Basic Abdominal Sonographic Anatomy and Protocol

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Objectives

- Know the organs in the abdominal cavities
- Learn how to recognize abdominal structures in multiple planes
- Know the correct orientation of an ultrasound image
- Understand the criteria for a quality ultrasound image
- Recognize the sectional ultrasound anatomy in the transverse and longitudinal planes
- Understand the basic abdominal protocol
- Describe the patient preparation, transducer selection, patient position, and images that should be obtained for all abdominal and soft tissue structures

Introduction

The purpose of this program is to provide the reader with a introduction into the basic abdominal scanning techniques and protocols utilized in the general ultrasound department. This is the second of a series of basic articles that focus on the concepts of sonography beginning with sonographic abdominal anatomy, instrumentation and transducer selection, basic scanning techniques and patient positions, patient preparation, and finally the general abdominal ultrasound protocol. Basic gynecology and obstetrics will be covered in a separate program. This program would be appropriate for an entry-level sonography student, medical student, or radiography student.

It is not unusual for the experienced sonographer to hear the phrase, "I didn't realize it would be this difficult to create make an ultrasound image - you make it look so easy!" The state of the art of ultrasound demands a high degree of manual dexterity and hand-eye coordination, and the ability to conceptualize two-dimensional information into a three-dimensional format. Coupled with this ability, the sonographer must also possess a background knowledge of anatomy and physiology, pathology, instrumentation, how to avoid ultrasound artifact production, and transducer characteristics. Ultrasound equipment today is so sophisticated that it demands a much greater understanding of the physical principles of sonography to produce quality images.

The beginning sonography student will soon learn that the "art of scanning" cannot be acquired from reading a textbook; the one-on-one individual "hands-on" training in a clinical atmosphere is a critical and intregal part of the sonographer's experience in producing high-quality scans.

Patient Preparation and Position for the Ultrasound Examination

Patient Preparation.
The ultrasound examination is most effective if the patient has been NPO for at least 6 hours. This allows the biliary system to be distended and easily imaged by the sonographer. When a patient is fasting there is a a decreased opportunity for gas to accumulate within the colon; gas prohibits the passage of the sound and thus limits visualization of abdominal structures. If the patient is able to consume liquids and the pancreas is not well-visualized, the administration of 32 oz. of water may be given to fill the stomach and duodenum to better delineate the pancreas.

The kidneys are best imaged when the patient is fully hydrated, therefore no patient preparation is necessary when only the kidneys are examined. Full hydration will also enable the sonographer to image the distended urinary bladder.

Patient Position.
The position of the patient for the general abdominal scan is usually supine for the initial images. The patient is then rolled into various degrees of obliquity to better demonstrate the biliary system, pancreas, liver, kidneys, or spleen. If the scanning plane is oblique, the sonographer should indicate the change of position on the documented image without specifying the exact degree of obliquity. The same would apply if the patient were in a lateral, upright, or prone position.

Transducer and Instrumentation Selection

Transducer
The upper abdomen is scanned with the highest-resolution transducer possible for the size of the patient. The transducer may be a sector or curved linear array, or in many cases, a combination of the two. The transducer frequency depends on the size, muscle and fat composition of the patient. Generally a 3-MHz transducer is used on most normal sized adult patients, with variations of 2.25 to 7.5 MHz, depending on image resolution and beam penetration through the deeper structures in the liver. Most transducers today actually are multi-focal with multiple frequencies available in one transducer; therefore, the liver may be scanned with the lower frequency, while the pancreas and gallbladder may be scanned with the higher frequency transducer. The lower-frequency transducers are often necessary in patients with fatty infiltration or cirrhosis of the liver.

Instrumentation
The primary controls the sonographer needs to utilize in the general abdominal scan are the depth, time-gain compensation, overall gain, and zoom control. The depth controls the size of the overall image. This should be set so the image fills the screen without loosing information along the posterior border. Most normal adult abdomens range in size from 15 to 20 cm deep.

