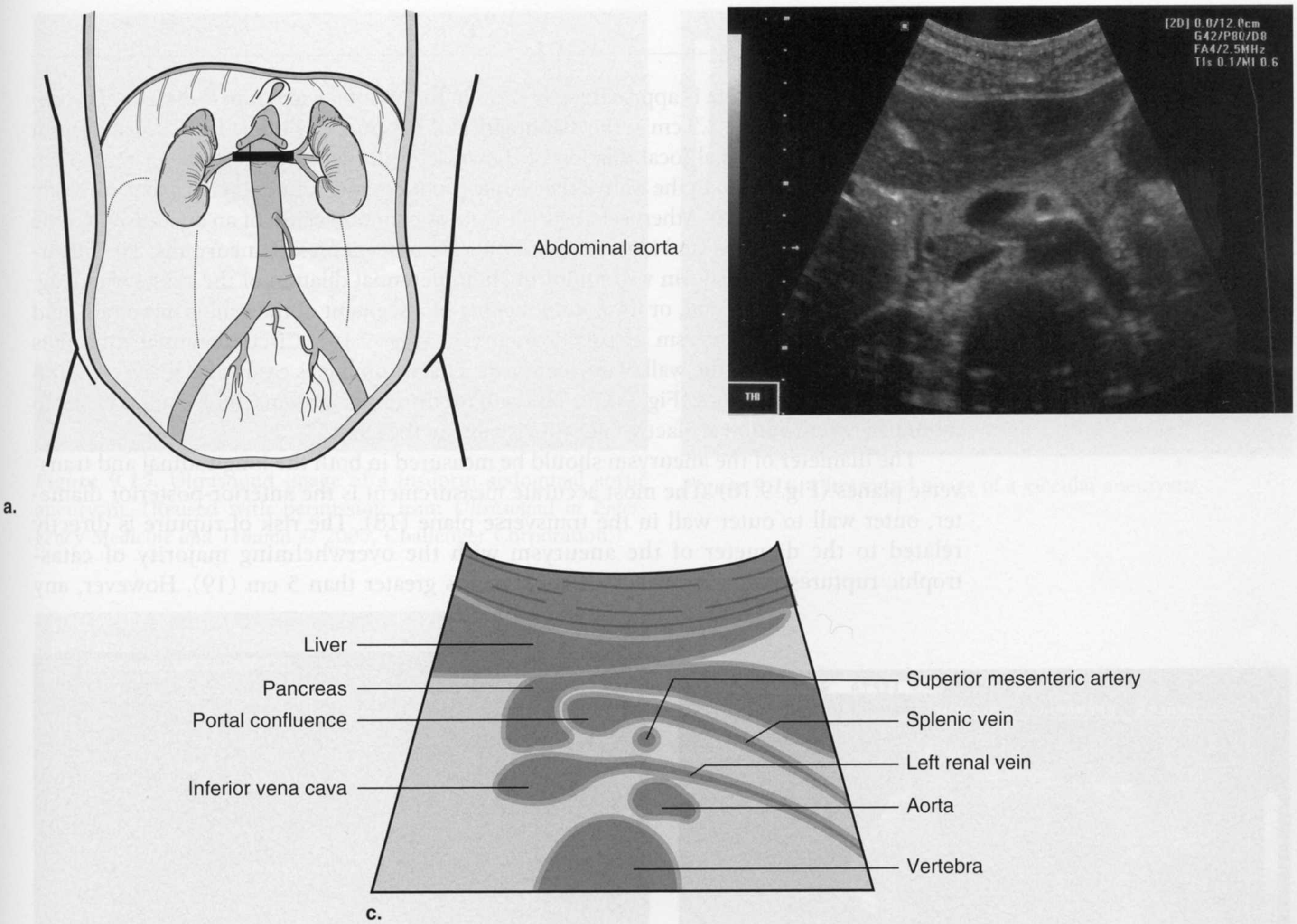


Figure 9.12. The aorta at the level of the superior mesenteric artery (SMA) in transverse orientation. The transducer is placed approximately 2 cm inferior to the take-off of the celiac trunk in a transverse orientation (A). Ultrasound image at the level of the superior mesenteric artery (B). The portal confluence, superior mesenteric artery, aorta, and inferior vena cava are all visible at this level (C).

