Percutaneous Ultrasound Guidance Techniques and Procedures

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Abbreviations

CT	Computed tomography
FAST	Focused assessment with sonography for trauma
FNA	Fine-needle aspiration
ICU	Intensive care unit
MRI	Magnetic resonance imaging
MW	Microwave ablation
PT	Prothrombin time
PTC	Percutaneous transhepatic cholangiography
PTT	Partial thromboplastin time

Introduction

The field of interventional ultrasound has expanded dramatically since the 1980s when indications for interventional ultrasound included biopsy guidance and simple aspiration of fluid collections. Since then, interventional ultrasound has been increasingly utilized in clinical practice, in part due to improved sonographic imaging, newer multifrequency ultrasonic probes, as well as the development of less invasive therapies such as ablation techniques, ideally suited to work with ultrasonography. Because of the remarkable success of interventional ultrasound, combined with an outstanding safety record, the number and types of interventional procedures performed under sonographic guidance will continue to grow. Surgeons rapidly have embraced the use of ultrasound not only for diagnostic purposes but also for interventional procedures.

Both diagnostic and therapeutic interventional ultrasonography are now widely accepted techniques that can be used as adjuncts in nearly all areas of the body. Indications for interventional ultrasound are numerous and expanding: needle aspiration, biopsy, drainage, catheterization, tumor ablation, and tissue dissection. There are many advantages of using ultrasound as the imaging modality to guide interventional procedures. In particular, the ability to monitor the procedure in real time, its safety, relatively low cost, portability, and expediency make ultrasound an ideal modality to perform interventional procedures at various locations including the surgeon's office, critical care areas, as well as the operating room. Introduction and availability of newer ultrasound technology, such as ultrasound contrast enhancement, three-dimensional ultrasound, and high-intensity focused ultrasound, will be utilized more and should improve outcomes. Devices such as automated core biopsy needles have allowed for increased reliability in the performance of interventional ultrasound. It is expected that the recent changes in the healthcare environment with its emphasis on resource utilization and efficiency will further foster an expanded role for interventional ultrasound in clinical medicine. In such a clinical environment, surgeon-performed interventional ultrasound should be cost-effective and beneficial for surgical patients.

History

Needle guidance under sonographic direction was first developed in the early 1970s; however, the earliest work describing the use of ultrasound needle guidance can be traced a decade earlier. In 1961, Berlyne described the use of an A-mode apparatus to guide performance of renal biopsy in 20 patients with renal disease and advocated its use to check the needle tip for biopsy [1]. In 1967, Joyner and

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Table 7.1 Indications for interventional ultrasound

Technique	Methods
Aspiration	Contrast, alcohol
Biopsy	Cytology, core biopsies
Catheter guidance	Drainage: cholecystostomy, abscess, etc.
Definition of intra-abdominal anatomy	Fluid collections (e.g., blood, puss, cyst, etc.)
Injection	Operative approach
Probe guidance	Tumor ablation

associates used ultrasound to select a site for aspiration of pleural fluid [2]. At the First World Congress on Ultrasound in Vienna, Austria, in 1969, Kratochwil described an ultrasonic transducer with a central slot for needle insertion using the A-mode ultrasound [3]. This guide had a flexible cable attached to the transducer. This was easily maneuvered for biopsies. Gammelgaard et al. described the use of a static B-scanning transducer for guidance of needle puncture at the American Institute of Ultrasound in Medicine meeting in Cleveland, Ohio, in 1970 [4]. This transducer had a center slot in which the needle could be placed for aspiration techniques. In these initial phases of interventional ultrasound, the needle was not monitored by sonography; the target was only visualized and marked before insertion of the needle.

The first manuscripts documenting the use of ultrasound to guide invasive procedures appeared in 1972, and interventional ultrasound began to grow. Holm et al. described a special transducer with a central hole through which a needle could be placed [5]. Goldberg and Pollack American radiologists, independently developed an ultrasonic transducer with a central perforation for needle placement [6]. Holm and Goldberg described the use of a static bistable B-scanning technique in which the target was visualized by manual compound scanning. The transducer was angled until a marked line indicating the detection of the puncture needle intersected the target. The needle was inserted, and the needle tip echo, in many cases, could be visualized on the simultaneous A-presentation as a moving echo.

In 1972, Rasmussen et al., using Holm's transducer, compared two methods for liver biopsy of patients with suspected liver metastases. Blind liver biopsy was compared with a sonographically guided liver biopsy. The rate for successful targeting of liver metastases by the blinded technique was 23 % compared with 85 % by the sonographically guided technique [7]. In 1972, Bang and Northeved described the successful use of ultrasound to guide aspiration of amniotic fluid [8]. Bahlmann and Otto, Bartels and Jorgensen, and Kristensen et al. described ultrasound in guiding renal biopsy in the same year [9–11]. These initial studies more than 30 years ago laid the foundation for the field of interventional sonography and its broad application across numerous medical specialties.

Indications for Interventional Ultrasonography

Initially, the principal use of interventional ultrasound was as a diagnostic adjunct (i.e., indirect guidance of biopsies). Currently, interventional ultrasound is used to guide therapeutic interventions as well; examples include drainage, injection, ablation, or tissue dissection. The use of ultrasound in such settings directly affects the therapeutic outcome. In this chapter, general principles of interventional ultrasound, mainly for needle, catheter, and cannula placement, are discussed. Specific applications regarding surgeons are subsequently addressed. The specific applications of interventional ultrasound in different organs are described in relevant chapters, as well as the use of intraoperative and laparoscopic ultrasound (Table 7.1).

Interventional procedures guided by ultrasound for needle placement include biopsy, aspiration, and injection/ablation. Both fine-needle aspiration (FNA) cytology and core-needle biopsy can be guided by ultrasound. Ultrasound-guided FNA cytology is usually indicated for neck masses, including thyroid nodules, parathyroid nodules, cervical or other lymph nodes, and pancreatic lesions. On the other hand, ultrasound-guided core-needle biopsy is indicated more commonly for breast lesions, abdominal diseases such as liver tumors, retroperitoneal or pelvic masses, prostate lesions, and transplanted organs [12–14]. For both FNA and core-needle biopsy, ultrasound greatly facilitates the diagnosis and management of hepatic disorders, particularly neoplasms. Ultrasound-guided biopsy of the liver can be performed percutaneously in most circumstances and is frequently indicated for definitive diagnosis of liver tumors [15] (Fig. 7.1). Percutaneous biopsy of intra-abdominal, retroperitoneal, or pelvic masses can be guided by ultrasound as well as computed tomography (CT). Percutaneous ultrasound-guided biopsy of tumors of the liver or intra-abdominal masses may confirm metastatic or unresectable disease, thereby avoiding unnecessary laparotomy in a patient with incurable malignancy [15]. Ultrasound can be used to biopsy retroperitoneal masses including lymph nodes [16], even preventing unnecessary laparotomy in a patient with retroperitoneal lymphoma (Fig. 7.2). Ultrasound-guided core-needle biopsy of transplanted organs such as

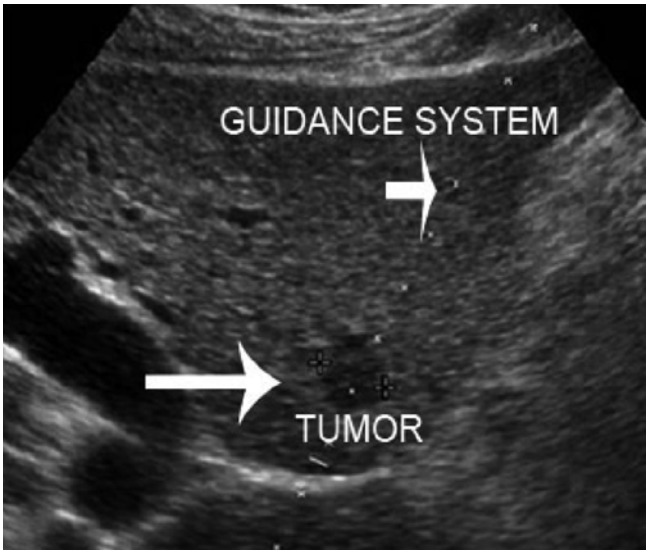

Fig. 7.1 Biopsy of liver tumor

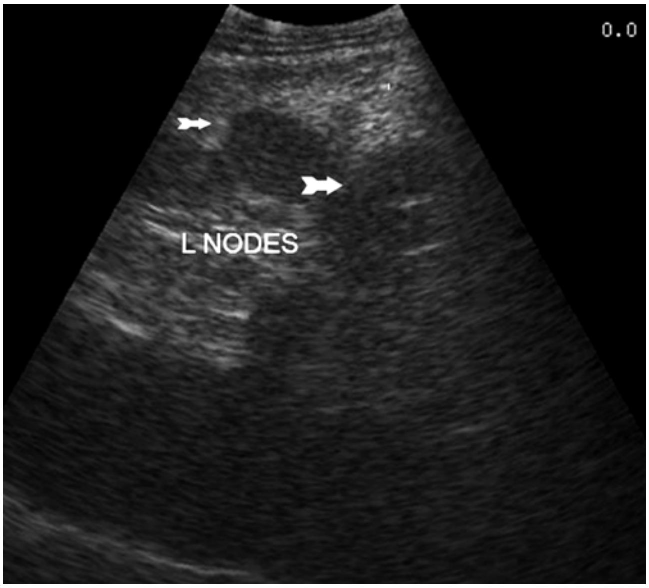

Fig. 7.2 Retroperitoneal lymph nodes (*arrows*)

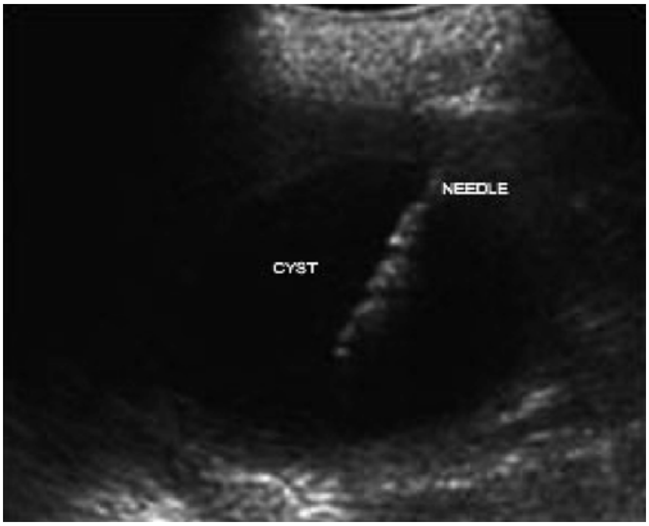

Fig. 7.3 Ultrasound-guided cyst aspiration

Fig. 7.4 Intra-abdominal abscess detected with ultrasound

the liver, kidney, and pancreas is indicated for histologic diagnosis of possible transplant rejection or other transplantation-related complications [17].

