Ultrasound scanning techniques

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ABSTRACT

Background: Ultrasound is an essential tool for the hepatobiliary and pancreatic surgeon.
Methods: This review focuses on transabdominal, open intraoperative, and laparoscopic ultrasonography of the liver, biliary tract, and pancreas. The goal is to obtain optimal ultrasound images through an understanding of the equipment setup, transducer (probe) selection, terminology, and general scanning principles. Outlined is a structured, standardized approach necessary to obtain complete information when doing intraoperative ultrasound. When done by the surgeon, the goal of the examination typically is to answer a question or questions through a focused rather than a comprehensive diagnostic examination. Finally, presented are the details of techniques specific to scanning each of the major organs.
Results: A structured, standardized ultrasound scanning approach provides for optimal image acquisition. It allows one to develop standardized views of common structures resulting in “pattern recognition,” making learning and interpreting images easier. A standardized approach ensures a complete ultrasound examination, and it minimizes the chance of missed findings.
Summary: The general principles for transabdominal, open intraoperative, and laparoscopic ultrasonography scanning are similar. One can gather considerable information using these modalities during a clinical examination, procedure, or operation. For success, it is critical to develop a standardized approach to scanning and use it every time. This facilitates familiarity when viewing images, making it easier for the novice to learn and gain experience. Using a systematic approach ensures that the experienced ultrasonographer obtains all the essential information needed at the time of surgery.

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This review focuses on transabdominal (TAUS), open intraoperative (IOUS), and laparoscopic (LUS) ultrasonography of the liver, biliary tract, and pancreas. When done by the surgeon, the goal of the examination typically is to answer a question or questions through a focused rather than a comprehensive diagnostic examination.

The goal is to obtain optimal ultrasound images through an understanding of the equipment setup, transducer (probe) selection, terminology, and general scanning principles. Finally, presented are the details of techniques specific to scanning each of the major organs.

GENERAL PRINCIPLES—EQUIPMENT SETUP, TERMINOLOGY, AND TRANSDUCER SELECTION AND USE

Equipment Setup. The equipment is set up based on the scan type, organ of interest, and the operator’s position relative to the patient.

Typically, one performs TAUS from the supine patient’s right side. Positioning the ultrasound machine to the right of the patient’s head is optimal to allow simultaneous scanning, use of the machine, and image viewing. Position the bed height to allow for comfortable scanning, either in a sitting or standing position.

For intraoperative scanning, ultrasound machine placement can be on either side of the bed depending on who will be doing the scanning and user preference. Now that most operating rooms have the ability to display images on remote monitors and modern ultrasound machines have standard presets, the circulator or surgeon (using a sterile drape over the machine controls) can change image settings or capture images. When performing LUS, the picture-in-picture feature is very helpful for matching external anatomic features with the corresponding ultrasound images.

Terminology and Image Display. To ensure a common standard that allows for unambiguous image interpretation, ultrasonographers use...
conventional terminology and display protocols for displaying static images. The two primary imaging planes are longitudinal and transverse (Fig 1). When doing TAUS, the longitudinal plane is the long axis of the body, whereas it is the long axis of the organ when doing IOUS or LUS. The longitudinal plane includes 2 views. The sagittal view, where the transducer is oriented anterior to posterior (perpendicular to the floor), and the coronal view, when the transducer is oriented side-to-side (parallel to the floor). A cross-sectional image is seen in the transverse plane, similar to the standard axial image seen on computed tomography (CT).

To communicate clearly what an ultrasound image represents, one uses standardized display protocols. In longitudinal scanning, the patient’s head is oriented to the left side of the display screen. For transverse scanning, the image is oriented such that the left side of the display screen corresponds to the right side of the patient (Fig 2). Importantly, then, when starting a new scan, be certain to ensure alignment between the transducer and monitor image. Equally important is annotation at the beginning of the study to include the patient’s name, medical record number, and date of the examination. During image acquisition, annotation of the image plane and anatomic features is essential.

Image acquisition consists of several important steps to obtain interpretable images: coupling, transducer selection, placement, and manipulation.

### Coupling and the Acoustic Interface

Adequate image acquisition requires sound wave transmission between the transducer and the object of interest. To acquire an image, one places the transducer in contact with a surface, a process called coupling. This creates an acoustic interface at the site of coupling. Coupling causes air (an inefficient sound transmitter) displacement from the interface between the transducer and the imaged object resulting in efficient sound transmission. Gel is the most common coupling agent used for TAUS (Fig 3); saline placed on the surface of the organ provides a good interface for IOUS and LUS.

The thickness of the acoustic interface alters the ultrasound image. Changing the thickness of the interface moves the transducer closer or farther from the object, improving its definition. The relationship of the transducer to the structure of interest defines contact or standoff techniques for scanning (Table 1). Contact or standoff scanning has specific advantages as outlined subsequently. Use of these different techniques is important. For instance, a probe standoff technique is important when objects are in the near field (close to the transducer), as they cannot be seen when too close to the transducer or the image suffers from low resolution.
Transducer Selection. Scanning circumstances dictate the appropriate transducer selection. For TAUS, transducers with curvilinear (convex) arrays are most common, giving a “pie”-shaped or triangular-appearing image. This results in a larger viewing area. The typical TAUS frequency is low, in the 3–3.5 MHz range. Obese patients may require a 2.5-MHz transducer, thin patients a 5-MHz one. The lower frequency results in a greater depth of imaging, allowing organ viewing through the body wall in obese patients.

IOUS transducers come in a variety of sizes, shapes, and array types. The most common are side-viewing linear and curvilinear arrays. On occasion, a front viewing transducer is useful. Unlike the curvilinear array, a linear array has a rectangular image. The linear image has more of a one-to-one correlation with the object of interest, making it easier when targeting lesions for biopsy or intervention. IOUS uses a higher frequency, 5–10 MHz, giving very high definition images and the ability to detect very small lesions.

Like IOUS, LUS uses similar high frequencies. Although they also come in a variety of configurations, the most common is a flexible shaft with a transducer placed as a side-viewing linear or curvilinear array. This allows for rapid scanning in a variety of planes and requires a minimal number of ports to complete the examination.

Transducer Placement. Surgeons’ understanding of three-dimensional anatomy makes ultrasound image recognition much easier. Understanding an organ’s external and internal anatomy allows for rapid pattern recognition of the ultrasound images, allowing identification of organs and structures based on experience. Finding the correct acoustic window through appropriate transducer placement allows examination and recognition of the relevant structures. Hence, the surgeon’s detailed anatomical knowledge makes learning correct transducer placement easier.

The following sections detail transducer placement with the scan type determining the transducer type and its use. A complete scan includes images in 2 planes, longitudinal and transverse, to ensure that a finding is not due to artifact. This accounts for the importance of transducer placement and movement during image acquisition. Finally, the technique of transducer and tissue coupling can affect the image and necessitate a change based on whether the imaged structure is clear.