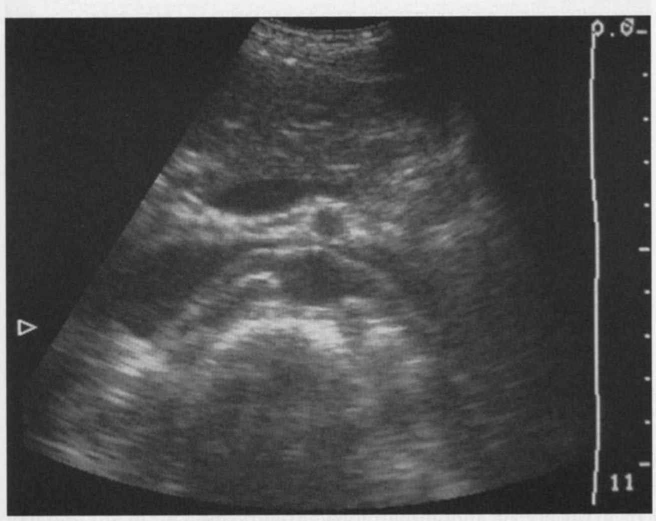


Figure 9.13. Transverse ultrasound image of the aorta at the level of the renal arteries.

PATHOLOGY

The diameter of the aorta is approximately 2 cm in the abdomen and tapers distally. The upper limits of normal are 2.5 cm at the diaphragm and 1.8 cm at the bifurcation. An aneurysm is defined as an abnormal focal dilation of the vessel wall that measures greater than 3 cm (Fig. 9.14). Calcification in the wall of the plaque produces bright linear echoes that are easily visualized on ultrasound. Atherosclerosis is the most common cause of an aneurysm. Cystic medial necrosis, syphilis, and Marfan's syndrome are other causes of aneurysms. The majority of aneurysms are fusiform with uniform circumferential dilation of the vessel wall (Fig. 9.15). A saccular aneurysm, or focal outpouching of a segment of the wall is more rare, and suggests a mycotic aneurysm or pseudoaneurysm (Fig. 9.16). Circumferential thrombus commonly develops in the wall of an aneurysm. This thrombus is easily visualized on ultrasound as increased echoes (Fig. 9.17). The gain on the ultrasound machine should be set to minimize reverberation artifact while still visualizing the clot (17).

The diameter of the aneurysm should be measured in both the longitudinal and transverse planes (Fig. 9.18). The most accurate measurement is the anterior-posterior diameter, outer wall to outer wall in the transverse plane (18). The risk of rupture is directly related to the diameter of the aneurysm with the overwhelming majority of catastrophic ruptures occurring when an aneurysm is greater than 5 cm (19). However, any