The time-gain compensation controls individual gain pods within the image. These pods are aligned to the depth control (i.e. if the depth is set at 20 cm and there are 10 pods, each pod would adjust the gain at 2 cm increments). The sound beam is absorbed, attenuated, and reflected as it strikes a surface; by adjusting the time-gain controls, the sonographer is able to electronically amplify the echo in a certain area so the sound will be stronger and produce a brighter echo return.

The overall gain controls the amount of echoes received by the transducer. It is analogous to the volume control on the radio, the higher you turn up the volume, the louder the sound. Such is the response of the overall gain control, as the sonographer increases the gain, more echoes are seen throughout the image. If the gain is set "too high" the sonographer will have difficulty in distinguishing the various gray scale interfaces. The vascular structures should be anechoic or echo-free and may be used as a control to make sure the gain is not set too high. On the other hand, if the gain is set too low, the overall image will be dark and texture patterns within the organs difficult to see.

In addition to the instrument controls, the sonographer must find the best "window" on the patient's abdomen. The window refers to the area which the transducer may be angled to record the majority of abdominal landmarks without interferance from the ribs, bowel, stomach, or lungs.

Introduction to Sonographic Abdominal Anatomy

Sectional Anatomy
The sonographer must have a working knowledge of anatomical structures with particular attention to spatial relationships within the body. Most students entering ultrasound have some basic understanding of anatomy. However few students have been exposed to gross anatomy or sectional anatomy or to all of the anatomical variations that may occur in the body.

The student in sonography needs to understand not only anterior to posterior anatomical structures, but also superior to inferior, medial to lateral relationships. This is the basics of how the three-dimensional reconstruction is developed from a two-dimensional image by the sonographer. The understanding of where the organ is in relation to the transducer as well as to other anatomical structures is critical for an adequate image to be constructed.

Ultrasound of the abdomen is generally performed in at least two image planes, transverse and longitudinal. It is not unusual for the sonographer to alter these imaging planes or change the patient position if adequate visualization is not obtained.

Transverse Plane
The transverse sectional images (Figures 1-4) are presented in descending order from the dome of the diaphragm to the umbilicus. The sonographer should review the relationship of each organ to it's neighboring structures as one proceeds in a caudal direction towards the umbilicus:

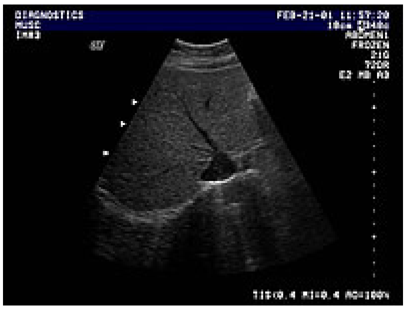

Figure 1: AC - Transverse image at the dome of the liver shows the middle hepatic vein draining into the inferior vena cava. The homogeneous liver texture is well seen.

Figure 2: AD - The right hepatic vein drains into the inferior vena cava; the liver parenchyma shows the portal and hepatic vascular structures within.

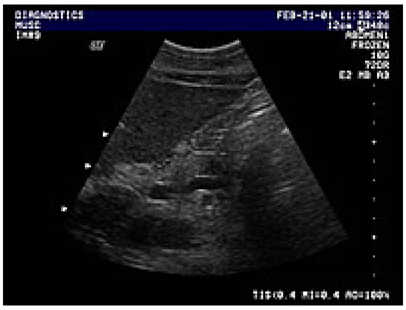

Figure 3: AI - Transverse image with the transducer angled inferior, using the left lobe of the liver as an acoustic window to image the pancreas and vascular structures.

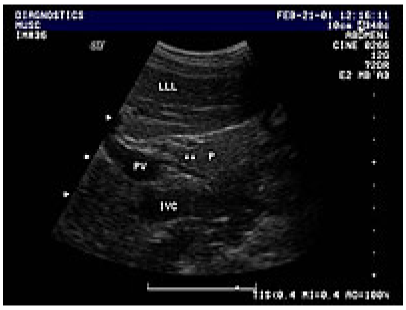

Figure 4: ACG - Transverse image of the pancreas and vascular structures.