Coupling the transducer by applying it directly to the object for imaging constitutes contact scanning (Table 1). Contact scanning varies from light contact to deep compression, depending on the goal of the scan. Most TAUS examinations use light, direct contact scanning. At times, to achieve a more favorable acoustic window, deep compression will displace bowel or other organs to allow a better view of the structure of interest. Images acquired when the transducer is not in direct contact with the tissue represent probe (transducer) standoff scanning. This technique has several advantages illustrated in Table 2. A fluid interface placed between the transducer and tissue allows the probe to “standoff” the surface of the tissue while achieving effective

![Fig 3. Transabdominal ultrasound. A, The transducer is placed on the skin without coupling gel. No discernible structures can be seen without an acoustic interface. B, Gel is placed on the transducer and used to “couple” the transducer to the skin. This provides an acoustic interface that permits sound wave transmission and consequently an image. Seen in this image are the body wall (black bracket), the liver, and the left portal vein (white arrow). Figure reprinted with permission [1].](image-url)
Acoustic coupling. Placing a fluid-filled glove between the probe and the tissue’s surface moves the probe 1–2 cm away from the surface, giving better definition when scanning superficial objects. Probe standoff scanning is frequent in IOUS and LUS by using a saline-filled glove placed between the transducer and organ or by filling the abdomen with saline and scanning through the fluid.

**Table 2**  
Probe standoff scanning advantages

- Places the object of interest into the focal zone
- Eliminates artifacts due to an irregular scanning surface
- Objects within 1–1.5 cm of the scanning surface can be seen
- Superficial objects are seen with high resolution
- Lack of tissue compression eliminates distortion of underlying structures
- Provides more angles of freedom for scanning maneuvers

**Table 3**  
Transducer movements

| Sliding | transducer remains in contact with scanning surface, while sliding it in a longitudinal or transverse plane |
| Rotating | transducer is spun clockwise or counterclockwise; central portion remains fixed to starting site |
| Rocking | transducer is moved (rocked) parallel to the scanning plane |
| Tilting | transducer is moved perpendicular to the scanning plane |

**Transducer Manipulation.** Following transducer selection and the appropriate type of probe contact, the next step is mastering transducer movements as shown in **Table 3**. It is critical to master these skills to obtain optimal ultrasound images. A common error early in the learning process is moving the transducer too much. Because most transducers have a wide viewing area, a few millimeters of probe movement will cause significant changes in the image. A similar situation occurs when lifting the transducer to move it; the familiar image is lost following uncoupling. In both instances, the novice loses the familiar patterns of a recognized structure, requiring them to restart the process to identify a recognizable structure or pattern. Uncoupling the transducer to move it removes one of the unique and important features of ultrasound, which is real-time image acquisition and viewing. Using the four basic transducer movements shown in **Fig 4** will eliminate these errors.

“Sliding” the probe in relationship to the tissue surface obviates the need to lift it from the organ’s surface. As the probe slides across the skin or organ, it acquires a series of parallel images in the same scanning plane. Rotating, rocking, or tilting the probe in relationship to a structure of interest further defines it. Rotation involves spinning the probe as if the central part of the transducer is stuck to the tissue. This allows continual acquisition of images through the longitudinal, oblique, and transverse planes, building a 3-dimensional view of the structure. Moving the transducer parallel to the original plane of imaging defines “rocking.” Tilting involves moving the probe perpendicular to the original scanning plane.

![Fig 4. Transducer movements. A, Sliding. The transducer is moved without picking it up off the abdominal wall. B, Rotating. The transducer is rotated clockwise or counterclockwise as if it were “pinned” to a central axis. C, Rocking. The transducer remains in the same position relative to the skin while moving the back of the probe forward or backward in relationship to its long axis. This results in a series of images parallel to the scanning plane. D, Tilting. The transducer remains in the same position relative to the skin while moving the back of the probe side-to-side relative to the long axis of the probe. The results in a series of images perpendicular to the scanning plane. Figure reprinted with permission [1].](image-url)
Using small probe movements with these maneuvers allows scanning of large areas with minimal transducer movement in relationship to its site of contact with the tissue. This permits detailed images of a structure(s) without getting lost during the scanning process. Using these techniques to obtain views in at least 2 dimensions ensures the viewed object is not an artifact. Multiple scanning planes allow one to develop a 3-dimensional understanding of the structure or organ.

Putting all the elements of an effective scan together is critical to develop a systematic scanning approach for each type of scan you do and for each organ. Fastidious adherence to a systematic scanning approach ensures a complete ultrasound examination every time.

**TRANSABDOMINAL ULTRASOUND**

Surgeon-performed TAUS typically seeks specific information for diagnostic or therapeutic reasons. It, therefore, is a focused examination and does not substitute for a standard complete diagnostic ultrasound or other imaging study. Rather, it is complimentary to these more complete studies.

The patient begins a TAUS examination in the supine position, often with the right arm positioned over the head. A 6-hour fast prior to the examination is ideal as it decreases bowel gas and allows the gallbladder to distend. While positioned on the patient’s right side, the examiner most commonly uses a 3.5-MHz curvilinear transducer. TAUS uses all the previously described standard scanning planes: longitudinal (sagittal, coronal) and transverse. Light contact scanning with the abdominal wall using a gel to couple the transducer with the skin is the most common approach. While scanning, place the base of the hypothenar eminence against the body wall to stabilize your hand and prevent fatigue (Fig 5). This facilitates small, fine transducer movements while scanning. The initial transducer placement and orientation vary based on the type of study or organ of interest.

**Liver Scanning Technique.** Transducers using frequencies in the 3.0–3.5-MHz range are ideal for evaluating the liver in most patients. Obese patients or those with steatosis may be imaged better using a 2.5-MHz probe, whereas a higher frequency, 5 MHz for instance, may be better in thin patients. An important theme here, as in all scanning, is to develop a systematic approach to scanning; using the same approach every time ensures that nothing is forgotten or missed. Start liver imaging by placing the probe transversely in the subxiphoid position. Identify the hepatic veins and their junction with the vena cava. This is a very constant landmark and is easily recognized, thus helping orient the examiner (Fig 6). If a steep, angulated costal margin obscures this view, have the patient take a half to whole breath and hold it. This pushes the liver inferiorly, bringing the superior liver into view. Identifying the hepatic vein/inferior vena cava (IVC) junction begins the systematic approach (Table 4) that allows complete visualization of the segmental hepatic anatomy. One can see the majority of the liver through rocking and tilting the probe while in the subxiphoid window (Fig 7), minimizing the need to move the probe and limiting movement to small increments. Next, slide the probe toward the left and then the right to provide views of the remaining left and right hemi-liver, respectively. Following acquisition of the transverse views, reorient the probe in a sagittal plane and repeat the process. If you cannot obtain adequate images in patients with steeply angled costal margins through the maneuvers outlined previously, use an intercostal window, scanning between ribs, to access structures lying beneath the ribs. This may require a smaller footprint probe. Scanning from an anterior and lateral approach is helpful.
The setup, transducer, and techniques are similar to liver scanning. With the patient supine, place the transducer in a right subcostal, sagittal plane in the mid-axillary line and locate the gallbladder. Slight sliding and tilting at this site permit a long-axis view of the gallbladder (Fig 8). Rotating the probe then gives transverse and oblique views of the gallbladder. Using standard views following identification of the gallbladder allows complete biliary scanning (Fig 9). To achieve complete biliary imaging, it may be necessary to use intercostal windows. To distinguish the nature of a gallbladder mass, move the patient from the supine position to the left lateral decubitus position. Stones typically move with repositioning, whereas polyps remain stationary. The left lateral position also may facilitate viewing the extrahepatic biliary ducts.