Ultrasound-guided needle placement is also indicated for aspiration of various fluids and cystic lesions involving the thoracic and abdominal cavities as well as other areas of the body. Ultrasound-guided aspiration is performed for both diagnostic and therapeutic purposes in the abdomen, for example, a paracentesis, and is much safer for the patient when done under ultrasound guidance. Abdominal cystic lesions that can be aspirated by ultrasound-guided needle placement are numerous and include, but are not limited to, liver cysts, renal cysts, and pancreatic cystic lesions [18] (Fig. 7.3).

Ultrasound-guided needle aspiration may be followed by ultrasound-guided catheter placement for drainage of various diseases. Intra-abdominal or pelvic abscesses and cysts can be aspirated and drained (Figs. 7.4 and 7.5). Some interventions require the placement of a catheter including percutaneous cholecystostomy, as well as percutaneous transhepatic cholangiography (PTC), nephrostomy, gastrostomy, and aspiration and drainage of abdominal wall and intra-abdominal fluid collections (Fig. 7.6).

Injection and/or tissue ablation of lesions is an important concept when discussing interventional sonography. Following needle placement, various agents can be injected under ultrasound guidance. Such agents include blue dye, radiographic contrast, or therapeutic agents such as alcohol. Blue dye injection may be used for marking the tissue or in the case of hepatic resections, injection into a branch of

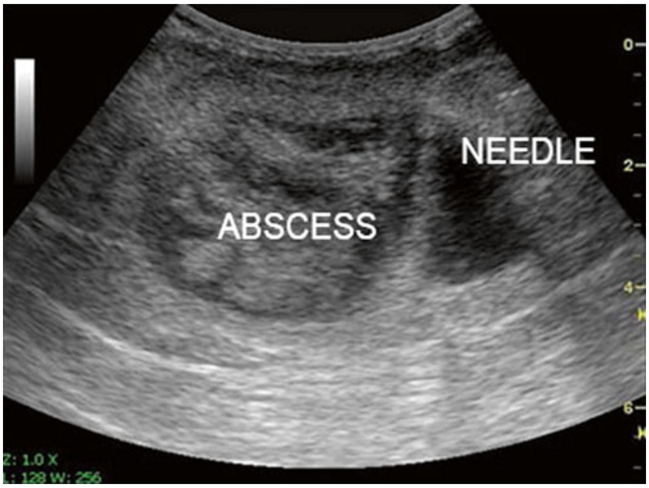

Fig. 7.5 Ultrasound-guided needle placement for abscess drainage

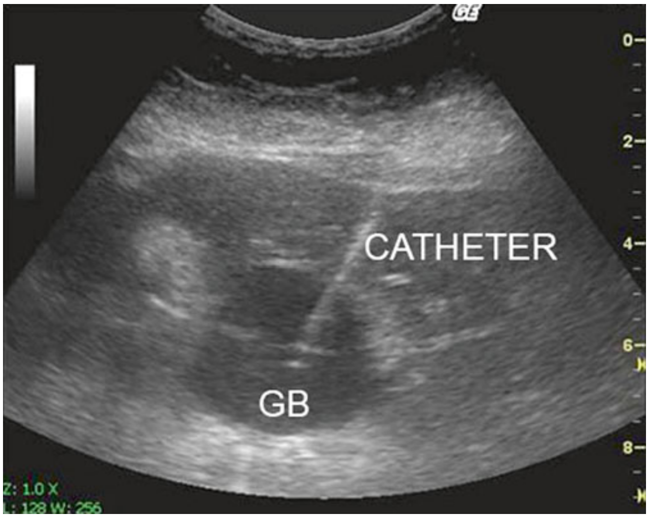

Fig. 7.6 Percutaneous cholecystostomy. *GB* Gallbladder

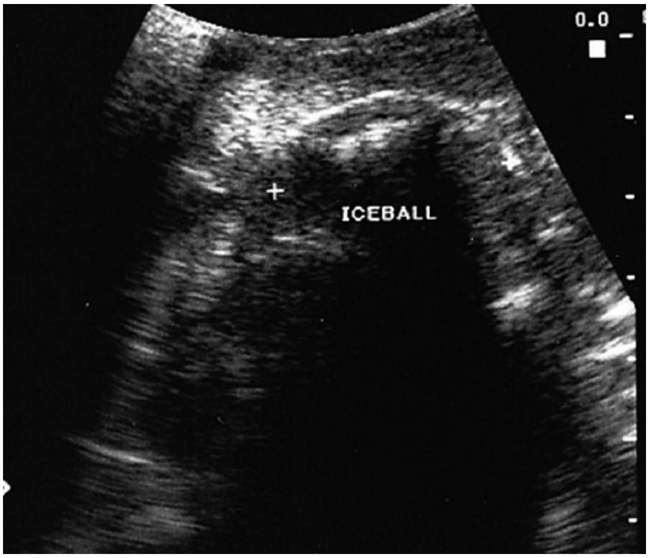

Fig. 7.7 Cryoablated liver lesion. Iceball between crossmarks

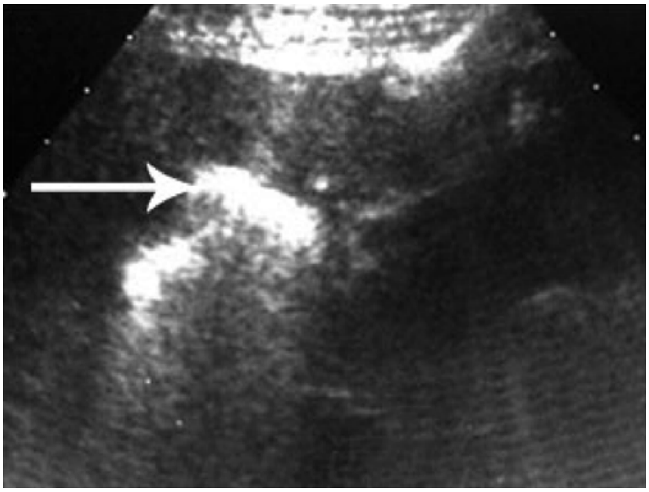

Fig. 7.8 Post-RFA of liver mass with hyperechoic residual effect

the portal vein to define the boundaries of a liver segment to facilitate subsegmental resection. Contrast can be injected into cystic lesions or biliary ducts for radiographic contrast studies (e.g., percutaneous transhepatic cholangiography). Ultrasound-guided ethanol injection has been used for management of hepatomas, parathyroid adenomas, thyroid nodules, and other diseases [19].

Tumor ablation is an effective therapeutic modality for the management of various types of cancers. Its success is dependent on accurate staging, precise targeting of the lesion, thorough ablation, and consecution of free margins. Cryoablation and thermal and microwave ablation have been extensively utilized in the treatment of liver tumors with good outcomes. Placement of the probes can be guided by ultrasound in an accurate, expeditious, and safe manner. Radiofrequency/microwave-ablated or cryoablated lesions become hyperechoic or hypoechoic, respectively, and associated with shadowing (Figs. 7.7 and 7.8) [20, 21].

Advantages and Disadvantages

With the wide variety of imaging modalities available to the surgeon presently, it is sometimes challenging to select the most effective method. What is best for the patient? Which modality will yield the greatest amount of information to guide clinical decision-making? Which one is the most cost-effective? (Table 7.2) The advantages of ultrasonography are numerous. The most significant is its visualization of an interventional procedure in real time, which allows for precise needle or cannula placement

Table 7.2 Advantages and disadvantages of interventional ultrasonography

Advantages	Disadvantages
Accurate	Difficult to image mid-abdomen and chest
Available	Interference from air and bone
Doppler capability	Learning curve
No ionizing radiation	Lower resolution
Portability	Sterilization of probes
Real-time visualization/dynamic study	
Repeatable: confirms procedure, complications	
Safe (no redirection)	
Versatile	

[22]. Ultrasound is a dynamic study with real-time imaging allowing for controlled intervention with a needle, catheter, etc. under visualization. With the exception of fluoroscopy, other image guidance modalities (e.g., CT and magnetic resonance imaging) require assessment of static images and, when necessary, subsequent adjustment of needle placement prior to rescanning. Precise placement of the needle and/or probe requires accurate definition of the target. If subsequent CT or magnetic resonance imaging (MRI) images are obtained without contrast, the risk for unsuccessful outcomes due to poor delineation of the lesion may be increased. Ultrasound also has the ability to be portable, which is extremely useful in the intensive care unit (ICU) setting or any setting in which a critically ill patient is involved. This minimizes any risk of transportation in a critically ill patient, and there is less of a burden on the collaborating departments (e.g., radiology) and the nursing staff. The portability of ultrasound also makes it ideal for the office or ambulatory setting. Focused assessment with sonography for trauma (FAST) in the emergency department to diagnose bleeding in the trauma patient has become extremely common and effective (Fig. 7.9). The uses of ultrasound to perform interventions due to its accessibility and portability will only continue to grow. Finally, ultrasound is considerably less expensive than CT, MRI, and other imaging modalities.

One of the main advantages to ultrasound is its lack of ionizing radiation. As a result, it can be used in circumstances in which image guidance would otherwise not be possible; examples include pregnant patients or radiation-sensitive areas (e.g., ultrasound-guided aspiration of amniotic fluid). Ultrasound also has the capability for immediate confirmatory imaging post-procedure. Successful aspiration of the fluid or drainage can be confirmed. Tumor-ablative procedures can be monitored by continuous ultrasound examination during the operation. During or at the end of the procedure, ultrasound may be used to detect early complications such as bleeding at the needle insertion site or hematoma formation [22].