Longitudinal Plane

The longitudinal sectional images (Figures 5-8) are presented from the midline of the abdomen to the right abdominal border. Images of the spleen and left kidney are made with the patient in a left lateral decubitus position.

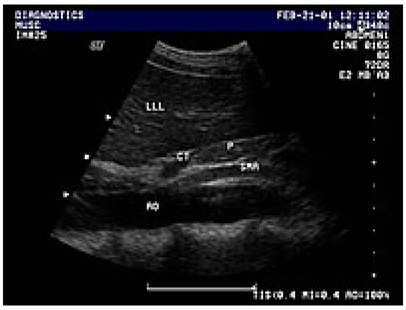

Figure 5: ABV - longitudinal image of the midline of the abdomen shows the aorta with the celiac axis and superior mesenteric artery arising from the anterior wall.

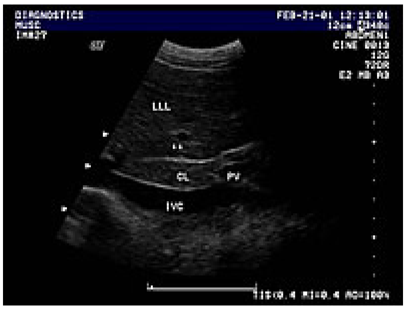

Figure 6: ABX - longitudinal image slightly to the right of midline shows the left lobe of the liver, ligamentum venosum, and caudate lobe of the liver anterior to the inferior vena cava.

Figure 7: ACA - longitudinal scan of the left lobe of the liver, with the middle hepatic vein draining into the inferior vena cava.

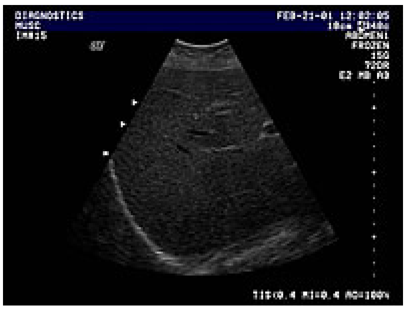

Figure 8: ABL - longitudinal scan over the right lobe of the liver. The diaphragm is shown to the left(towards the patient's head) of the liver.

Patient Care Protocols
It is the responsibility of the sonographer to ensure that patients are afforded the highest quality care possible during their ultrasound procedure. This entails identifying the patient properly, ensuring confidentiality of information and patient privacy, providing proper nursing care, and maintaining clean and sanitary equipment and examination rooms.

Basic Scanning Techniques & Patient Position

Scanning Techniques
Ultrasound can distinguish interfaces among soft tissue structures of different acoustic densities. The strength of the echoes reflected depends on the acoustic interface and the angle at which the sound beam strikes the interface. The sonographer must determine which "window" on the patient is the best to record optimal ultrasound images and which transducer will best fit into that window. The curved array transducer provides a large field of view, but may be difficult to scan between intercostal patient ribs in some examinations. The small-diameter sector transducer allows the sonographer to go in between intercostal spaces from a supine, coronal, decubitus, or upright position.

Criteria for an Adequate Scan
With the use of real time ultrasound, it is sometimes difficult to become oriented to all of the anatomic structures on a single frozen image; therefore it is critical to obtain as many anatomical landmarks as possible. With careful scanning technique and experience, the sonographer will be able to determine the appropriate transducer and instrumentation settings necessary to perform a high-quality ultrasound examination .

Avoiding rib interference is important to eliminate artifact "ring-down" reverberation that may destroy information. The small-diameter real time transducers allow the sonographer to scan in between the ribs but limit the near field visualization. Variations in the patient's respiration may also help eliminate rib interference and improve image quality.