The extrahepatic bile duct lies anterior to the portal vein, facilitating its identification on ultrasound. To view the duct, obtain a longitudinal view of the portal vein by placing a transducer perpendicular to, and just beneath, the right costal margin midway between the mid-axillary line and the epigastrium (Fig 9, B); this allows identification of the portal vein at the hilar plate. Move the probe caudally to obtain a longitudinal view of the bile duct anterior to the portal vein (Fig 10). Follow the duct distally by sliding the probe toward the midline while maintaining a longitudinal or oblique orientation.

| Table 4 |
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| **Stepwise approach to liver scanning—transabdominal.** |
| **Identify hepatic veins** |
| • Find junction with vena cava |
| • Follow to terminal branches |
| • Identify any anomalous branches |
| • Follow vena cava from hepatic vein branches to inferior liver |
| **Identify portal branches** |
| • Find bifurcation, main, right, left portal veins |
| • Follow right and left veins to their segmental branches |
| **Systemic parenchymal scan** |
| • Develop a standard scanning approach |
| • Examine all the parenchyma |
| • Note lesion location, size, and features |
| • Identify any vasculobiliary involvement or thrombosis |

**Biliary Scanning Technique.** The setup, transducer, and techniques are similar to liver scanning. With the patient supine, place the transducer in a right subcostal, sagittal plane in the mid-axillary line and locate the gallbladder. Slight sliding and tilting at this site permit a long-axis view of the gallbladder (Fig 8). Rotating the probe then gives transverse and oblique views of the gallbladder. Using standard views following identification of the gallbladder allows complete biliary scanning (Fig 9). To achieve complete biliary imaging, it may be necessary to use intercostal windows. To distinguish the nature of a gallbladder mass, move the patient from the supine position to the left lateral decubitus position. Stones typically move with repositioning, whereas polyps remain stationary. The left lateral position also may facilitate viewing the extrahepatic biliary ducts.

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**Fig 7.** Transabdominal ultrasound with the transducer placed transversely in the subxiphoid position. Rocking (A) and tilting (B) the probe in this single position allows one to image a large portion of the liver with relatively little probe movement relative to the body wall. Figure reprinted with permission [1].

**Fig 8.** Gallbladder imaging. A, The transducer is oriented in the sagittal plane in the mid-axillary line. B, This allows a longitudinal view of the gallbladder (GB). IVC. Figure reprinted with permission [1].
If unseen from the supine position, place the patient in the left lateral decubitus position. Reposition the probe to a subcostal, mid-axillary position, with longitudinal orientation. Bowel gas in the duodenum frequently obscures the retroduodenal duct. Similarly, the intrapancreatic duct can be difficult to see.

Imaging through the pancreatic head allows transverse views of the duct. Small, nondilated intrahepatic ducts can be hard to see. Viewing the right lobe through an intercostal window may allow better imaging of these ducts, whereas optimal viewing of the left ducts is from a subxiphoid/left subcostal window (Fig 9, D).
Pancreas Scanning Techniques. Thin patients without overlying bowel gas allow excellent TAUS imaging of the pancreas. If the patient is obese or has overlying gas, pancreatic imaging is challenging. Again, the setup, transducers, and techniques are similar to those described for the liver and biliary tract. Fasting is essential to minimize bowel gas. If overlying gas impedes the acoustic window, several techniques may improve the view. Deep pressure compression scanning can push gas-filled structures aside, giving a better acoustic window. Holding a deep breath pushes the liver below the costal margin, allowing imaging through the liver as an acoustic window to the pancreas. Having the patient drink 500 mL of water and imaging them in a semi-upright position can improve the window by imaging through the fluid-filled stomach. Placing the patient in the right lateral decubitus position may improve the image. Viewing the pancreatic tail often is best from a left lateral flank view using the spleen as the acoustic window.

The pancreas is difficult to discern from similar-appearing surrounding soft tissues. Using adjacent anatomic landmarks as guides helps identify the pancreas. Place the transducer transversely in the subxiphoid, midline position. First, identify the vertebral body, aorta, vena cava, and the splenic vein junction with the superior mesenteric vein. These structures allow one to identify the pancreas based on its relationship to these structures. Figure 11 shows the prototypical image used to identify the pancreas. Viewing the remaining gland in 2 planes is easier after identifying the neck and body based on recognizing the adjacent structures.

Liver Scanning Technique. Using a linear array transducer in a flat, side-viewing probe gives a long rectangular image (footprint) as illustrated in Fig 12. This allows fast, efficient imaging. Linear array images make interventions such as a needle biopsy or ablation comparatively easier than procedures using curvilinear array views. The low-profile flat probe fits better in limited working spaces between the liver, abdominal wall, and diaphragm compared to higher-profile probes. Scanning in the 7.5-MHz range works well for most liver IOUS, penetrating sufficiently to view the whole organ while giving excellent detail of small intrahepatic structures. When imaging a steatotic or cirrhotic liver, a 5-MHz probe may be necessary to obtain images through the whole organ.

Developing a systematic approach to scanning the liver, analogous to TAUS, is critical to ensure complete and successful IOUS. Strict adherence to a systematic approach will result in a thorough evaluation every time. Identifying intrahepatic vasculature is the first step in liver scanning. This allows segmental anatomy identification and mapping of each segment. Once done, find known and occult lesions. Document their location and relationship to the segmental anatomy and intrahepatic structures.

Begin with contact scanning using saline to moisten the liver, creating an acoustic interface to allow sufficient coupling (Fig 13, A). Knowing the

**Fig 10.** Transabdominal ultrasound of the extrahepatic bile duct. The probe is positioned in the sagittal plane. The bile duct (white arrow) lies anterior to the portal vein (PV). Color Doppler is helpful to distinguish vascular structures from the bile duct. Figure reprinted with permission [1].