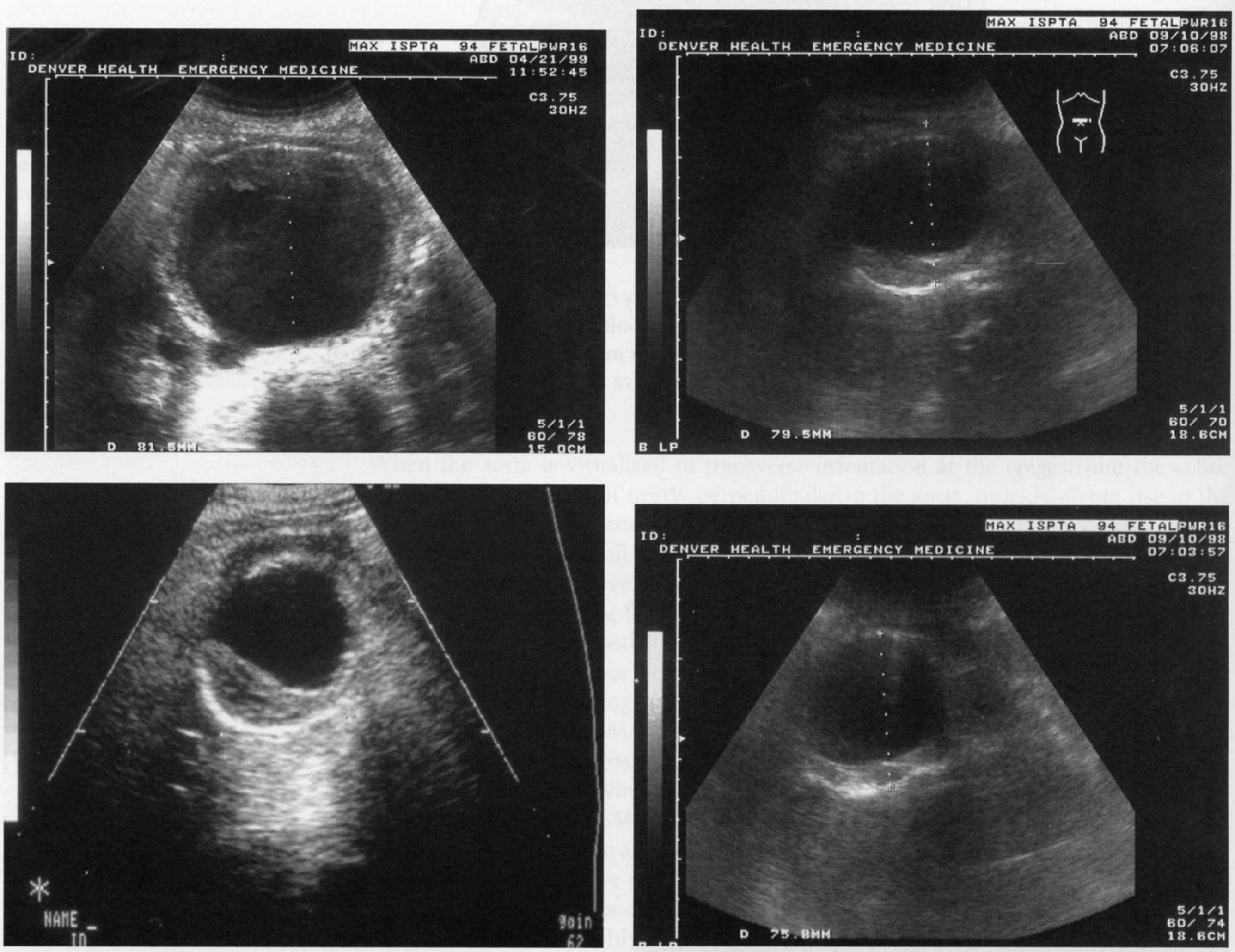


Figure 9.14. Ultrasound images of a variety of abdominal aortic aneurysms (A, B, C, and D). (Reused with permission from *Ultrasound in Emergency Medicine and Trauma* © 2005, Challenger Corporation.)

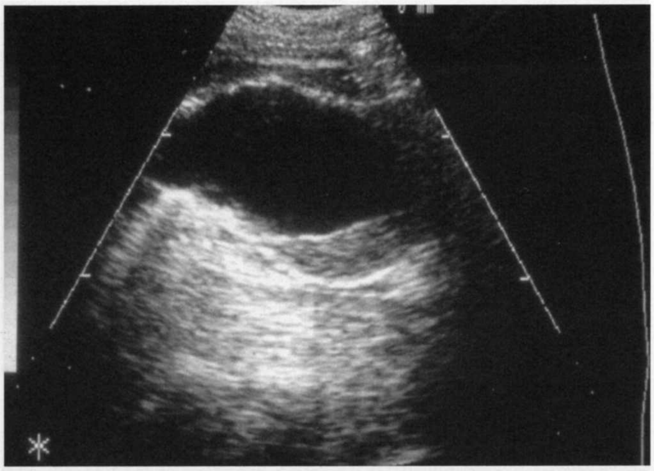


Figure 9.15. Ultrasound image of a fusiform abdominal aortic aneurysm. (Reused with permission from *Ultrasound in Emergency Medicine and Trauma* © 2005, Challenger Corporation.)

Figure 9.16. Ultrasound image of a saccular aneurysm.

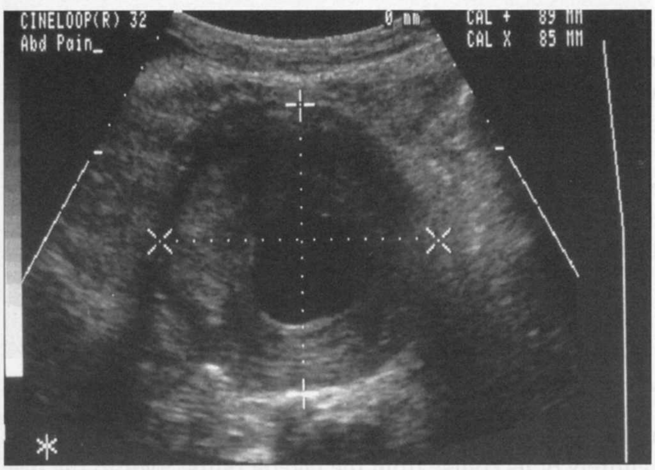


Figure 9.17. Abdominal aortic aneurysm with a large thrombus. (Reused with permission from *Ultrasound in Emergency Medicine and Trauma* © 2005, Challenger Corporation.)