Despite its myriad of uses and the abovementioned advantages, there are some disadvantages to ultrasonography [23]. Because ultrasound does not penetrate bone or air well, ribs or air within the lung, limits its use in evaluating the chest. Specifically in the abdomen, gas within the bowel lumen limits the value of ultrasound in evaluating the mid-abdominal region. Therefore, in most circumstances, CT guidance is required for intervention in those areas. The cumbersome mechanism for disinfection and sterilization of ultrasound transducers is a minor impediment to their use. Current transducers have limited tolerance to high temperature, preventing their sterilization by autoclaving. Alternative techniques necessitate time-consuming cold gas sterilization or soaking procedures with or without the use of sterile drape covers [20].

Fig. 7.9 Portable ultrasound used in the emergency department for FAST scan

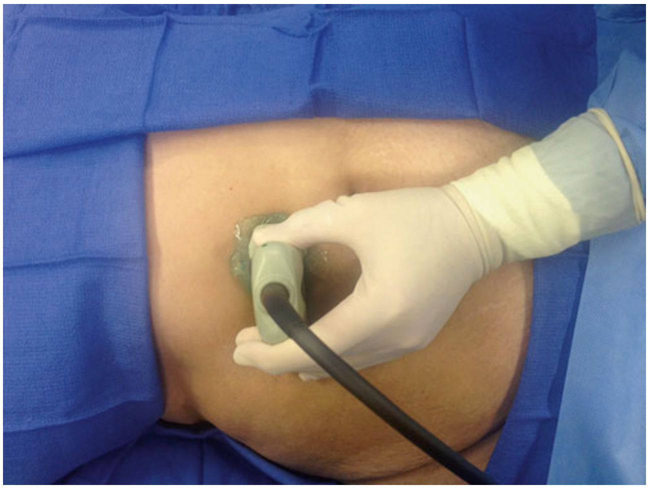

Fig. 7.10 Preliminary scan of abdomen prior to needle aspiration

Procedure Preparation

As with any interventional procedure, routine background information with attention to a history of bleeding disorders, liver disease, and medications is required. Specifically, the use of platelet-inhibiting drugs (e.g., aspirin, clopidogrel, etc.) and anticoagulants (e.g., warfarin, etc.) should be investigated. A review of the patient's coagulation profile including the prothrombin time (PT) and partial thromboplastin time (PTT) are always recommended before an interventional or invasive procedure. Informed consent must always be obtained before a procedure, outlining the procedure itself as well as the potential complications and morbidities associated with the specific procedure.

In most cases, optimal patient position for interventional ultrasound procedures is the same as that used for diagnostic ultrasonography of the area. In general, one should attempt to take the shortest possible path to a lesion. For example, to optimally visualize lesions in the abdomen (such as the liver), it may be necessary to move the patient from the supine to the left lateral decubitus position [22]. Raising the patient's right arm over the head, thereby moving the rib cage in a more cephalad direction, may further enhance exposure of the liver. Such maneuvers may be required to optimally visualize and access a liver mass. For most interventional ultrasound procedures, it is beneficial to perform a brief diagnostic scan of the patient prior to setting up for the planned intervention. This preliminary scan confirms the safest and most direct route to the area in question. When such a position is ascertained, the patient can be prepared in the usual manner (Fig. 7.10).

Skin preparation for ultrasound-guided procedures requires routine painting with antiseptic solutions and full operative drape of the patient and ultrasound equipment. The method will vary according to the nature and severity of the planned interventional ultrasound procedure. For acoustic coupling between the transducer and the skin, sterile ultrasound coupling gel can be used. During open surgical procedures, saline solution is used in the operative field for acoustic coupling.

The use and type of anesthesia varies depending on the nature and extent of the procedure and the anxiety and cooperation of the patient. Most percutaneous interventional ultrasound procedures are accomplished readily with a of local anesthetic. For more complex procedures, such as drainage of an intra-abdominal abscess or percutaneous biliary drainage, or for patients with anxiety, intravenous sedation is generally required (typically with a narcotic and benzodiazepine). When using sedation, the patient must be in a monitored setting, watching heart rate, blood pressure, respiratory rate, and oxygen saturation. Prolonged ultrasound-guided procedures, such as liver tumor ablation, are more frequently performed under general anesthesia.

Ultrasound Guidance and Visualization

Ultrasound guidance was a major advancement in the area of interventional sonography. Saitoh et al. first described the use of real-time guidance for sonographically guided puncture in 1979 [24]. Shortly thereafter, almost every manufacturer developed some type of transducer or needle guidance system for biopsy or aspiration techniques. There are advantages and disadvantages to each guidance system. Presently, the use of detachable guidance systems for sonographically guided needle puncture techniques is common, including the development of endoluminal transducers with biopsy guidance attachments to use with these transducers. These guidance techniques have become increasingly specialized and the equipment very specific for various ultrasound-guided procedures.

Various ultrasound guidance methods are utilized to optimally guide a needle, cannula, or probe. Indirect ultrasound guidance uses the ultrasound to select the site of intervention and aids in determining the angle of insertion for the needle. Despite this, it is essentially a blind technique. First, the size and the exact location of the lesion are evaluated by ultrasound. The needle puncture site is selected and marked with a marking pen or other convenient tool. The direction and depth of the needle insertion are determined by ultrasound. The needle is inserted from the predetermined site without concomitant use of ultrasound visualization. This method is less precise than direct ultrasound guidance, and thus inferior. However, skin and equipment preparation is easier because disinfection or sterilization of the ultrasound transducer is not needed. An indirect ultrasound guidance method is generally used when the target lesion is relatively large, e.g., aspiration or drainage of large fluid collections such as ascites, a large cystic lesion, or biopsy of a large tumor (Figs. 7.11 and 7.12).

Direct ultrasound guidance methods allow real-time needle visualization and therefore more precise needle placement. There are two techniques of needle insertion in

Fig. 7.11 Indirect ultrasound guidance method showing ascites

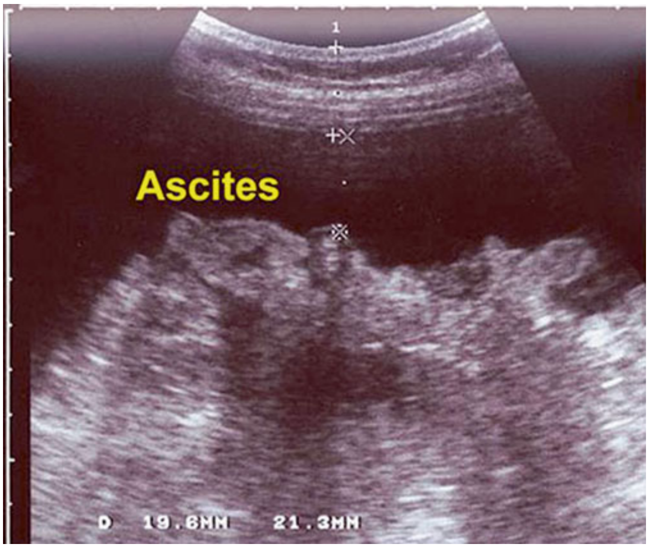

Fig. 7.12 Indirect ultrasound guidance method showing ascites

relation to the ultrasound scanning plane along the long axis of the transducer. The better and preferred technique is to insert and advance a needle in the plane parallel to the long axis of the transducer (i.e., ultrasound scanning plane). This allows for constant visualization of the shaft and tip of the needle throughout its entire path to the target. This is a safer and more accurate method because the needle tip is always demonstrated on the ultrasound monitor. The second and less preferable technique is to insert the needle perpendicular to the long axis of the transducer. This technique increases the difficulty of needle tip visualization because the tip is not seen until it enters the ultrasound scanning plane (Fig. 7.13a, b). This may increase the risk of significant past pointing of the needle tip, which may lead to complications such as pneumothorax and bleeding. For this reason, the use of this second technique should be limited to the situation in which the placement of transducer or access of the needle to the target cannot be achieved by the first technique [22].

Direct ultrasound guidance is the preferred method in interventional ultrasonography, and it can be accomplished typically in one of two ways: the "freehand" technique (Fig. 7.14) or by using the needle guidance system (so-called biopsy guide) (Fig. 7.15). In the freehand technique, the needle can be placed either adjacent to or remote from the transducer, and parallel or perpendicular to the ultrasound scanning. Another advantage of the freehand technique is that it allows independent movement of the transducer and the needle. The main disadvantage of the freehand technique is that it is sometimes difficult to keep or advance the needle within the ultrasound scanning plane for needle visualization. Various types of needle guidance systems are available. In this system, the needle is in a fixed location relative to the transducer. As a result, this guidance system allows for placement of the needle precisely along a predetermined course into the target site, which is often displayed as a needle guideline on the ultrasound monitor (Fig. 7.16). However, because of the fixation of the needle, it cannot be inserted from a remote site, which limits the usefulness of this system. Also, the transducer/needle devices can be somewhat cumbersome and more difficult to use.

Despite which technique the surgeon chooses to employ, it is the experience of the surgeon or the operator with that system that is paramount. The location and size of the target lesion will also aid one in determining which system to use. In general, more superficially located organs or lesions such as the thyroid or breast can be approached by the freehand technique. On the other hand, deeply situated lesions in locations such as the intra-abdominal organs often require a needle guidance system to access (Fig. 7.17).