Transverse Scans

1. The horseshoe-shaped contour of the vertebral column should be well delineated to ensure sound penetration through the abdomen without obstruction from bowel gas interference.
2. The aorta, celiac axis, superior mesenteric artery and vein, and inferior vena cava should be well seen anterior to the vertebral column as anechoic structures.
3. The posterior border of the liver should be imaged as the transducer is angled from the dome of the liver to its inferior edge. This ensures that time gain compensation (TGC) is set correctly (at the back edge of the liver). The overall gain should be adjusted to provide a smooth, homogeneous liver parenchyma throughout.

Longitudinal Scans

1. The transducer should be angled from the diaphragm to the inferior border of the right lobe of the liver. The diaphragm should be well defined as a linear bright line superior to the dome of the liver. The liver parenchyma should be homogeneous and uniform throughout. If the overall gain is at the maximum limit without good uniform penetration, a lower-frequency transducer should be used to provide increased sensitivity.
2. Vascular structures should be outlined with the patient in deep inspiration. This allows the inferior vena cava to dilate slightly and thus become easier to image.

Abdominal Doppler
Doppler ultrasound has been used for many decades to evaluate cardiovascular flow patterns. As in other areas of ultrasound, there have been many improvements in the technology, such as the development of pulsed-wave Doppler, spectral analysis of the returning wave form, and color-flow mapping. These advances in Doppler instrumentation, combined with high-resolution real time imaging of the vessels, have led to duplex scanning equipment, which integrates these modalities into a single probe.

Doppler is used to ascertain the presence or absence of flow. It can be used to differentiate vessels from nonvascular structures with confusingly similar images (e.g., common duct from hepatic artery, arterial aneurysm from a cyst). The documentation and direction of flow may also be of diagnostic value. Once the presence and direction of flow have been documented, spectral analysis of the flow gives further information on flow velocity and turbulence. Increased velocity and poststenotic turbulence may be seen in vascular stenoses. In postoperative patients, increased turbulence alone may be present at the site of a graft anastomosis with the native vessel. The evaluation of the shape of the wave form, with comparison of the systolic and diastolic components, may give information on increased vascular impedance, such as is seen in renal transplant rejection.

Doppler Scanning Techniques
The normal routine sagittal, transverse, coronal, and oblique scans of vascular structures are used to produce adequate images of vascular structures. Doppler techniques supplement the routine examination by permitting blood flow within those vessels to be detected and characterized. Flow toward the transducer is positive, or above the baseline, whereas flow away from the transducer is negative, or below the baseline. Arterial flow pulsates with the cardiac cycle and shows its maximal peak during the systolic part of the cycle. Venous flow shows no pulsatility and has lower flow than arterial structures.

As seen in echocardiology, many of the abdominal vessels have characteristic waveforms. If the sample volume can be directed parallel to the flow, quantification of peak gradients can be estimated. However, in the tortuous course of most vascular structures, this is very difficult.

Pulsed Doppler is the most common instrumentation used to evaluate abdominal flow patterns. This equipment uses a combined real time with pulsed or continuous-wave Doppler. The pulsed Doppler allows placement of the small sample volume within the vascular structure of interest by means of a trackball.

Aorta
The Doppler flow in the pulsatile aorta demonstrates arterial signals in the patent lumen. If the vessel were occluded, no arterial signals would be recorded.

Inferior Vena Cava
The Doppler waveform recorded in the inferior vena cava shows a lower flow than is found in arterial structures. The flow is increased in the presence of thrombus formation.

Portal Venous System

- Doppler flow patterns can be used to diagnose varices or collaterals in the portal venous system.
- Flow patterns can evaluate changes occurring in the course of portal hypertension.
- As liver function improves, normal hepatopetal flow is restored.
- If pressures worsen, there may be increased shunting away from the liver.
- If a shunt is present in the porta hepatis, Doppler may be useful to determine the patency of the shunt.

General Scanning Guidelines
The baseline upper abdominal ultrasound examination includes a survey of the liver and porta hepatis, vascular structures, biliary system, pancreas, kidneys, spleen, and paraaortic area. If variations in anatomy or pathology are seen, multiple views are obtained over the area of interest.