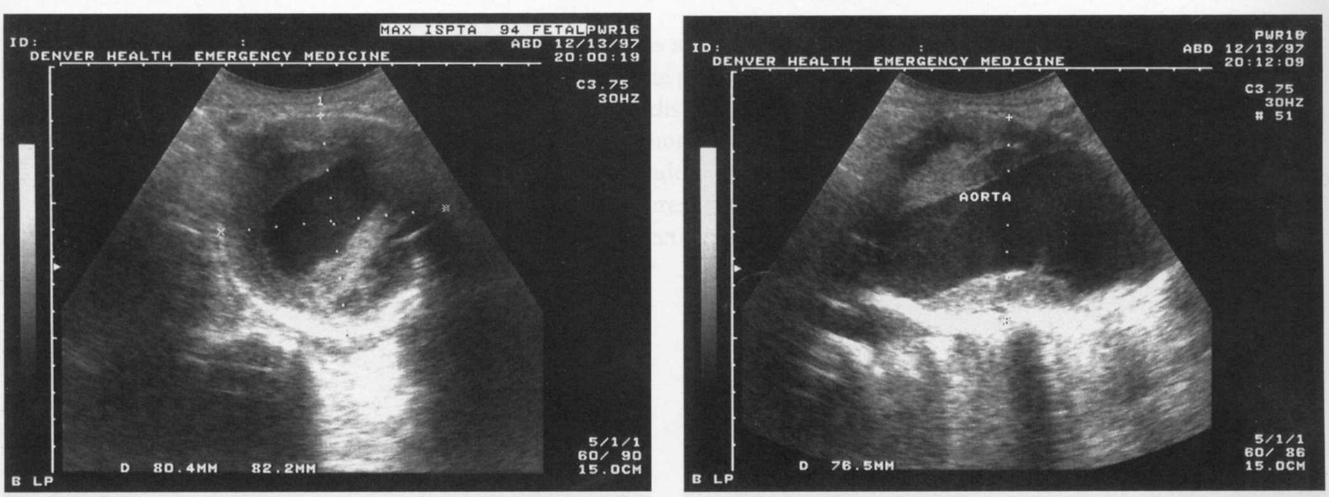
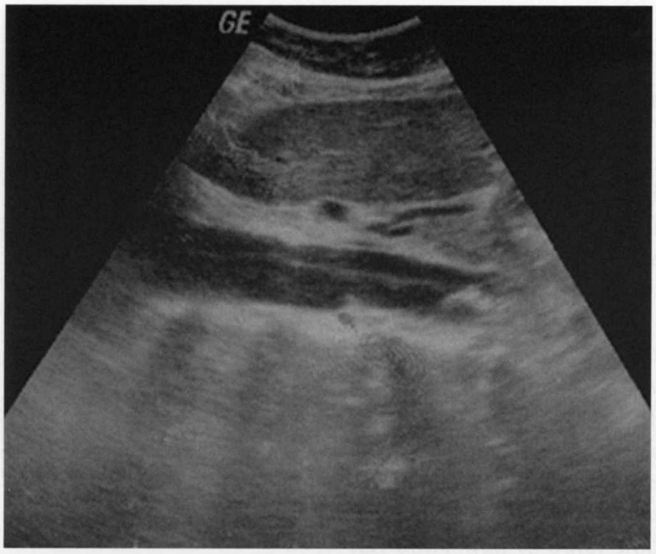
A  B

Figure 9.18. Measurement of an abdominal aortic aneurysm. Three measurements should be taken to accurately describe the dimensions of an aneurysm. In a transverse view, two measurements are taken of the cross-section of the aneurysm (A). An anterior-posterior measurement should be taken in the longitudinal view of the aorta (B). The measurements should include any thrombus in the wall of the aneurysm (A, B).



A

B

Figure 9.19. Ultrasound image of an abdominal aorta demonstrating dissection in longitudinal (A) and transverse (B) orientations.

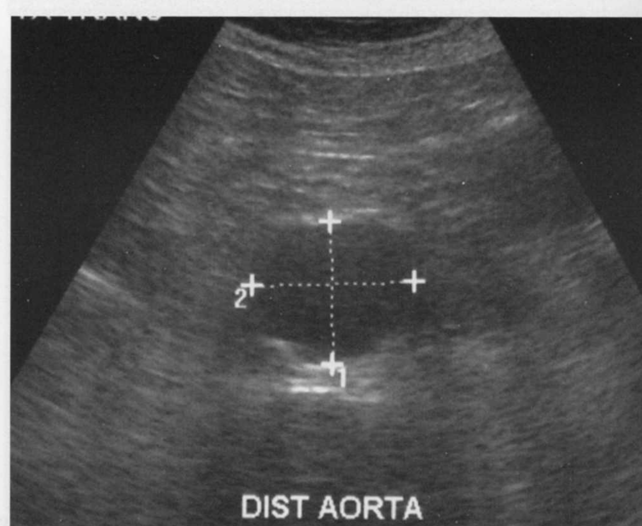
symptomatic aneurysm, regardless of size, is suspicious for rupture or leak. Up to 40% of aneurysms extend into the iliac arteries.