Equipment

The transducers used for interventional ultrasound procedures have been either those that are biopsy dedicated or those that have the potential for needle guidance system (biopsy guide) attachment. Biopsy-dedicated transducers have fallen out of favor, primarily as a result of difficulty in needle visualization using such a transducer, but also because of the considerable difficulty in sterilizing the transducer's

Fig. 7.13 (**a**, **b**) Two techniques of needle insertion: (**a**) demonstrates parallel insertion and (**b**) demonstrates perpendicular insertion to long axis of ultrasound scanning plane

Fig. 7.14 Freehand technique

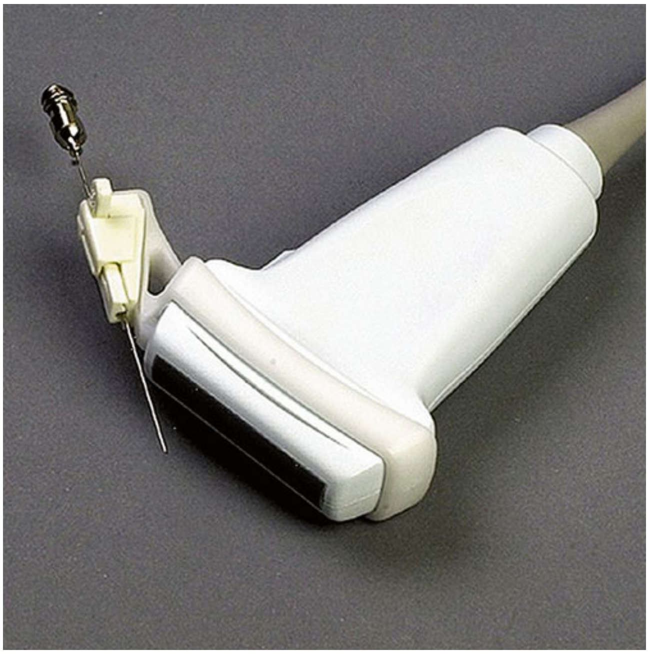

Fig. 7.15 Transducer equipped with needle guidance system

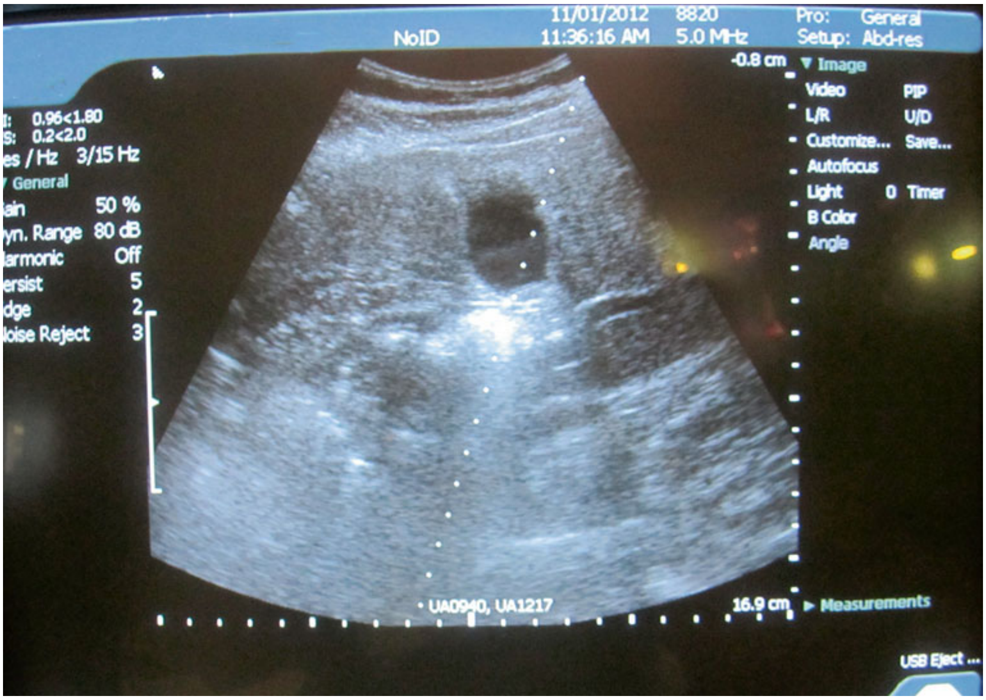

Fig. 7.16 Display of predetermined course into the target site on the monitor

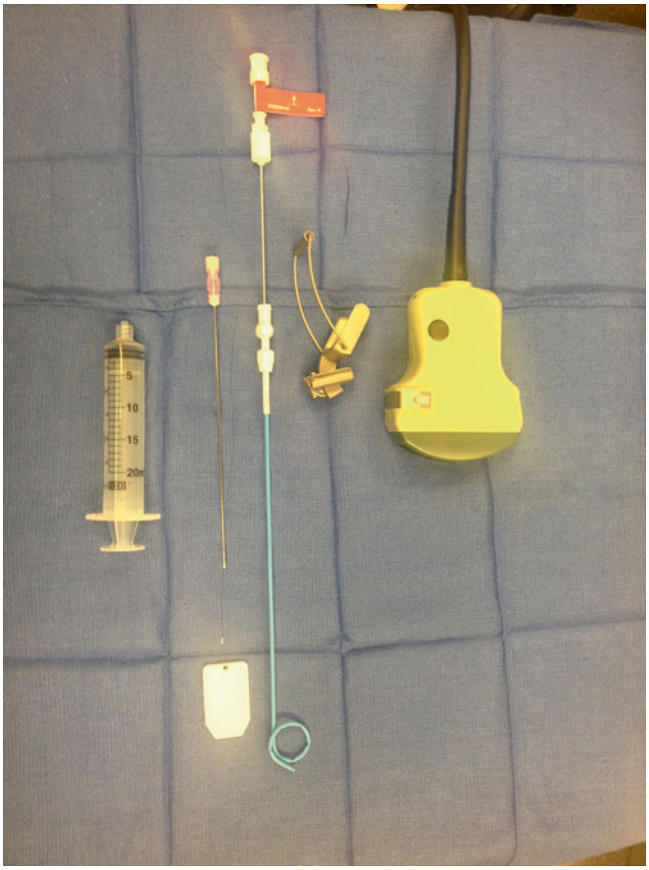

Fig. 7.17 Low-frequency transducer with needle-guided system used for percutaneous cholecystostomy

central canal. Needle guidance systems are available in multiple shapes and sizes to accommodate various types of transducers. Most systems hold the needle firmly in place along a predetermined angle. Some have variable angles of insertion, which greatly facilitates appropriate and safe approach of the needle into targets. Some systems keep the needle in the ultrasound scanning plane, but the insertion angle is not fixed. Needle guidance systems either can be reusable and require cleaning/sterilization or can be disposable.

Optimal visualization of the needle, cannula, or probe is the key for successful interventional ultrasound. Needle visualization is determined by many factors, one of which is the type of tissue or fluid. In general, needle visualization is much better in fluid than in soft tissues. Usually, the tip of needle is better visualized than the shaft. Ultrasound parameters such as transducer frequency and focal zone should be optimized to improve ultrasound image quality prior to intervention (Fig. 7.18).

Needles vary according to their echogenicity. The larger the needle diameter, the more easily it can be visualized by ultrasound. Needle echogenicity can be enhanced by maneuvers that roughen, scratch, or alter its outer surface or by coating with materials such as Teflon [25]. There are specific needles made for interventional sonography with these properties (Fig. 7.19).

Visualization of needles is dependent on the angle of needle insertion in reference to the ultrasound beam because it is determined by reflection of the sound. When the needle is placed perpendicular to the ultrasound beam (i.e., parallel to the transducer surface), much of the sound is reflected back to the transducer, thus providing better needle visualization.

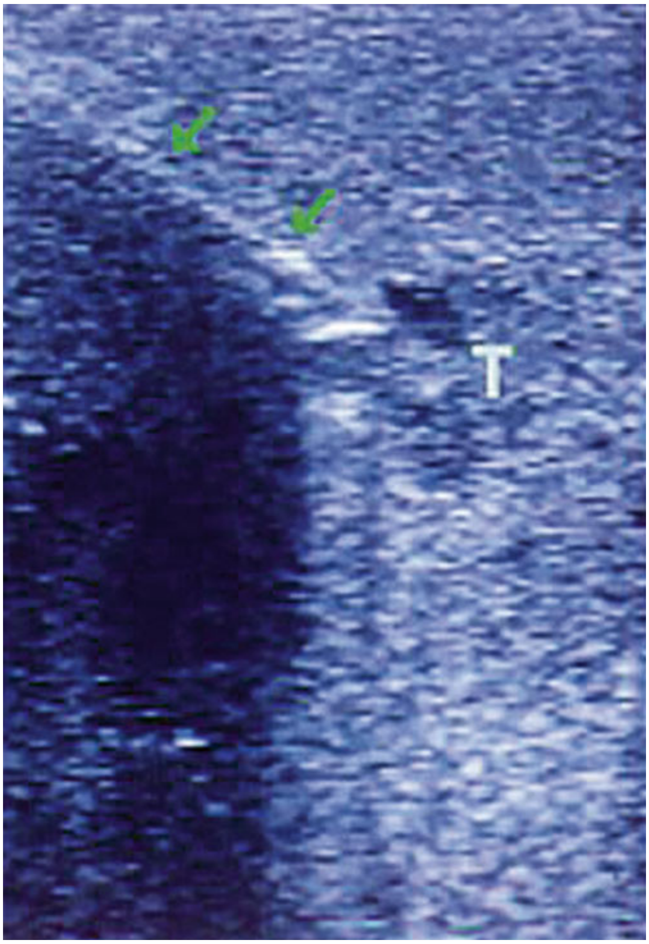

Fig. 7.18 Needle visualization during biopsy of a deep liver lesion. *Green arrow* depicts entire length of needle, note the acoustic shadowing inferior to the needle. “T” indicates lesion

Conversely, when the needle is parallel to the ultrasound beam, visualization is not as good. Another way in which the needle can be better visualized, specifically when using the freehand technique, is simply moving the needle. Also, the lumen of the needle may be made more anechoic relative to the needle wall by removal of the stylet and instillation of a fluid such as saline, thereby facilitating its visualization. Alternatively, introducing a guidewire or filling the needle lumen with air or air-gel mixture can make the lumen more echogenic. The use of color Doppler imaging when using the ultrasound can also aid in the identification and location of the needle.

There are a variety of types and gauges of needles used in interventional ultrasonography to perform the procedures described below. When a biopsy is to be obtained, determining whether or not the specimen needs to be evaluated cytologically or histologically is essential. This main division determines the type of procedure to be performed and the type/gauge of needle to be used. For core-needle biopsies for histologic examination, needles of 18 gauge or larger (up to 14 gauge) are usually required (Fig. 7.20).