**Fig 11.** Transabdominal ultrasound of the pancreas. The transducer is placed in the transverse plane in the midline just inferior to the xiphoid. This is the prototypical image of the vasculature surrounding the pancreas that facilitates its identification. The anterior border of the pancreas is denoted by the white arrows. The pancreas lies just anterior to the superior mesenteric vein (SMV) and the splenic vein (white line). Other vascular structures that comprise this prototypical image include the aorta (Ao), the IVC, and the superior mesenteric artery (*). The left renal vein (LRV) also can be seen. Figure reprinted with permission [1].

**Fig 12.** A, Intraoperative linear array transducer. This probe has a relatively large “footprint” due to its long crystal array (white arrow). B, This results in a long, rectangular image. Figure reprinted with permission [1].

**OPEN INTRAOPERATIVE ULTRASOUND**

Intraoperative ultrasound is an essential and critical tool for abdominal surgery, particularly for evaluation and management of hepatic, biliary, and pancreatic diseases. IOUS offers real-time imaging in the operating room. It is easily repeatable throughout a procedure, offering ongoing information to guide the operation.

The target organ and procedure needs determine transducer and frequency selection. A sterile transducer requires no cover, allowing direct scanning without need for an acoustic interface. A nonsterile transducer requires a sterile cover with gel placed inside the probe cover. This provides an acoustic interface and ensures adequate coupling. Scanning techniques and probe movement are similar to those used for TAUS. IOUS scanning planes differ from TAUS. They are in relationship to the examined organ rather than the axis of the body, thus differing in some instances to conventional TAUS planes.
probe’s exact location on the liver facilitates IOUS image interpretation by correlating its position to underlying intrahepatic structures. Although contact scanning is most useful for the majority of the liver, structures within 5–10 mm of the scanning surface fall in a “blind spot” due to their proximity to the probe (Fig 14). Similarly, when scanning an irregular surface such as a cirrhotic liver, images can be incomplete or poor due to inadequate coupling to the rough surface of the organ. A probe standoff technique circumvents these issues (Fig 13, B and C). For better clarity and resolution of superficial objects, use saline as an acoustic window in a probe standoff technique by separating the probe and liver surface. Several probe standoff techniques work well. Difficulty imaging superficial objects also reinforces the essential role of liver inspection and palpation as complementary techniques to IOUS for complete liver evaluation.

A 3-dimensional image of intrahepatic structures is generated by scanning first in the transverse plane followed by longitudinal and oblique views (Fig 15). Multiplanar views are critical when examining structures or lesions to confirm that they are not artifacts. A rapid way to achieve this is probe rotation over a fixed point, giving a quick multiplanar image of an object (Fig 16). Rocking or tilting gives a wider field of view, alleviating the need to slide the transducer in relationship to the contact point (Fig 17). Probe movement in this fashion maps an object and its relationship to structures in close proximity. Probe standoff using saline immersion combined with rocking and tilting provides excellent imaging of the superior hepatic segments (Fig 18).

Table 5 shows the steps for a systematic approach to liver scanning. Begin scanning before mobilizing the liver. Scanning before mobilization avoids the introduction of artifacts, such as air, which can obscure the field of vision. Following liver mobilization, repeat a complete scan. The initial goal of systematic liver IOUS is identifying and defining the hepatic vasculature. This allows definition of segmental anatomy. Once defined, interrogate each segment to identify any lesions and/or develop a treatment plan.

Prior to liver mobilization, begin the examination as follows:

1) Identify intrahepatic vascular anatomy. Identify and map the hepatic veins and portal pedicles first, as they define the segmental hepatic anatomy. The segments define the surgical anatomy of the liver.

a) Identify the junction of the major hepatic veins with the vena cava. Place the probe at the superior border of the liver to find this

Fig 13. Probe placement for intraoperative ultrasonography. A, Contact scanning places the transducer directly in contact with the organ’s surface. B, Probe standoff scanning using a saline-filled glove. C, Probe standoff scanning using saline (gray area) immersion. Probe standoff techniques hold the transducer away from the organ surface to allow imaging of superficial structures. Figure reprinted with permission [1].

Fig 14. Intraoperative imaging of a superficial liver mass (white arrow). A, Contact scanning. B, Probe standoff scanning using saline immersion allows a view of the entire mass, which cannot be seen in the contact scanning view. The saline provides the acoustic window (aw) for adequate viewing. Figure reprinted with permission [1].
junction. Follow each hepatic vein peripherally to its terminal branches. The hepatic veins define the sectors of the liver as they course between them. Identify anomalous hepatic veins. Evaluate for tumor involvement of the veins.

b) At the inferior edge of the liver, identify the distal main portal vein and follow it superiorly to its bifurcation into the right and left portal branches. Follow each to their terminal branches. Identify vascular or biliary involvement by tumor.

Fig 15. Standard intraoperative transducer positions for liver scanning. A, Transverse. B, Longitudinal. C, Oblique. Figure reprinted with permission [1].

Fig 16. Rotational transducer movement. The probe is rotated clockwise or counterclockwise on a fixed point. This allows examination of a structure or mass in two planes. Figure reprinted with permission [1].
2) Scan the entire liver parenchyma. By mapping the hepatic and portal veins, one defines the segmental anatomy. Use a systematic approach to identify known tumors and note any occult lesions. Multiplanar scanning from various directions, including the inferior and posterior liver surfaces, allows full evaluation of each segment and any lesions within them.

Fig 17. Rocking/tilting transducer movement. The probe is “rocked” or “tilted” at a fixed point on the organ’s surface. This allows examination of a wide area surrounding a structure of interest and prevents the examiner from “getting lost” by moving the probe too much. Figure reprinted with permission [1].

Fig 18. Rocking/tilting combined with saline immersion. This technique allows an excellent view of the superior surface of the liver and its associated structures. A, Contact scanning along the superior liver gives a view of the central liver and portions of the hepatic veins (MHV, middle hepatic vein; RHV, right hepatic vein). However, imaging the junction of the hepatic veins with the IVC can be difficult with contact scanning. B, Probe standoff using saline immersion combined with rocking the transducer allows the crystal to be positioned in a way that allows imaging of the junction between the hepatic veins and the IVC. Figure reprinted with permission [1].
Establish the relationship between any lesions or anomalies and the hepatic vasculature. Construct a 3-dimensional model through multiplanar scanning. This delineates the precise segmental location of detected lesions and their relationships to intrahepatic structures.

For procedures requiring liver mobilization, repeat the examination following mobilization and focus on the following:

1) Repeat a systematic scan with added focus on segment 7 (posterosuperior segment). Deeper areas not adequately seen on initial scanning may be more accessible following mobilization. Scanning from the posterior and inferior surfaces helps view hard to access areas.