Ultrasound may also detect complications of an AAA. For example, compression of the ureter by an expanding aneurysm or retroperitoneal hematoma can lead to hydronephrosis. Hemoperitoneum from intraperitoneal rupture may be seen as fluid in Morison's pouch. As well, 2% to 4% of aortic dissections involve the abdominal aorta. Ultrasound is not a primary modality for evaluating aortic dissections; however an intimal flap, false lumen, or other signs of a dissection may be seen on ultrasound examination of the aorta (Fig. 9.19) (20).

Artifacts and Pitfalls

1. Far and away the greatest pitfall in the sonographic evaluation of the abdominal aorta is failing to fully visualize the entirety of its course from the takeoff of the SMA to the iliac

A



B

Figure 9.20. A small distal aortic aneurysm is seen near the bifurcation in an otherwise normal-appearing aorta. This aneurysm would be missed if the scan did not include the distal aorta. (A) Longitudinal view. (B) Transverse view.

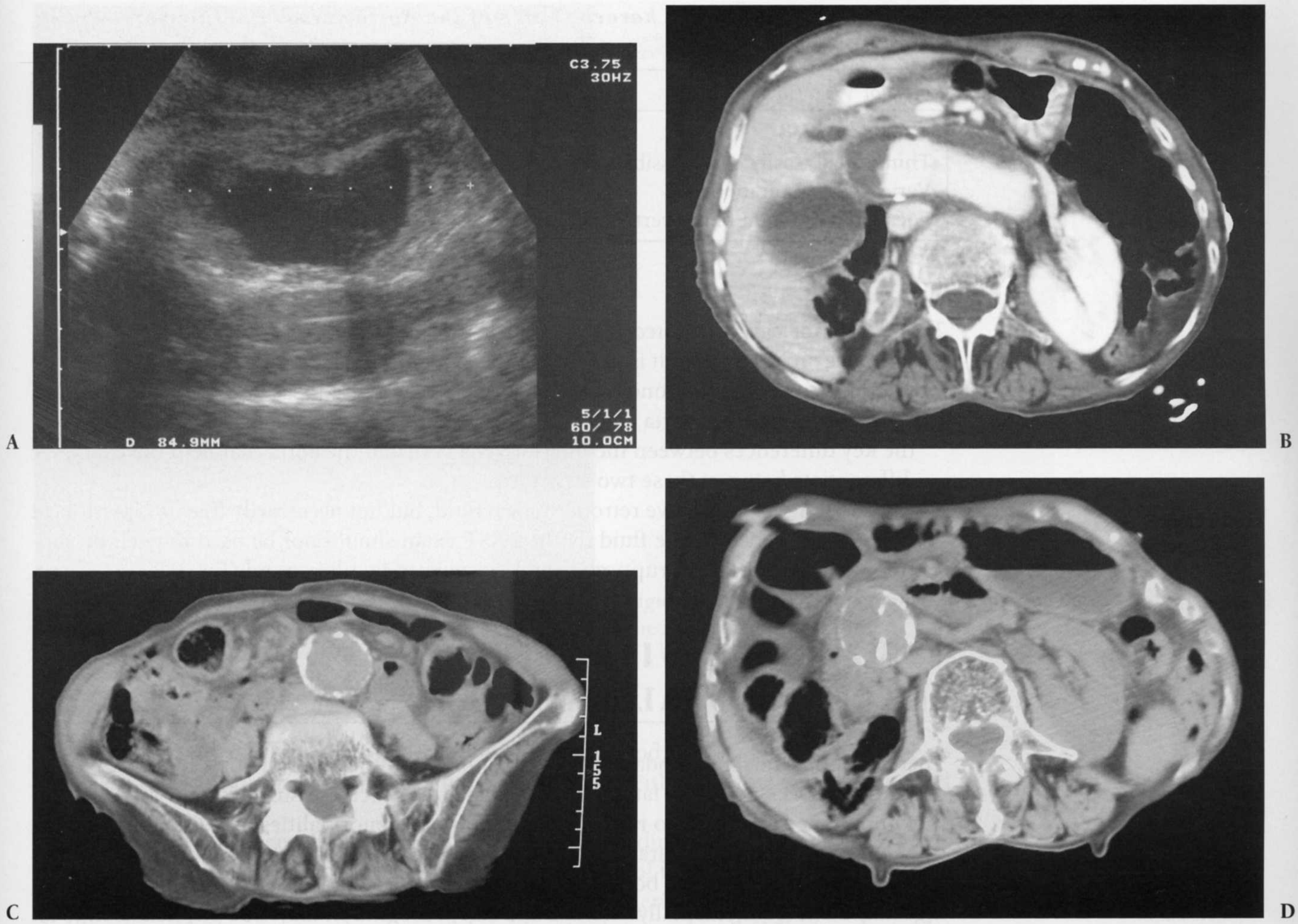


Figure 9.21. Ultrasound image taken with transducer in a transverse orientation demonstrating a tortuous aorta. (A). Computer tomography of the same patient (B, C, D). Noncontrast computed tomography scan showing the abdominal aortic aneurysm on either side of the vertebral body in two different axial planes (C–D).