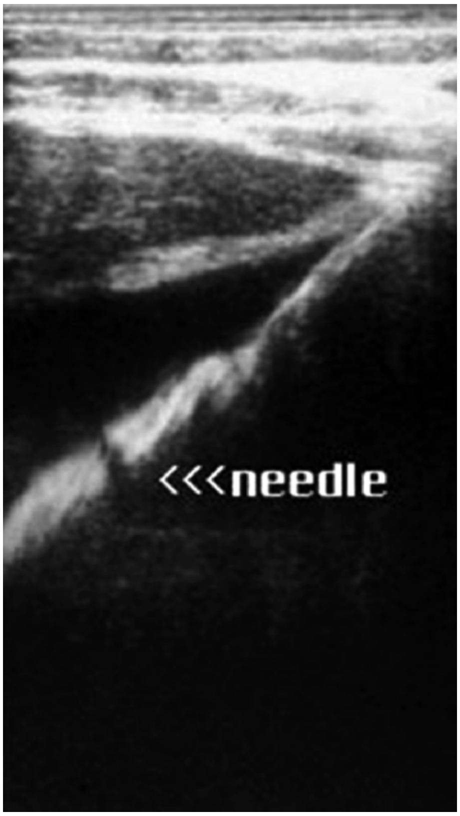

Fig. 7.19 Ultrasound image of a needle with an echogenic tip

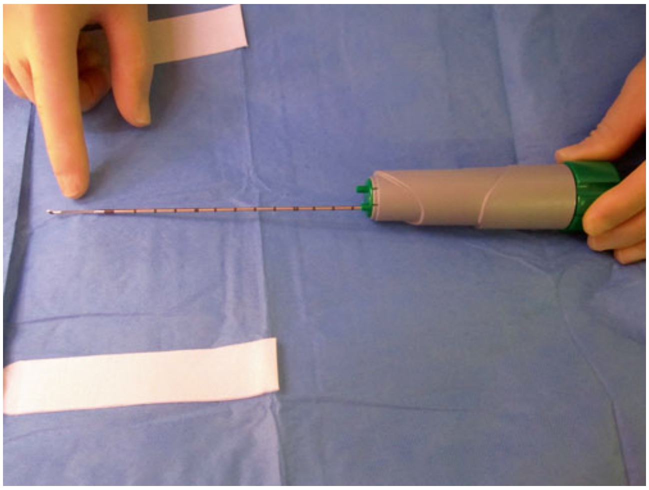

Fig. 7.20 Example of core-needle biopsy used for histologic biopsy specimens

Although there are a variety of means for distinguishing needle types, the primary discriminant involves gauge or diameter. The thin needles are those with a gauge less than or equal to 20–22, while the large-bore needles are those with a gauge greater than or equal to 18. Needles smaller than 18 gauge may safely transverse the bowel without consequent damage, whereas 18-gauge and larger needles have the potential

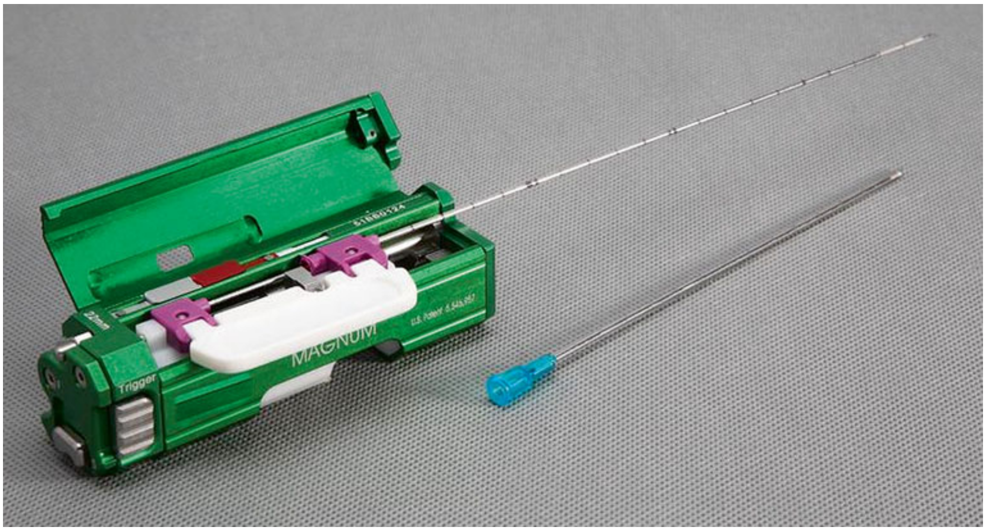

Fig. 7.21 Automatic core-needle biopsy system

to injure the bowel wall with resultant laceration and leak. Biopsy needles are available with several different tips. The needle tips fall somewhere within a spectrum that includes the spinal needle, which has an acutely angled, beveled tip, and the Greene needle, which has a non-angled, circumferentially sharpened tip. Most needle tips are somewhere between these two and have a less acutely angled end. Beveled-tip needles usually yield more suitable specimens than non-beveled ones. However, beveled-tip needles, particularly thin needles, tend to bend as they advance through tissues [22].

The use of spring-loaded automated biopsy needles is now readily available and effective (Fig. 7.21). As a result, it is now preferred over simple aspiration techniques alone. Such biopsy needles are available in a variety of gauges and specimen sizes and in both disposable and non-disposable forms; the latter may be used with single-use needles.

Procedures

Biopsy/Aspiration

Concomitant with the use of sonography as a method of guidance of needle puncture, a number of different pathologic techniques had been developed and refined. As a result, highly accurate pathologic specimen retrieval rates were seen, some with similar diagnostic accuracy rates to that of open surgical biopsies without the disadvantages and complications of surgery. Martin and Ellis and Stewart initiated the practice of aspiration cytologic examination [26, 27]. However, it was not until years later that this technique was widely applied, and it is now extensively used in almost all anatomic regions. Years later, another advancement in ultrasound-guided biopsy was the development of automated Tru-Cut-type needles. These automated Tru-Cut-type needles allowed for rapid performance of core biopsy for histologic diagnosis. These needles were described first in the prostate in 1987 and later described for use in other solid organs in 1989 [28, 29].

For aspiration or biopsy (particularly when using a needle of 20 gauge or larger), the use of a stylet within the needle is recommended to prevent contamination or obstruction of the lumen by tissue or blood clot before it reaches the target. When a relatively small amount of fluid is aspirated (e.g., aspiration of small cysts, diagnostic paracentesis), thin needles with or without stylets suffice using 5- to 20-mL syringes. Even with thin needles, when inserting through the skin is difficult, the skin may be punctured first using a no. 11 blade. When a large amount of fluid is aspirated (e.g., therapeutic paracentesis), the use of a flexible catheter (e.g., long angiocatheter) that is left in a fluid during aspiration is preferred because of a decreased risk of associated tissue injury. In addition, a three-way stopcock with tubing attached to a larger syringe (30–60 mL) is useful and convenient because the syringe need not be detached after each aspiration (Figs. 7.22 and 7.23).

FNA cytology is performed by either an aspiration or a non-aspiration method [25]. Under ultrasound guidance, a needle with a syringe attached is placed in appropriate position. Several millimeters to 1 cm of negative suction is applied to the syringe. At least three to four passes are made by withdrawing and advancing the needle back and forth 1–2 cm. The syringe is then detached and the needle withdrawn from the skin. The specimen is better if it is not aspirated into the syringe because this may cause fragmentation of cells. The specimen is then placed on a slide and smeared. A non-aspiration cytology method is performed in a similar technique. After removal of the stylet, a syringe is not attached. Several back-and-forth movements are performed. It is preferable for a cytopathologist to be available to examine the specimen immediately so that the adequacy of the specimen can be evaluated and determined (Fig. 7.24).

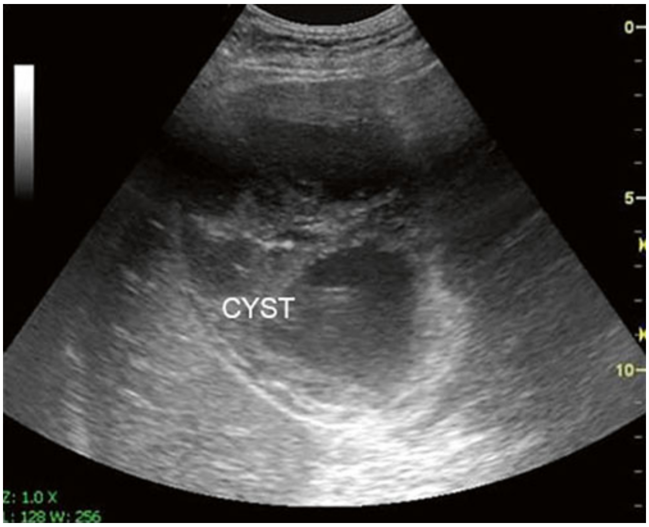

Fig. 7.22 Cyst identified by ultrasound

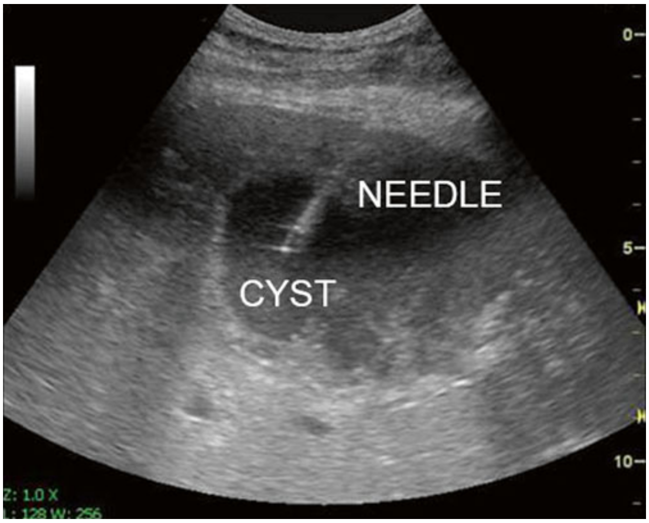

Fig. 7.23 Ultrasound-guided needle aspiration of cyst

As previously discussed, ultrasound guidance is ideal to procure core-needle biopsy specimens. For core-needle biopsy, availability of a pathologist for immediate frozen-section examination is also helpful. If such an examination is not possible, at least three or four core-needle specimens should be obtained from the lesion.