2) Use multiplanar views and different probe locations to confirm the spatial relationship between any lesions of interest, the anatomic segments they reside in, and adjacent vascular structures. It is critical to view and understand the 3-dimensional images of these relationships. This helps one understand how the anatomic relationships may appear different by IOUS when the liver’s position is changed during resection or other interventions.

Begin liver IOUS by finding the junction of the 3 hepatic veins with the vena cava at the superior-most portion of the liver [Fig 19]. Use

| Table 5 |
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| Stepwise approach to liver scanning—intraoperative |

Scan liver

- Before mobilization
- Repeat scan after liver mobilization
- Contact scanning
- Saline immersion probe standoff as necessary
- Scan from inferior and posterior surfaces as necessary

Identify hepatic veins
- Find junction with vena cava
- Follow to terminal branches
- Identify anomalous branches
- Follow vena cava from hepatic vein branches to inferior liver

Identify portal branches
- Find bifurcation, main, right, left portal veins
- Follow right and left veins to their segmental branches

Systemic parenchymal scan
- Develop a standard scanning approach
- Examine all the parenchyma
- Note lesion location, size, and features
- Identify any vasculobiliary involvement or thrombosis

Fig 19. Intraoperative ultrasound, transverse plane. This is the prototypical image seen at the superior border of the liver. The middle (MHV) and left (LHV) hepatic veins usually join to form a common trunk prior to joining the IVC. This has the appearance of “rabbit ears” and is a standard image that is helpful for orienting oneself during liver ultrasound. The right hepatic vein (RHV) is usually seen joining the vena cava in the same image. Figure reprinted with permission [1].

Fig 20. Intraoperative ultrasound, longitudinal (sagittal) plane. The IVC can be followed along its entire course in this plane. The middle hepatic vein (white arrow) is seen joining the vena cava. Figure reprinted with permission [1].

Fig 21. Intraoperative ultrasound, transverse plane. View of the hepatic hilum through the anterior liver shows the main (MPV) portal vein as it branches into the right (RPV) and left (LPV) portal veins. Figure reprinted with permission [1].
contact scanning on the anterior liver surface by placing the probe transversely over the upper portion of the falciform ligament. Through experience, one learns to obtain archetypal images that result in “pattern recognition” of common features that will help identify intrahepatic structures. Learning these patterns makes scanning easier and more efficient and prevents getting lost when manipulating the probe. The junction of the hepatic veins with the vena cava gives the first prototypical image of “rabbit ears.” This is a relatively consistent imaging feature. Finding it is straightforward and helps one get oriented at the beginning of the scan. Once obtained, map each hepatic vein by following it peripherally to its terminus. Use light contact scanning as deeper compression can cause collapse of the hepatic vein, rendering it less visible. Rotate the probe and reevaluate each vein in the longitudinal (sagittal) plane. The retrohepatic vena cava can be examined similarly along its full length (Fig 20).

Transverse contact scanning at the inferior border of the liver to the patient’s right of the falciform ligament provides the typical view of the hepatic hilum (Fig 21). Identification of the termination of the main portal vein leads to the portal bifurcation; following it to the patient’s right shows the right portal vein. Following this more peripherally, it divides into the anterior (segments 5 and 8) and posterior (segments 6 and 7) sectorial branches (Fig 22). By defining the sectorial branches and following each peripherally, one can view their respective superior and inferior segmental branches. This method completely maps the entire inflow to the right lobe of the liver. Next, map the left portal vein. Return to the portal bifurcation view while maintaining a transverse scanning plane. Follow the transverse portion of the left portal vein to the base of the umbilical fissure. Here, the left portal vein courses anteriorly and inferiorly in the umbilical fissure. The image at this location gives another prototypical image as the left portal vein has the appearance of a tree trunk with branches coming off to its left and right (Fig 23). Branches coursing to the right of the patient’s umbilical fissure supply the medial segment of the left lobe (segment 4). Those to the left of the fissure go to the lateral portion of the anterior (inferior) segment of the left lobe (segment 3) and the posterior (superior) segment of the left lobe (segment 2), which is posterior–superior to the left hepatic vein.

Completing these scanning sequences fully delineates the segmental anatomy of the liver and the intrahepatic vasculature. Next, perform a systematic survey of the parenchyma to assess for diffuse and focal abnormalities, particularly mass lesions. Find preoperatively known hepatic masses; identify any new, occult lesions; and document the specific location of each and their proximity to any intrahepatic structures. Do contact scanning from both the anterior and diaphragmatic surfaces for a full assessment. Once you develop a systematic approach, use it for every procedure. This ensures scanning of all segments and minimizes missed findings. Finish the survey by scanning in the longitudinal and, if needed, oblique planes. Alternative approaches such as probe standoff or scanning from the posterior surface are helpful for complete viewing of segment 7. Finally, segment 1 direct contact scanning may provide the best images of this parenchyma.

Strictly adhering to the described systematic approach for liver scanning will minimize missed findings and allow achievement of the goals outlined earlier. These approach and techniques coupled with a detailed knowledge of intrahepatic anatomy allow the precise localization of any structure or mass within the liver. This enables intraoperative diagnosis of hepatic pathology and decision-making as to the optimal therapeutic approach.
Biliary Scanning Technique. A 2-probe approach provides optimal biliary scanning. Begin with the same linear array transducer used for liver imaging. Contact scanning on the anterior liver surface gives excellent images of the gallbladder. Scanning through the inferior liver edge as an acoustic window also gives good views of the extrahepatic bile ducts (Fig 24). Probe standoff scanning allows direct scanning through the free (peritoneal) gallbladder wall. Filling the subhepatic space with saline provides the acoustic interface needed to accomplish this approach. Scan the gallbladder through the anterior liver to start (Fig 25, A). Slide the probe inferiorly to the edge of the liver to image the hilar structures at the hepatic plate (Fig 25, B). Moving the probe more inferiorly provides transverse (cross-sectional) images of the hepatoduodenal ligament (Fig 25, C).

Changing to a different, higher (>7.5 MHz)-frequency end-viewing probe provides images with greater resolution of the extrahepatic bile ducts. Table 6 shows a standardized technique for this approach. Start scanning before doing any dissection of the gallbladder or hepatoduodenal ligament; this avoids artifacts introduced during dissection. Similarly, perform imaging prior to cholangiography. Early on in one’s experience, do IOUS first followed by cholangiography. Correlation of the findings between the two will accelerate learning of biliary IOUS and image interpretation.