bifurcation. Failure to visualize the entire aorta may miss an infrarenal aneurysm (Fig. 9.20). The most common obstacle to obtaining an adequate picture of the aorta is overlying bowel gas. Gentle pressure with the transducer may displace the bowel gas and improve the image. As a person ages the aorta may become more tortuous, making it harder to visualize and measure (Fig. 9.21). The aorta is a cylinder, and obtaining an oblique measurement may result in underestimating or even overestimating the diameter (Fig. 9.22). This can be avoided by orienting the transducer directly perpendicular to the aorta.

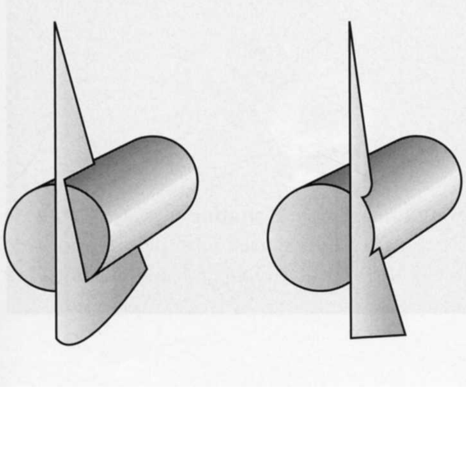


Figure 9.22. The cylinder tangential effect. An oblique view of a cylinder will underestimate the diameter.

Table 9.1: Ultrasound Characteristics of the Aorta versus the Inferior Vena Cava

Inferior Vena Cava	*Aorta*
Almond shaped	Round
Thin walled, easily compressible	Thicker wall
Varies with respiration	Does not vary with respiration
Located to the right of the vertebral body	Located above the vertebral body

2. The inferior cava is located just to the right of the aorta. Because it has a similar appearance on ultrasound, it is possible to mistake the inferior vena cava for the aorta. The inferior vena cava is almond or tear shaped on cross section, easily compressible, has a thinner wall than the aorta, and varies in size with respiration (Fig. 9.4). Table 9.1 lists the key differences between the inferior vena cava and the aorta that help the examiner differentiate between these two structures.
3. Ruptured AAAs often have retroperitoneal fluid, but not necessarily free intraperitoneal fluid. The absence of free fluid by the FAST exam should not be used to exclude rupture. As well, the site of rupture is rarely visualized by ultrasound (Fig. 9.23).

Comparison with Other Imaging Modalities

There are other imaging modalities available to the physician evaluating for an AAA. Radiographs, especially of the lateral lumbar spine, may increase suspicion for an AAA, but they should never be used to rule out this condition. Abnormalities may include calcification of the aortic wall or a paravertebral soft tissue mass (Fig. 9.24). Less common findings include erosion of vertebral bodies or an obscured renal shadow. Occasionally these findings may be noted incidentally on films and early recognition may clue physicians in to an unsuspected diagnosis (21).

Computed tomography (CT) is highly sensitive for the detection of AAA (Figs. 9.25, 9.26). It is superior to ultrasound for the detection of retroperitoneal hemorrhage or other signs of rupture and it can demonstrate the extent of aneurysmal involvement. Specifically, it can determine whether the aneurysm is above or below the renal arteries, information that is helpful to the surgeon planning a surgical repair. Because an abdominal CT visualizes the entire abdomen, it also has the advantage of revealing alternative diagnoses, such

Figure 9.23. Ultrasound image demonstrating the site of rupture of an abdominal aortic aneurysm. (Reused with permission from *Ultrasound in Emergency Medicine and Trauma* @ 2005, Challenger Corporation.)

Figure 9.24. Lateral radiograph demonstrating the outline of a calcified aneurysm.

as renal stones or bowel pathology (22). On the other hand, CT scanning takes time to complete and requires moving the patient from the ED—neither of which can be afforded in an unstable patient.

The role of arteriography in the evaluation of AAA has diminished in recent years. Arteriography is useful in defining the extent of involvement of the branch vessels, and gives an accurate assessment of the lumen diameter. However arteriography may underestimate the diameter of the aneurysm because of thrombus in the vessel wall (17). Arteriography is also time intensive, invasive, requires intravenous contrast, and necessitates moving the patient from the ED.