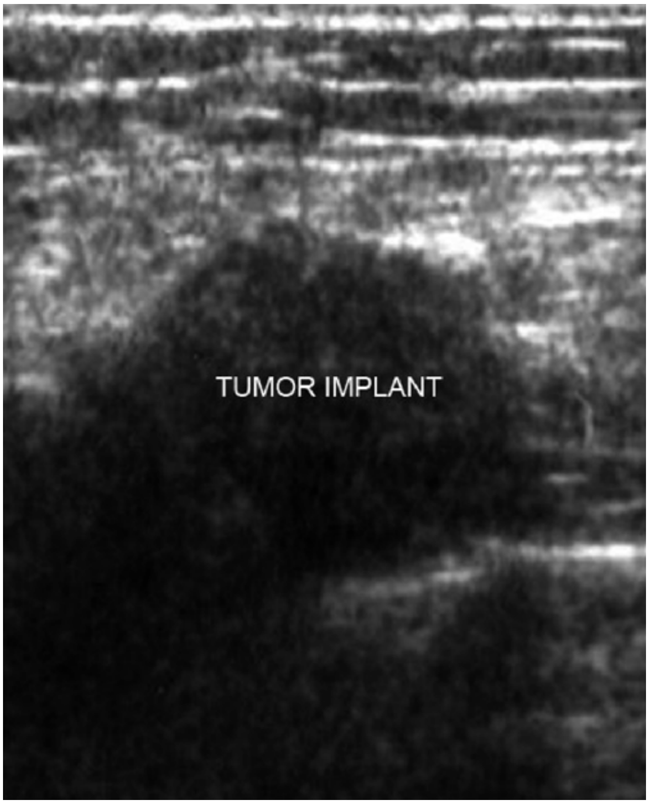

Fig. 7.24 Abdominal wall tumor implant following colectomy for carcinoma

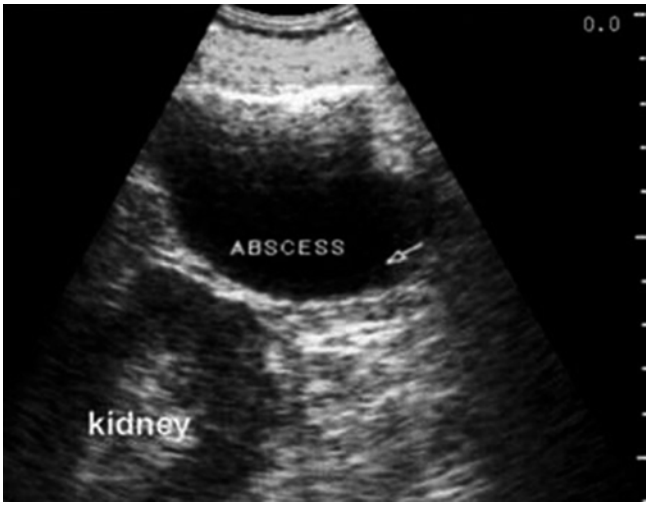

Fig. 7.25 Intra-abdominal abscess

Drainage

Percutaneous sonographically guided fluid aspiration/drainage techniques are applied to almost all areas of the body and allow the surgeon to treat a variety of pathology throughout the body. Again, Goldberg and Pollack first described sonographically guided thoracentesis and paracentesis as early as 1972. Holm et al. described the use of ultrasound to aspirate fluid collections throughout the chest and abdomen. These included aspiration of pericardial fluid, thoracentesis, paracentesis, and amniocentesis. Holm et al. also described abdominal abscess aspiration guided by sonography (Figs. 7.25 and 7.26). At the onset of interventional sonography, the majority of procedures being performed were obstetric and renal

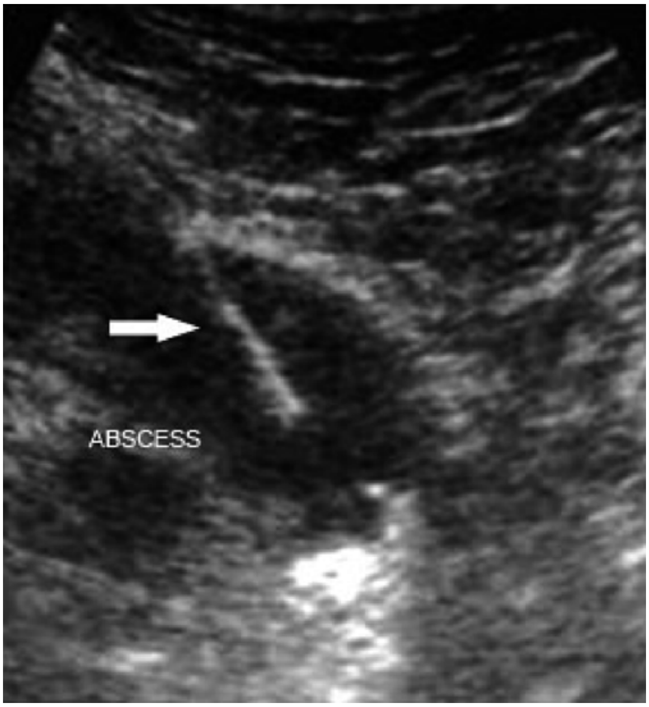

Fig. 7.26 Example of ultrasound-guided abscess drainage. *Arrow* indicates needle

in origin. However, this soon evolved into use in the hepatobiliary tree, an area of particular interest to the surgeon. Cholangiographic techniques guided by sonography were described in 1978 by Makuuchi et al., including percutaneous transhepatic cholangiography [30]. After the initial applications of ultrasound-guided techniques proved to be extremely useful and successful, its uses grew exponentially. These included, among other procedures, pericardiocentesis, empyema drainage, pleural sclerotherapy, abdomen abscess drainage, transhepatic cholangiography, biliary drainage, cholecystostomy, cyst sclerosis, gastrostomy, nephrostomy, nephroureterolithotomy, and sonographically guided arterial and venous catheterization techniques (Fig. 7.27).

Various types of catheters and needle-catheter systems are commercially available for drainage. Two fundamental ultrasound-guided catheter placement methods are a guidewire exchange technique and a trocar technique [25]. A guidewire exchange technique (or Seldinger technique) is more commonly used. A large needle (usually 18 gauge) is introduced into the target lesion or organ under ultrasound guidance. A guidewire is introduced through the needle, and the needle is removed. The tract is then progressively dilated over the wire. Once the tract is appropriately dilated, a catheter is introduced and advanced into the lesion or organ. Ultrasound can be used to confirm the location of the catheter in the lesion (Fig. 7.28).

A trocar technique employs a special needle-catheter unit (e.g., McGahan drainage catheter), which includes a pigtail catheter, a cannula, an inner blunted obturator, and a sharp inner stylet [23]. Under ultrasound guidance, the unit is inserted through the skin and advanced. Once the tip of the cannula is confirmed to be in the lesion or organ, the catheter is pushed from the cannula. Reformation of a loop of the pigtail catheter can be visualized by ultrasound. In general, catheters are more difficult to visualize than needles [22] (Figs. 7.29 and 7.30).

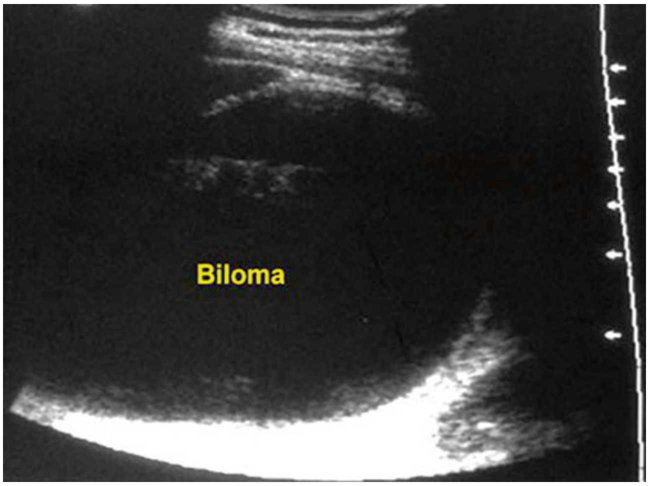

Fig. 7.27 Ultrasound-guided drainage of postoperative biloma

One of the most common applications for ultrasound is the evaluation and treatment of acute cholecystitis. In some circumstances, patients may present with a diagnosis of acute cholecystitis and not being able to tolerate a cholecystectomy. The surgeon can use ultrasound to confirm the diagnosis and to perform a percutaneous cholecystostomy. Such would be the case in critically ill patients and patients following major cardiovascular procedures, etc. There are numerous indications for a percutaneous cholecystostomy besides those who cannot tolerate an operation in the setting of acute biliary sepsis. Because of this continued need, it is essential the surgeon is familiar with ultrasound of the hepatobiliary system and percutaneous interventions. Ultrasound is the least invasive radiologic modality for imaging the liver and biliary tract. Unlike CT scanning and MRI, the technique is portable and quick and can be used to guide interventional procedures. Ultrasound uses no ionizing radiation to create the image and is therefore the technique of choice in pregnant women, in patients with contrast.