Contact scanning directly on the hepatoduodenal ligament may give adequate images if sufficient tissue surrounds the duct. Even if this is the case, a probe standoff technique typically provides better images (Fig 26). The most useful view of the bile duct is longitudinal...
Table 6
Stepwise approach to biliary scanning—intraoperative/laparoscopic

| Scan gallbladder                                      |
|------------------------------------------------------|
| • Contact scanning, transhepatic                     |
| • Saline immersion probe standoff from inferior surface |

| Scan extrahepatic bile duct                          |
|------------------------------------------------------|
| • Contact scanning, transhepatic                     |
| • Saline immersion probe standoff, transverse, and longitudinal planes |

| Scan intrapancreatic bile duct                       |
|------------------------------------------------------|
| • Transduodenal compression scanning                 |
| • Transpancreatic contact/probe standoff scanning     |

(Figs 27, A and 28, A); transverse scanning helps confirm findings, ensuring that they are not artifacts (Fig 27, B). Using a standoff technique, the entire extrahepatic bile duct from the hilum to the duodenum is visible. Angling the probe downward (cord toward the floor) focuses the array on the hilar plate, providing adequate images of this area. Compression scanning on the first portion of the duodenum allows examination of the posterior duodenal and intrapancreatic bile duct (Figs 27, C and 28, B). This displaces gas from beneath the probe, providing an acoustic window to view the bile duct. This view allows imaging of the intrapancreatic bile duct. If it is not visible, slide the probe to the pancreatic head to scan through it. Again, if unsuccessfully seen with these techniques, use a probe standoff approach or compression scanning through the lateral duodenal wall, or scan from the posterior surface after mobilizing the duodenum and pancreatic head. Unless dilated at the level of the ampulla or the presence of a stone, the biliary junction with the duodenum is difficult to see. Use color Doppler to distinguish small intrahepatic bile ducts from vasculature.

Pancreas Scanning Technique. Either an end- or a side-viewing probe is useful for IOUS of the pancreas. Do imaging prior to any dissection. Multiple acoustic windows are available to view the pancreas by indirect scanning through the duodenum, stomach, gastrohepatic/gastrocolic ligaments, or the transverse mesocolon (Fig 29). Following access to the lesser sac, direct contact scanning and a probe standoff technique through the anterior surface of the gland provide excellent images. Probe standoff scanning is important to avoid missing details beneath the transducer during contact scanning, particularly in thin glands (Fig 30). Scanning through a pool of saline in the lesser sac works well for diagnostic scanning. Placing a saline-filled glove on the gland and scanning through this often work better for interventions such as guiding a needle for biopsy or duct cannulation rather than working while the gland is underwater.

Again as with the liver and bile ducts, a standard approach to pancreatic scanning is essential to ensure a complete examination (Table 7).

Fig 26. Longitudinal (sagittal) scanning of the hepatoduodenal ligament using a probe standoff, saline immersion technique. This allows very detailed images of the common bile duct (black arrow), which lies along the anterolateral surface of the main portal vein (MPV). Figure reprinted with permission [1].
Begin indirect scanning in the longitudinal plane (Fig 31, A) followed by transverse imaging (Fig 31, B). If needed, follow up with direct and/or probe standoff scanning. If difficult to identify, use the principles outlined for TAUS to find the pancreas based on the adjacent peripancreatic landmarks. Begin the study by finding the superior mesenteric/portal vein as it passes posterior to the pancreatic neck (Fig 32). Scan the neck, body, and tail of the gland longitudinally, and then rotate the probe and repeat imaging in the transverse plane. If doing direct contact scanning of the gland, repeat the steps using a probe standoff approach. This assures high-resolution images of superficial pancreatic structures, particularly in a thin gland. Carefully characterize the relationship between any lesion and the pancreatic duct during the longitudinal portion of the study (Fig 33). After scanning the left pancreas, start back at the pancreatic neck and work to the patient’s right to examine the

Fig 27. A, Longitudinal scanning of the bile duct during laparotomy. B, Transverse scanning of the bile duct. C, Compression of the duodenum displaces intraluminal air and allows imaging of the retroduodenal and intrapancreatic portions of the common bile duct. Figure reprinted with permission [1].

Fig 28. A, Contact scanning of the hepatoduodenal ligament in the longitudinal plane. This patient has aberrant anatomy. There is a right hepatic artery (white arrow and a signal on color Doppler) that courses anterior to the common bile duct (CBD, no flow signal). The main portal vein (MPV and a flow signal) is posterior to the bile duct. B, Compression scanning through the duodenum (D) in the longitudinal plane shows the common bile duct (white arrow), the superior head of the pancreas (P), and the inferior vena cava (asterisk and flow signal). Figure reprinted with permission [1].
head of the gland. Use the techniques described to view the distal bile duct to achieve complete scanning of the pancreatic head. These maneuvers allow a clear view of all the surrounding vascular structures.

IOUS also permits detailed mapping of the association between a pancreatic mass and the vessels. If necessary, mobilize the gland after completing the entire scan to define small lesions. This is particularly useful

![Image](image1.png)

**Fig 29.** Intraoperative pancreatic scanning. Several acoustic interfaces allow pancreatic imaging without dissection. A, Transgastric. B, Gastrocolic or gastrohepatic ligaments. C, Transverse mesocolon. Figure reprinted with permission [1].

![Image](image2.png)

**Fig 30.** A, Contact scanning shows very little detail in the pancreas due to the thin gland (white bracket), which lies anterior to the portal (PV) and splenic (SV) veins. B, Probe standoff scanning using a saline immersion technique to provide an acoustic window (aw) shows the detail missing with contact scanning. This patient has a very dilated pancreatic duct (white bracket) due to a pancreatic duct stone (white arrowhead) with posterior shadowing. A pancreatic duct stent (white arrow, * within the lumen of the stent) is present within the duct. The anterior and posterior surfaces of the gland are shown by the thin white opposing arrows. Superior mesenteric vein (SMV). Figure reprinted with permission [1].
for small neuroendocrine tumors, which can require a combination of palpation and IOUS for localization and characterization.

**LAPAROSCOPIC ULTRASOUND**

With the rise of minimally invasive surgical (MIS) approaches, LUS has become an essential tool. It is a critical substitute for palpation, helping overcome the loss of tactile information during MIS procedures. Absent palpation, LUS allows recognition of specific anatomic structures or mass lesions. It provides guidance for MIS resection or ablation procedures as open IOUS or palpation is not feasible.