Magnetic resonance imaging (MRI) is very sensitive for the detection of AAA and signs of rupture. Because of the time and effort required to obtain the images, MRI is usually not practical in the acute setting, especially in the unstable patient.

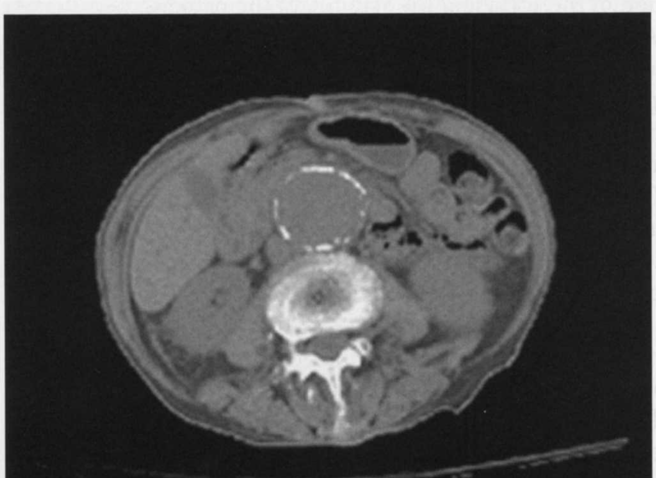
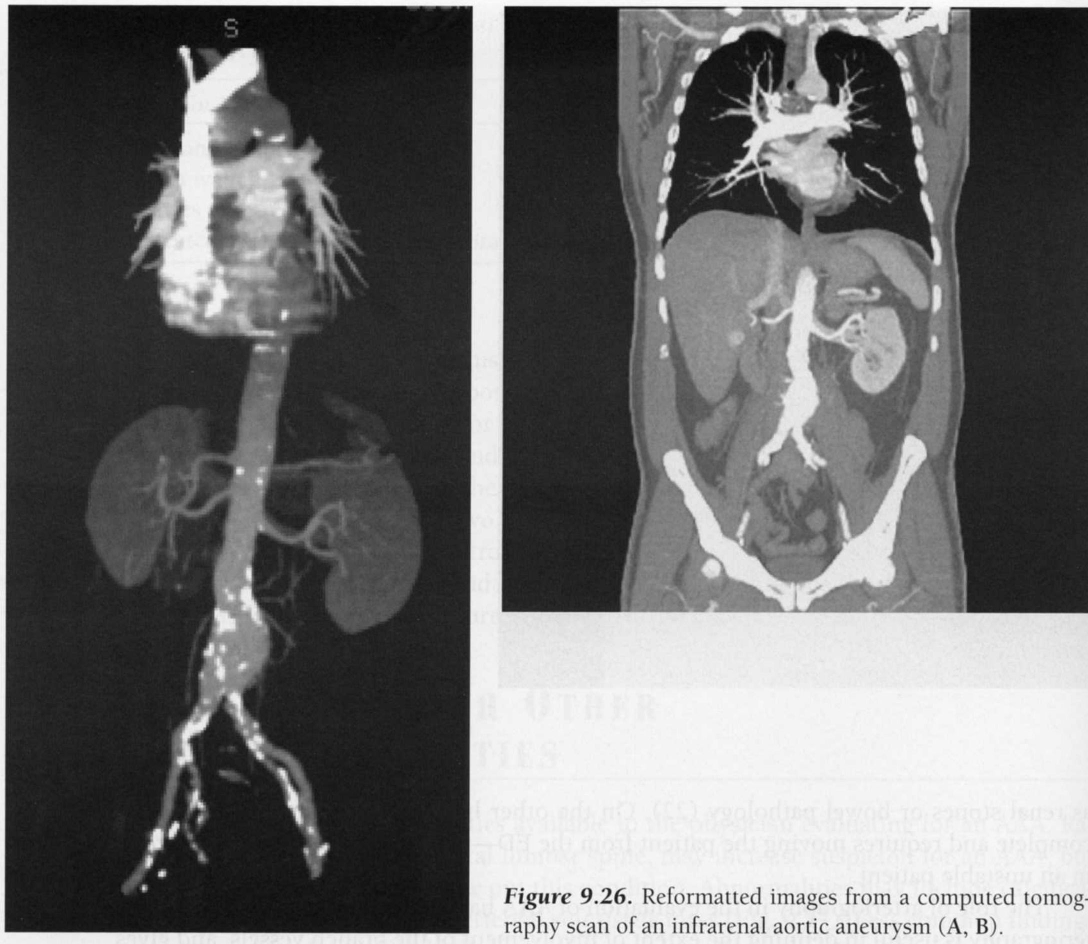


Figure 9.25. Computed tomography scan of the abdomen demonstrating an abdominal aortic aneurysm.