When performing a percutaneous cholecystostomy, a catheter is inserted percutaneously under ultrasonographic guidance. First, the gallbladder is located ultrasonographically, and a transparietal puncture is performed by passing a Seldinger needle through the hepatic parenchyma and into the gallbladder. A sample of gallbladder fluid is collected for microbiology and culture. Typically, an 8.5-F pigtail catheter is then placed under US guidance via a two-step method

Fig. 7.28 Kit for ultrasound-guided drainage of intra-abdominal collections

Fig. 7.29 *Arrow* points to needle used to drain cyst

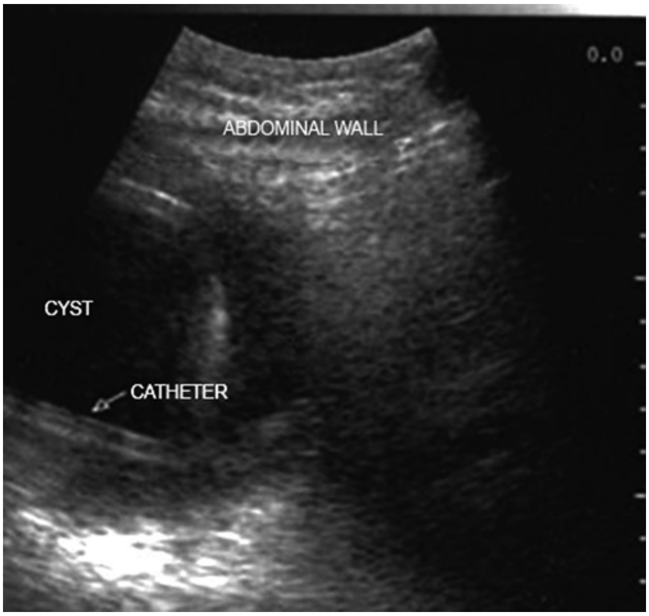

Fig. 7.30 Ultrasound confirming catheter placement

involving guidewire exchange. After all bile is aspirated from the gallbladder, cholecystography is usually performed via the catheter to confirm the type of pathology present (calculous or acalculous cholecystitis). The catheter is left in place for drainage and is flushed with saline solution. Repeat cholecystography can then be performed at the bedside is needed via the cholecystostomy tube to investigate cystic duct patency and assess the common bile duct (Figs. 7.31, 7.32, 7.33 and 7.34).

An additional indication for ultrasound-guided aspiration is in the setting of a symptomatic postoperative fluid collection after laparoscopic or open hernia repair. Abdominal wall hernia repair is one of the most common surgical procedures worldwide. The use of mesh has been adopted as an important adjunct in the management of abdominal wall hernias. One of the most common complications following repair is an increased incidence of seroma formation with a reported incidence as high as 50 % following laparoscopic ventral herniorrhaphy. Wound complications after herniorrhaphy that result in the need for mesh excision have a high morbidity. In case of large fluid collections following hernia repair, ultrasound facilitates diagnosis and guides aspiration and even catheter drainage as needed. Furthermore, aspiration of fluid collection can facilitate diagnosis and management of suspected infected fluid collections (Fig. 7.35) [31, 32].

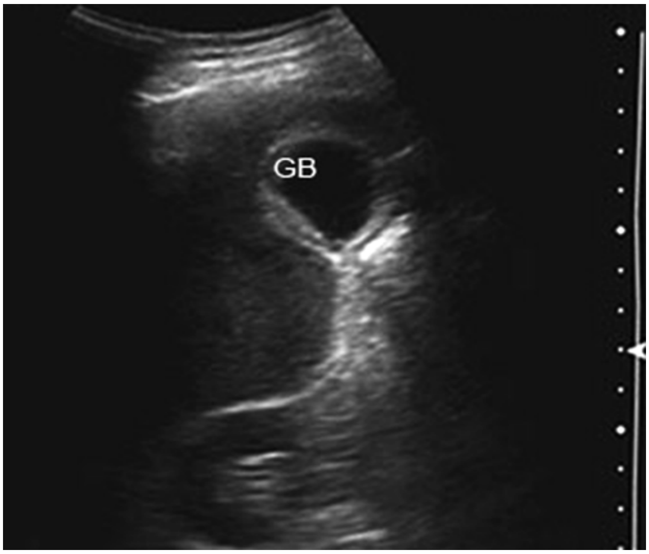

Fig. 7.31 Acute cholecystitis. *GB* Gallbladder

Ablation

Initially, ultrasound was used to guide puncture and instillation of sclerosing agents into renal cysts or recurrent lymphoceles; however, this technique can be applied to the sclerosis of cysts elsewhere in the body. Various agents have been used for sclerosis, including alcohol, povidone iodine, autologous clots, hot saline, and other agents. Ultrasound is used to guide puncture and aspiration of cyst content. To rule out the possibility of communication between the cyst and other structures, fluoroscopy can be used. Once ruled out, the cyst can be sclerosed under ultrasound, followed again by respiration. These techniques have proved more successful than simple cyst aspiration alone in permanent cyst or lymphocyst sclerosis [33].

In addition to cyst ablation, ultrasound has been used for ablation of soft tissue masses. Initially, this was done with alcohol alone. For the surgeon, this proved particularly useful in the thyroid, parathyroid, prostate, and liver. Sonographically guided ethanol injection has been used for ablation of hepatocellular carcinoma. In 1992, Livraghi et al. showed that patients with small hepatocellular carcinoma treated with absolute alcohol injections had better survival rates than those who underwent surgery [34]. Livraghi et al.

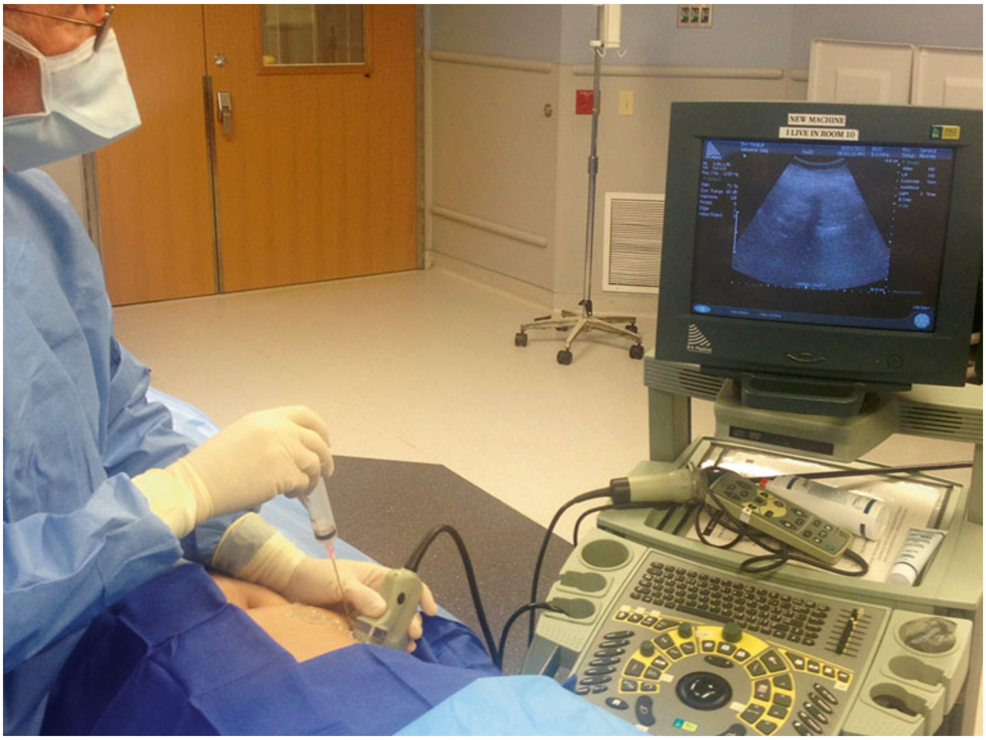

Fig. 7.32 Ultrasound-guided aspiration of gallbladder using a freehand technique

Fig. 7.33 Ultrasound-guided aspiration of gallbladder using a freehand technique

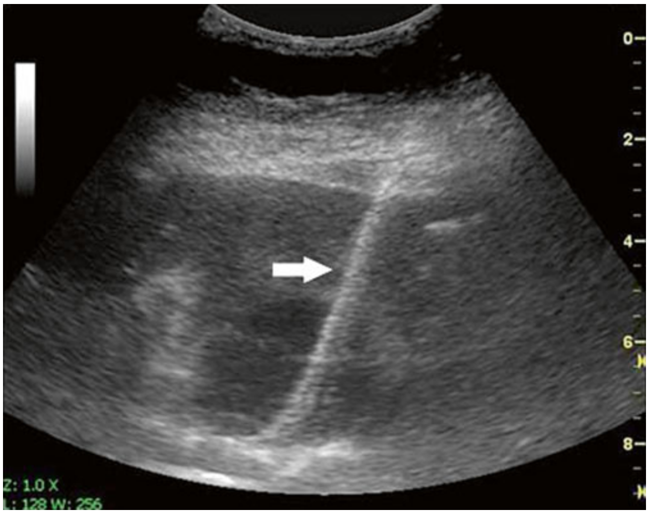

Fig. 7.34 Cholecystostomy catheter in place (*arrow*)

Fig. 7.35 Seroma following abdominal wall hernia. *Arrow* points to mesh

injected small amounts of absolute alcohol into hepatomas smaller than 3 cm in diameter. After injection, there is an increased echogenicity with dispersion of the alcohol in the tumor. This procedure, which is totally guided by sonography, is well tolerated by patients who have had low complication rates. It is still considered an effective alternative to surgery (Fig. 7.36).

Other types of tissue ablation that have been described under ultrasound guidance include microwave ablation, laser coagulation, and cryotherapy. Cryoablation of hepatic lesions was initially performed under sonographic guidance during laparotomy. More recently, with smaller probe designs, cryoablation can be performed percutaneously with sonographic guidance. When freezing a tissue, a very echogenic rim corresponding to the freeze zone is observed on sonography (Fig. 7.7). In 1990, two groups independently described the use of percutaneous ablation of liver tissue using radiofrequency waves: McGahan et al. and Rossi et al. described the use of a monopolar needle that was insulated

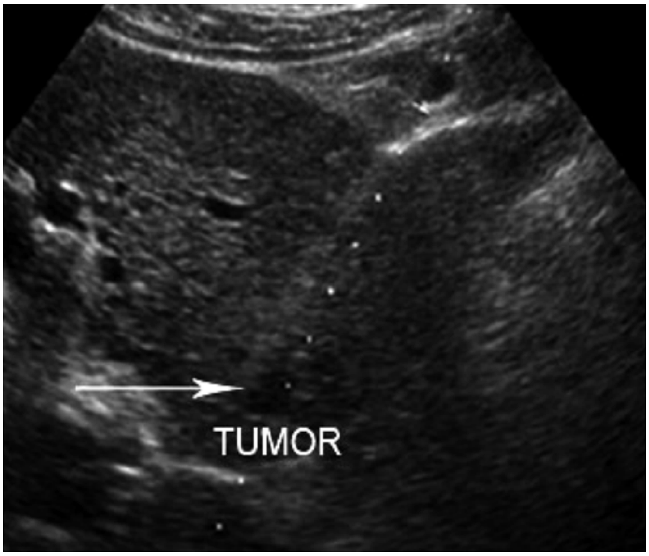

Fig. 7.36 Ultrasound showing needle used for ethanol tumor ablation of hepatocellular carcinoma

at the distal tip to cause local tissue coagulation in the liver [35, 36]. This coagulation occurred at the needle tip, where radiofrequency energy was most concentrated. This technique was then later applied in ablating primary liver tumors in patients undergoing hepatic resections, as well as metastatic liver lesions. Radiofrequency electrocautery, guided by sonography, has been used to ablate tumors in the brain, thyroid, liver, kidney, and other sites. It has become a well-accepted, less invasive method of treatment of tumors throughout the body.