Significantly improved since inception, typical current LUS probes are side-viewing, high-frequency transducers at the end of a flexible shaft. Most are 10 mm in diameter, necessitating introduction through 10–12-mm trocars. The significantly improved freedom of movement with a flexible shaft enables easier scanning of difficult-to-reach areas while limiting the number of access ports needed for a complete examination. Because it has a long footprint, scanning is very efficient because of the wide views. The organ and type of examination intended dictate trocar placement for LUS, as illustrated in the following sections.
Although probe placement and movement are similar to IOUS, LUS includes some important differences. Room and equipment setup is important to facilitate image acquisition. If a picture-in-picture setup is available, placement of the ultrasound machine and the MIS monitors side-by-side is less critical. If image display on a single screen is not available, a side-by-side monitor setup facilitates probe manipulation and image interpretation. Adjacency of the MIS and LUS images allows correlation of the probe’s position on an organ with the expected LUS image, making image interpretation simpler. Another important distinction is probe orientation. As configured, the array aligns with the probe’s shaft, giving a longitudinal image. Although this is often the easiest configuration for image acquisition, particularly when working through a single port, the images can be confusing compared to IOUS. A complete examination typically requires moving the probe between trocars (Fig 34). To achieve images that correspond to views from a side-viewing probe, orient the LUS probe to give a transverse planar image (Fig 35, A). When moved, be certain that the displayed image is oriented in the conventional fashion to avoid confusion (Fig 35, B). If not carefully checked, an inverted image may display. Address this by changing the image orientation on the ultrasound machine’s control panel. Despite these actions, LUS remains challenging because of difficulty replicating the typical patterns recognized from transverse images, particularly when imaging the liver. LUS, therefore, is more difficult to learn, as one must think in longitudinal images rather than transverse. Until sufficiently experienced, this can be disconcerting.

LUS probe movements mirror those used in open IOUS, with sliding (Fig 36) and tilting (Fig 37) the most common. LUS multiplanar imaging is tedious as rotational movement is more difficult to master. This makes 3-dimensional mapping demanding. Flexing the tip up and down best simulates rocking done in open IOUS (Fig 38). However, during contact scanning, the probe often loses coupling with the organ surface when rocking the probe. A probe standoff technique combined with rocking obviates this shortcoming and is very useful for scanning the superior liver and extrahepatic bile duct.

Liver Scanning Technique. Begin with a 5-mm trocar in the supraumbilical midline. This allows a full visual examination of the peritoneal surfaces and the abdominal contents. If no findings are seen that preclude the proposed procedure, placing a right 10–12 mm subcostal trocar is a good place to begin hepatic scanning. Place the trocar in the subcostal incision line if using this for the procedure. A subcostal trocar position also is useful if using a midline incision. Be sure that the probe can access the superior liver when placing the trocar. Judge the distance by placing the tip of the probe at the level of the right nipple. If the fully inserted probe exits inferior to the proposed trocar placement, this will allow examination of the superior-most aspects of the liver. Beginning at the right subcostal site is the easiest as it provides views that most closely approximate the transverse images seen in IOUS. If a complete...

Fig 33. Intraoperative ultrasound, pancreas, longitudinal plane. A, An image through the head of the pancreas shows the duodenum (D) just to the patient’s right of the pancreatic head. Within the head are a transverse view of the distal common bile duct (white arrow) and a longitudinal view of the distal pancreatic duct (white arrowhead). B, Longitudinal view at the neck of the pancreas showing the pancreatic duct (white arrow) draped over a neuroendocrine tumor (white arrowheads). The tumor lies anterior to the superior mesenteric vein (SMV). Figure reprinted with permission [1].

Fig 34. Trocar placement for laparoscopic ultrasonography of upper abdominal organs. Common viewing sites include a subxiphoid port (A), a right subcostal port (B), and the periumbilical port (C). Figure reprinted with permission [1].
examination is not possible from this position, exchange the midline 5-mm trocar for another 10–12-mm one, and move the probe to this position. Ensure proper image orientation after moving the probe. Place a left subcostal trocar, if needed, to completely examine the liver.

The LUS scanning steps to image the liver are similar to IOUS. Map the vessels, define the segmental anatomy, and scan the segmental parenchyma. A systematic approach similar to IOUS is critical. This is particularly so, as a complete examination using LUS is more difficult with mobility limited by working through fixed trocars. Hence, achieving the correct planar orientation to find familiar patterns is challenging. This emphasizes the need for an orderly approach to scanning.

Beginning at the right subcostal position affords views most similar to the familiar transverse images seen during open IOUS (Fig 39, A). Sliding the probe along the anterior surface, from superior to inferior, efficiently develops the initial hepatic map (Fig 39, C and E). Vessel mapping requires a combination of transverse, oblique, and longitudinal views. Scanning in the longitudinal plane (Fig 39, B) quickly and easily images the parenchyma. In the longitudinal position with the probe

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**Fig 35.** Laparoscopic ultrasound examination of the liver in the transverse plane. A, The probe is placed through the right subcostal port and the tip deflected to orient it transversely. Be sure the tip (white arrow) is oriented such that the image on the monitor (B) has it on the right side of the screen (green dot corresponds to white arrow in panel A). Figure reprinted with permission [1].

**Fig 36.** Laparoscopic ultrasound, sliding probe movement for liver scanning. Nearly all the liver can be scanned in the transverse, longitudinal, and oblique planes using a sliding movement through the 3 standard port sites. Figure reprinted with permission [1].
on the liver surface, roll the shaft side to side. This covers a wide area of parenchyma without moving the probe in relationship to the surface of the liver, lessening the risk of losing familiar images and having to start again. Starting at the superior surface of the liver, scan the parenchyma by rolling the probe side-to-side. Then slide the probe inferiorly and repeat the process (Fig. 39, D and F). This allows complete parenchymal scanning using a series of overlapping movements, thereby allowing complete parenchymal scanning. As mentioned, the superior and posterior liver may pose difficulties in achieving adequate images. Acquiring a complete set of images requires using a combination of contact and probe standoff scanning.

If imaging the posterior liver is difficult from the anterior surface, move the probe to the inferior surface and use either contact or probe standoff scanning. Filling the subhepatic fossa with saline while the patient is in slight Trendelenburg gives a good window for a probe standoff technique. Similarly, placing the probe on the posterior liver surface gives good views of difficult to images sites.

**Biliary Scanning Technique.** Use a 2-trocar approach for the best biliary imaging. Begin with the probe through the epigastric port (Fig. 34), as the laparoscope usually is in the umbilical port. Scan the biliary ducts similarly to IOUS using both contact and probe standoff techniques. Remember to scan prior to doing any dissection or cholangiography to avoid imaging artifacts. The use of color Doppler can help distinguish vessels from the bile ducts.

Initially, begin with transverse scanning at the hepatoduodenal ligament and its structures (Fig. 40). Push the gallbladder cephalad with a grasper exposing the ligament. Slide the probe along the gallbladder wall to scan it directly (Fig. 41, A and B). Begin at the dome, work toward its junction with the cystic duct (Fig. 41, C and D) and then slide the probe further inferiorly to the hepatoduodenal ligament. With the probe at this junction, examine the common hepatic duct and hilum by rotating the probe shaft counterclockwise to direct the array crystals toward the hepatic hilum. If you cannot see all the common hepatic duct and hilum, slide the probe slightly superiorly along the hepatoduodenal
ligament and rotate the probe shaft to find the remaining ducts. After seeing all the ducts, rotate the shaft back to neutral and slide it inferiorly on the hepatoduodenal ligament. Do probe contact scanning of the ducts with light pressure, as the ducts are very collapsible and may appear absent if too much pressure is applied. Again, if the imaging is inadequate, change to a probe standoff approach.