A

B

Figure 9.26. Reformatted images from a computed tomography scan of an infrarenal aortic aneurysm (A, B).

Use of the Image in Clinical Decision Making

There are two factors that influence the decisions of an emergency physician who detects an AAA: the amount of dilatation of the aorta and the stability of the patient.

Regardless of whether an AAA is detected secondary to an exam done for symptoms or incidentally, if the aorta is greater than 3.0 cm in diameter, the patient should be referred for vascular surgery follow-up with repeat ultrasound exams. Studies that have tracked AAAs longitudinally have found that the natural history of an aneurysm is to expand at an average rate of 0.4 cm per year. More importantly, the risk of rupture is directly related to the diameter of the aneurysm (18). Once an aneurysm reaches 5.0 cm the risk of rupture is 22% in two years (19). Therefore, most surgeons recommend elective repair of the aneurysm once it reaches 5.0 cm and that a vascular surgeon be contacted to arrange close follow-up for the patient. The patient should receive careful instructions to return to the ED immediately if he or she develops any symptoms suggestive of an expanding or leaking aneurysm.

In the hemodynamically unstable patient, the rapid detection of an AAA facilitates immediate vascular surgery consultation. Plummer et al demonstrated that the time to the operating room was decreased from an average of 90 minutes to 12 minutes when an ED ultrasound was performed to detect the aneurysm (23).

Incidental Findings

The presentation of patients with an AAA may be very nonspecific. For instance, patients may present with pain in the flank, back, abdomen, buttock, leg, groin, scrotum, or chest. Historically, studies have focused on presentations that have led to the misdiagnosis of AAA, but this data was collected in an era lacking significant influence of bedside ultrasound (13). The opposite end of the spectrum is that emergency physicians using broad indications for performing ultrasounds looking for an AAA will encounter patients having a normal caliber aorta, but with other findings such as hydronephrosis, gallstones, or urinary retention that are the actual etiology of the patient's symptoms. To date, the incidence of detecting alternative diagnoses during routine scanning of the abdominal aorta has not been determined.

Clinical Case

A 74-year-old man presents to the ED with a chief complaint of light-headedness. He has a history of hypertension and hypercholesterolemia. He currently takes metoprolol and lisinopril. He has no known drug allergies and quit smoking over 10 years ago. Along with a sensation of light-headedness on standing for the last 2 to 3 days, he also notes a dull abdominal pain most severe in the right lower quadrant, as well as occasional right back pain. He is afebrile, has a heart rate of 78 beats per minute, blood pressure of 88/52 mm Hg and 18 breaths per minute. The physical examination of his head, lungs and heart is unremarkable. His abdomen is slightly distended with normoactive bowel sounds. He is moderately tender in the right lower quadrant and periumbilical region without rebound or guarding. There are no palpable masses. He is guaiac negative on rectal exam. His vascular exam reveals a 2+ left femoral pulse and a 1+ right femoral pulse. The rest of his physical exam is normal.

After adequate intravenous access is established, the patient is started on crystalloid fluids and his blood pressure improves to 104/64. A rapid bedside ultrasound in the ED reveals a 6-cm abdominal aortic aneurysm starting approximately 1 cm below the renal arteries (Fig. 9.27). He remains hemodynamically stable during his ED stay. His hematocrit returns at 22 and a blood transfusion is initiated. An emergent vascular surgery consult is obtained. He is taken immediately to the operating room and has successful repair of his 6.4-cm AAA and is discharged to home on hospital day 7.

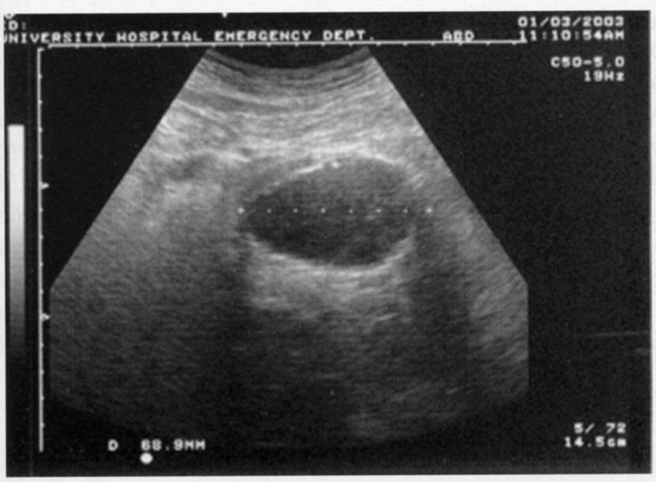


Figure 9.27. An abdominal aortic aneurysm. (Courtesy of Kristen Nordenholz, MD, University of Colorado.)

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