Radiofrequency thermal ablation management of abdominal pathology such as tumors of the liver can be performed percutaneously, laparoscopically, or via laparotomy [21]. Surgeons should use different approaches appropriately depending on the condition of patients and tumors to be ablated.

With ultrasound guidance, cannulas or needles (ranging from 14 to 18 gauge) are inserted into the tumor under needle guidance. The percutaneous approach has the advantage of being less invasive, possibly can be performed on an outpatient basis. However, it is less accurate in cancer staging, and some areas may not be easily accessible. In addition, it could result in possible adjacent thermal organ injury. Ultrasound allows for the advantage to monitor the region being ablated in real time, but in order to accurately do this, the tip of the needle must be confirmed at a specific location within the lesion prior to initiation. The ablated region becomes hyperechoic; however, this area does not always directly correspond to the true area of ablation. Depending on the size of the tumor and the achievable size of ablation, a single ablation or multiple overlapping ablation sessions are performed. A disadvantage of this technique is the hyperechoic area obscures the ultrasound images around the tumor, limiting surrounding visualization. Therefore, it is critical to make a good plan for multiple ablation sessions before the first ablation starts. When the cannula is withdrawn at the completion of ablation, the cannula track is also ablated under ultrasound visualization to prevent bleeding and possible tumor seeding. If color or power Doppler imaging demonstrates intra-tumoral blood flow prior to ablation, Doppler imaging can be repeated after ablation to confirm loss of blood flow within the tumor [37] (Figs. 7.37 and 7.38).

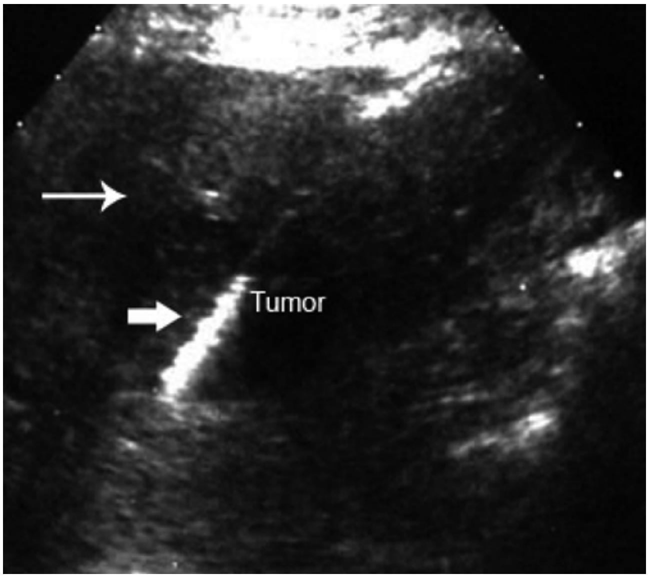

Fig. 7.37 Radiofrequency ablation of mass in the liver, tip of catheter seen in the mass with hyperechoic tip and “prongs” extended

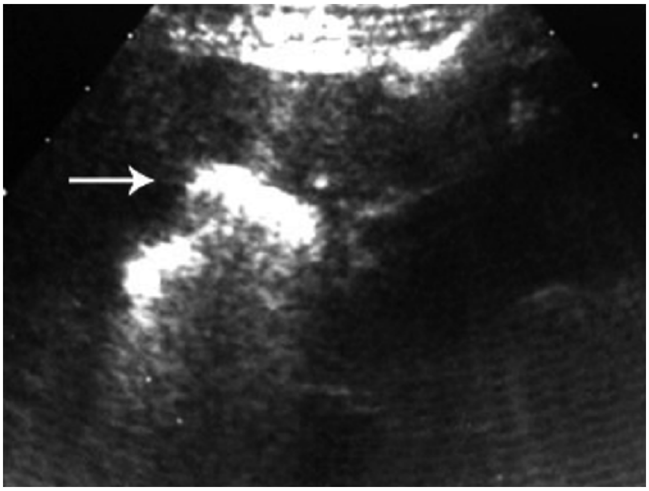

Fig. 7.38 Post-ablation of liver mass with hyperechoic residual effect (*arrow*)

Microwave ablation (MW) is a treatment option for the management of many cancers. Frequencies of the electromagnetic spectrum between 915 MHz and 2.45 GHz have been most frequently used for ablation procedures. Recently, higher frequencies have been applied in an effort to achieve better outcomes. Preliminary reports indicate that this technology can be safely applied to the management of

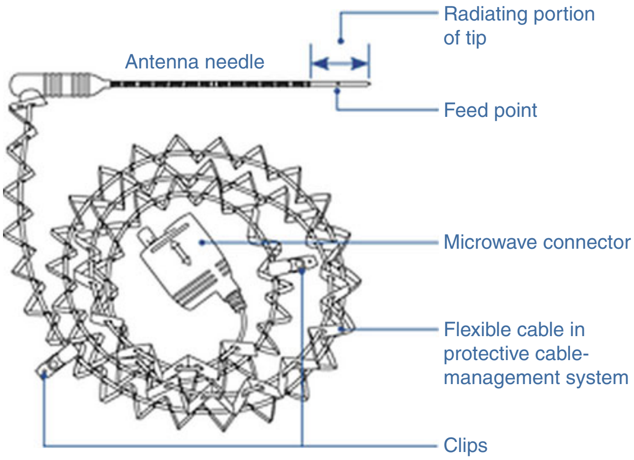

Fig. 7.39 Microwave ablation probe

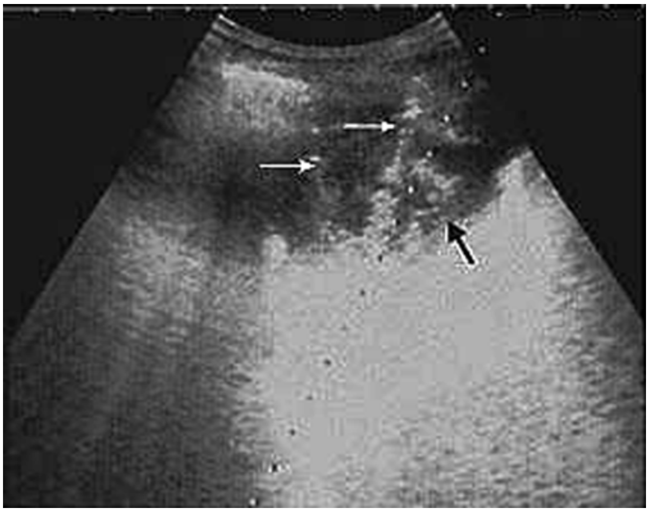

Fig. 7.40 Microwave ablation of liver tumor showing echoic effect. *Arrows* point to area of ablation

patients with bone, kidney, liver, and prostate tumors [38]. Microwave energy differs from other energies for thermal therapy in a number of ways. The most important is that microwaves propagate through all type of tissues, including water vapor, and dehydrated, charred, and dessicated tissues. During radiofrequency, laser, and ultrasound energies ablation, high-temperature heating of tissues can inhibit energy application unless the tissue is cooled and/or rehydrated. Furthermore, MW can ablate up to 3 mm in diameter vessels as opposed to radiofrequency ablation. A single application will ablate liver tumors between 3 and 4 cm in diameter. Liver tumors up to 7 cm can be successfully ablated provided multiple MW antennas are used. However, these properties require real-life monitoring of the ablative procedure to capture rapid heating and tissue changes since energy is rapidly absorbed. Thus, ultrasound guidance and monitoring of thermal ablation is paramount to the success of the procedure [39].

Microwave ablation requires an antenna usually composed of an applicator with a rigid shaft and distal radiating section (Fig. 7.39). Antenna properties include radiation pattern and reflection coefficient. Recently, antenna cooling has been utilized in an effort to eliminate excessive heat generation in the applicator, thus permitting the passage of higher power through the antenna and resulting in larger ablation zones. The primary benefit of using MW ablation in the liver appears to be the ability to overcome large heat sinks due to the vascularity of this organ. In a recently published series of 1,136 patients with 1,928 malignant liver tumors treated with percutaneous MW ablation, Liang et al. reported successful completion of the ablation with minimal mortality, 0.2 %, and major morbidity of 2.6 % of patients. Ultrasound guidance is used for guided biopsy, for introduction of the MW antenna (S), and for monitoring the ablation zone [40]. Ultrasound allows real-time monitoring of the ablation and facilitates identification of the treated zone by showing hyperechoic microbubbles enveloping the treated area (Fig. 7.40) (please refer to Chap. 17 for further information).

Conclusion

The use of ultrasound beyond diagnosis of abdominal conditions is now widely accepted. Surgeons can use interventional ultrasound for diagnostic and therapeutic purposes in most areas of the body. Indications for interventional ultrasound in the abdomen include but are not limited to aspiration, biopsy, drainage, placement of catheters, and tumor ablation. The portability, safety, low cost, and ability to observe a procedure on real time make ultrasound an ideal technology to embrace and master. Introduction of guiding systems, better automatic biopsy needles, and the increased utilization of ablation in the surgical field make learning these techniques an absolute necessity for the practicing surgeon. Furthermore, interventional ultrasound can be an effective and efficient adjunct to the surgeon in the operative approach to various intra-abdominal conditions. Both open and laparoscopic approaches to the management of hepatobiliary and pancreatic disease benefit from the use of ultrasound. The field of surgery is constantly evolving and interventional sonography continues to grow with it. As more applications for this field continue to be discovered, this will only further the practice of surgery.

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