As the probes slide along the ligament from the hepatic hilum to the duodenum, correlate the ultrasound images with your knowledge of the anatomy. Superiorly, the common hepatic duct lies between the right and left hepatic arteries and anterior to the portal vein. Moving the probe inferiorly shows the right hepatic artery (in typical anatomy) coursing posterior to the common hepatic duct until its junction with the proper hepatic artery. At this point, you see the characteristic "Mickey Mouse" image of the bile duct and hepatic artery sitting anterior to the portal vein (Fig 41, E and F).

Through these techniques, one can examine the entire suprapancreatic bile ducts. To view the retro/intrapancreatic portion of the bile duct, slide the probe onto the anterior duodenum and/or head of the pancreas. This allows a transverse image of the bile duct and a longitudinal one of the pancreatic duct (Fig 41, G and H). With careful movement of the probe in this area, one often sees the junction of the bile and pancreatic ducts (Fig 42). Remember that compression of the duodenum is necessary to image through it. Scan from the anterior and lateral sides of the duodenum for the best views.

If obscured during initial imaging, obtain better views of the common hepatic duct by opening Calot’s triangle. Place the probe in the triangle, rotating it counterclockwise toward the hilum to view the proximal common hepatic duct and hilum.

Once done, move the probe to the umbilical port. This allows longitudinal views of the ducts and surrounding structures (Fig 43). Begin viewing the gallbladder by placing the probe on the anterior liver to use it as the acoustic interface (Fig 43, A and B). Minimal sliding and rotating at this site give excellent images of the proximal right, left, and common hepatic ducts. Next, move the probe to the anterior hepatoduodenal ligament and begin contact scanning (Fig 43, C). With the probe tip at the hepatic hilum to view the superior most ducts, complete the examination by moving the probe inferiorly along the ligament to the level of the duodenum. Before moving the probe to its next position, rotate it slightly left and right to fully view the structures in the ligament. This gives longitudinal views of the bile duct and the portal vein (Fig 43, D). Using duodenal compression, view the duct as it runs posterior to the duodenum (Fig 43, E and F). View the intrapancreatic duct from
this position or move the probe to the anterior surface of the pancreas to complete the examination.

Pancreas Scanning Technique. Laparoscopic pancreatic scanning is similar to IOUS. Viewing through a right subcostal trocar gives the best longitudinal images (Fig 44, A and B). An umbilical/periumbilical trocar is best for transverse imaging (Fig 44, C and D). The most efficient initial imaging uses the stomach or gastrohepatic/gastrocolic ligaments as acoustic interfaces in a probe standoff fashion (Fig 44, A). This obviates the need to enter the lesser sac for screening examinations. Identifying the surrounding vascular structures, as described previously, facilitates recognition of the pancreas (Fig 45).

Beginning with the probe in the right subcostal position allows excellent longitudinal views from the head/neck to the pancreatic tail. View the portal/superior mesenteric vein as it passes posterior to the pancreatic neck and scan the gland to the patient’s left of the vessel. Once done, relocate the vein and scan to the patient’s right, examining the pancreatic head. Obtain transverse views through the umbilical port. If inadequately seen using contact scanning, complete the examination by a saline immersion, probe standoff technique. This often provides better views of the head and uncinate. Use minimal probe sliding and rotation to view the entire gland.

SUMMARY

The general principles for TAUS, IOUS, and LUS scanning are similar. One can gather considerable information using these modalities during a clinical examination, procedure, or operation. For success, it is critical to develop a standardized approach to scanning and use it every time. This facilitates "pattern recognition" of familiar ultrasound images, making it easier for the novice to learn and gain experience. Using a systematic approach ensures the experienced ultrasonographer obtains all the essential information, avoiding missed findings.

Author Contribution

RB Adams: conceptualization, original draft, reviewing, editing. All figures and artwork were developed and created by the author.

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Fig 41. Laparoscopic biliary ultrasonography. Initially, the gallbladder (GB) is scanned by direct contact (A, B). The probe is slid inferiorly to the cystic duct and its junction with the hepatoduodenal ligament (C). This allows viewing of the cystic duct (D, white arrow). Sliding the probe further inferiorly along the hepatoduodenal ligament (E) brings the portal triad into view (F) so that the common bile duct (white arrow), portal vein (PV), and common hepatic artery (black arrowhead) are seen ("Mickey Mouse" view). The IVC is seen in this image. Finally, transduodenal compression views (G, H) allow imaging of the intrapancreatic bile duct (black arrow). Duodenum (Du). Figure reprinted with permission [1].
Fig 42. Laparoscopic ultrasonography of the intrapancreatic bile duct and pancreatic duct. Direct scanning through the pancreatic head or duodenal (Duo) compression scanning allows a detailed view of the common bile duct (white arrow) and the pancreatic duct (white arrowhead). A, Color Doppler shows no flow in the two ducts and a flow signal in the vena cava, directly posterior to the head of the pancreas. Figure reprinted with permission [1].

Fig 43. Laparoscopic biliary ultrasonography. In this case, biliary scanning is done through the periumbilical port, giving longitudinal views. A and B, Gallbladder (GB). C and D, Hepatoduodenal ligament with the common bile duct (CBD) and portal vein (PV). E and F, Transduodenal (Duo) compression scanning showing the retroduodenal common bile duct (black arrow). Figure reprinted with permission [1].
Fig 44. Laparoscopic pancreatic ultrasonography. A, Longitudinal scanning of the pancreas from the right subcostal trocar. A transgastric window is used to view the gland. B, Longitudinal view of the head and neck of the pancreas (black bracket). The pancreatic duct is seen (black arrow), as well as the portal vein (PV). C, Transverse scanning of the pancreas through the periumbilical trocar. Again, a transgastric window is used. D, Transverse view of the neck of the pancreas (black bracket) with the pancreatic duct seen in transverse section (black arrow). The portal vein (PV) is seen in longitudinal section passing posterior to the neck of the pancreas. Figure reprinted with permission [1].

Fig 45. Laparoscopic pancreatic ultrasound. The principles and images are very similar to those for transabdominal and intraoperative pancreatic scanning. A, The transducer is placed in the longitudinal plane using a transgastric window. This gives the prototypical image of the vasculature surrounding the pancreas that facilitates its identification. The pancreas (black bracket) lies anterior to the portal vein (PV) and the splenic vein (SV). The superior mesenteric artery (white *) is seen posterior to the veins. The aorta (Ao) is posterior to the superior mesenteric artery. B, Transverse position of the transducer using a transgastric (S) window. The pancreatic neck (black bracket) is seen with the splenic artery (SA) running along its anterior border, whereas the superior mesenteric vein (SMV) passes posterior to the neck of the pancreas. Figure reprinted with permission [1].

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