Images and observations should include the following:

- The echogenicity of the liver parenchyma should be compared with that of the renal parenchyma. The liver should be homogeneous and show more echoes than the renal parenchyma.
- The hepatic veins, inferior vena cava, main portal vein with right and left portal branches should be imaged.
- The ligamentum teres should be identified in the left lobe of the liver as a bright "triangular" shaped echo focus.
- The dome of the right lobe of the liver at the level of the hepatic veins should be surveyed with the patient in deep inspiration.
- The right hemidiaphragm and right pleural gutter should be evaluated for fluid or abscess collection.
- The main lobar fissure, as it projects from the right portal vein to the neck of the gallbladder, should be imaged as a bright linear structure on the sagittal scan.
- Document liver size in a midclavicular parasagittal scan demonstrating the diaphragm and tip of the right lobe of the liver. Measure from the dome of the diaphragm to the tip of the right lobe of the liver.
- Document the size and location of any demonstrated mass.
- Evaluate and document the presence of ascites (include the four quadrants of the abdomen).

Doppler of the vascular structures in the liver if pathology is present:

- Assess the patency and direction of flow of the main, right, and left portal veins.
- Assess the patency of the right, middle, and left hepatic veins.
- Assess the patency of the hepatic artery in hepatic transplant patients.
- Assess the patency of the umbilical vein (recanalized umbilical vein).
- Assess the patency of surgically or angiographically placed shunts.
- Perform pulsed Doppler analysis of the hepatic artery with resistance measurements.

General Abdominal Ultrasound Protocol

Abdominal Protocol

PANCREAS	Trv.	Head/ IVC/ SMV Body and Tail/ SMV/ SMA	**GALLBLADDER SUPINE AND LLD**	Sag.	Body/Fundus Body/Neck
	Sag.	Head/ Portal Vein/ IVC Body and Tail/ Aorta		Trv.	Body (**measure wall**) Body/ Neck
AORTA	Sag.	Prox., Mid, and Distal	**CBD**	Trv.	Portal Triad
	Trv.	High, Mid, Low		Sag.	**Measure duct**
LIVER	Trv.	Rt. Lobe/Lung Rt. Lobe/ (dome) Hepatic Veins Lt. Lobe/Lt. Portal Vein Lt.Lobe/ Caudate Lobe Rt. Lobe/ Portal Veins (main, rt.) Rt. Lobe/ GB/ Kidney	**KIDNEYS**	Trv.	Upper pole Mid pole (at pelvis) Lower pole
	Sag.	Lt. Lobe/ Aorta Lt. Lobe/ Caudate Lobe/ IVC Rt. Lobe/ Dome (diaphr.) Rt. Lobe/ Lung Rt. Lobe/ Portal Vein Rt. Lobe/ Kidney (**measure Rt. lobe**)		Sag.	Mid (**measure length**) Lateral Medial
			SPLEEN	Sag.	Spleen/ LK (**measure length**)
				Trv.	Splenic hilum

Documentation

Labeling
Real time scans are labeled as transverse or longitudinal for a specific organ, such as the liver, gallbladder, pancreas, spleen, or uterus. The smaller organs that can be imaged on a single plane, such as the kidney, are labeled as long-midline, -lateral, or -medial; whereas the transverse scans are labeled as transverse-low, -mid, and -high.

All transverse supine scans are oriented with the liver on the left of the screen; this means you would be viewing the body from the feet up to the head ("optimistic view"). Longitudinal scans present the patient's head to the left and feet to the right of the screen and use the xyphoid, umbilicus, or symphysis to denote the midline of the scan plane.

All scans should be appropriately labeled for future reference. This includes the patient's name, date, and anatomic position. Body position markers are available on many ultrasound machines and may be utilized in the place of written labels.

Conclusion

Correlation of ultrasound images with sectional anatomy is a critical talent that must be mastered by every sonographer in order to produce consistent, quality images. The abdominal protocol presented is a generic one that may be adapted to your particular lab situation. Careful manipulation of the instrumentation and recognition of adequate scanning windows will allow the sonographer to obtain quality images for interpretation.

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