Laparoscopic Ultrasound: A Valuable Adjunct to Laparoscopic Surgery

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Laparoscopic ultrasound represents a recent merger in the laparoscopic technology and intraoperative ultrasound and shows a diagnostic accuracy higher than preoperative studies. Laparoscopic ultrasound can be used during laparoscopic cholecystectomy to screen the bile duct. It is particularly useful for diagnosing and staging malignancies, including hepatobiliary, pancreatic and gastroesophageal cancers. By demonstrating the interior of organs and deep structures, it can compensate for the limitation of laparoscopic examination. Laparoscopic ultrasound will become a valuable adjunct to laparoscopic surgery.

Laparoscopic surgery has a number of advantages including minimal invasiveness or operative trauma, less pain, quicker recovery and return to normal activity, and shorter hospitalization. In comparison to conventional open surgery, however, laparoscopic procedures possess certain disadvantages such as lack of binocular vision and restricted freedom of instrument movement. A major limitation is the lack of sufficient tactile feedback from the tissues. During laparoscopic surgery, surgeons are unable to palpate organs directly. Intraoperative examinations of deep tissues or retroperitoneal structures are difficult or impossible. These limitations of laparoscopy may result in decreased accuracy in intraoperative examination and increased operating time.

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Intraoperative ultrasound, the use of ultrasound during open surgery, has proven invaluable during various abdominal operations.[1-3] The main advantage of intraoperative ultrasound is the high diagnostic accuracy due to high-frequency, high-resolution instruments employed. For example, the accuracy of intraoperative ultrasound is equal to or superior to intraoperative cholangiography in screening bile duct calculi during open cholecystectomy. It is the most accurate method for detecting liver metastases or localizing islet cell tumors, exceeding the sensitivity of intraoperative inspection and palpation by surgeons. The stage and resectability of hepatobiliary, pancreatic or other abdominal cancers can be determined more precisely than by preoperative tests. Thus, intraoperative ultrasound helps surgical decision-making, and occasionally alters planned surgical procedures. In addition, with its guidance capability, intraoperative ultrasound enables procedures such as needle biopsy of nonpalpable tumors or facilitates hepatic resection or ablative treatment of tumors.

Laparoscopic ultrasound (LUS) is one form of intraoperative ultrasound that represents a merger in the laparoscopic and intraoperative ultrasound technologies. LUS utilizes the same high-frequency instruments that provide high-resolution images. This ultrasound technique allows surgeons to visualize the interior of organs and deep structures, thereby compensating for the limitation of laparoscopic examination. With increasing number of laparoscopic procedures being performed, the application of LUS to laparoscopic surgery is a logical extension of intraoperative ultrasound.

History

LUS using A-mode (one-dimensional) ultrasound was first attempted by Japanese investigators in the 1960s, for the diagnosis of gallstones or liver tumors. In the early to mid-1980s, several prototype LUS probes using B-mode (two-dimensional) ultrasound were developed in Japan and Europe.[4-6] In spite of excellent images obtained by these prototype probes, LUS was not widely accepted in the 1980s, mainly because of declined interest in diagnostic laparoscopy among surgeons. However, shortly after the explosion of laparoscopic surgery with a video laparoscope, interest in LUS was rekindled in the early 1990s. Initially, LUS was introduced during laparoscopic cholecystectomy to screen the bile duct. Subsequently, LUS was performed for staging of abdominal malignancies and for diagnosing hepatic or pancreatic lesions. During the last several years, numerous experiences with LUS have been reported.

Instruments

Current LUS instruments employ a high-frequency (5 to 10 MHz) real-time B-mode ultrasound system, which is basically the same as

Fig 1.—Flexible laparoscopic ultrasound probe with side-viewing linear-array transducers, which are electronically interchangeable from 5 to 7 to 8 MHz.

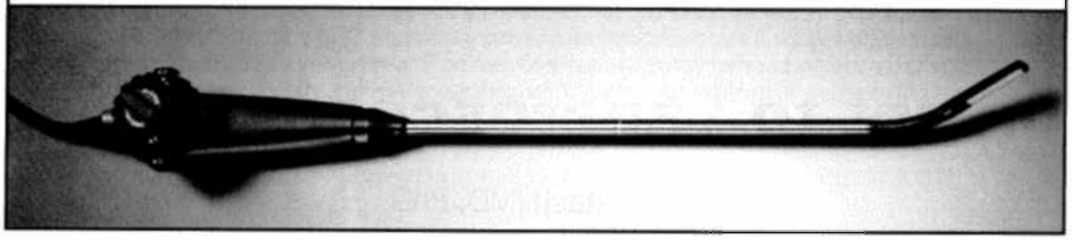


Fig 2.— Multiple small calculi (arrowheads) were detected in the intrapancreatic portion of the bile duct (BD) by laparoscopic ultrasound during laparoscopic cholecystectomy. P = pancreas, S = acoustic shadow of calculi.

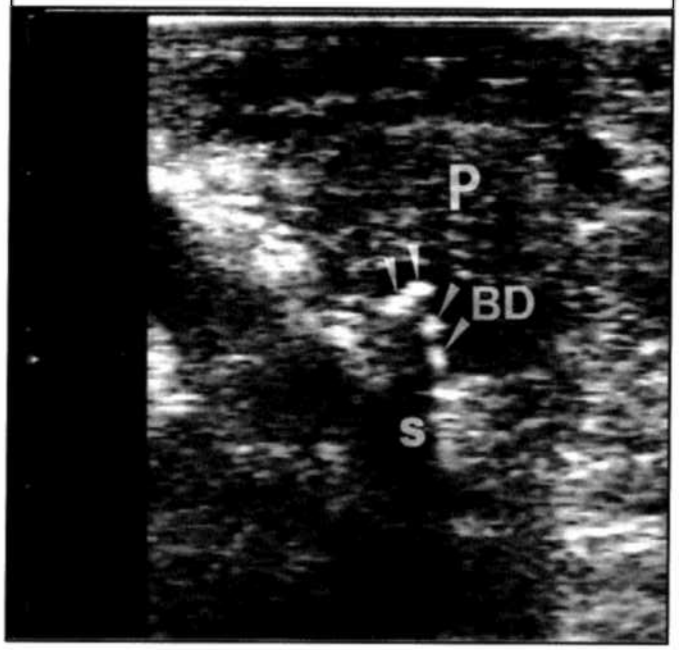
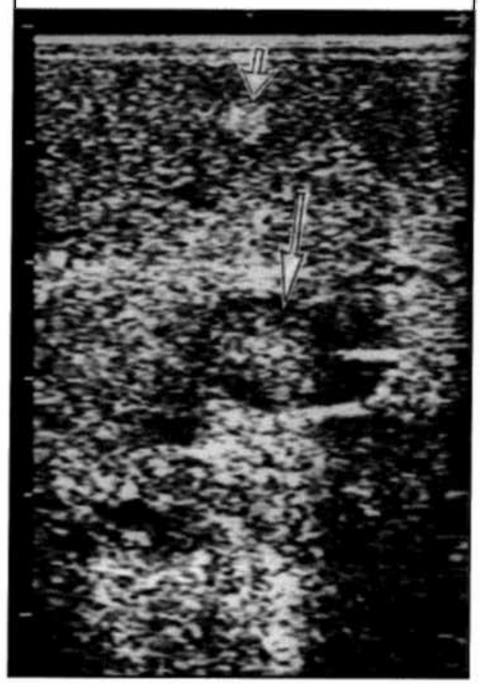


Fig 3.—Invisible metastatic tumors (arrow), 5mm and 12mm in size, were detected in the right lobe of the liver by laparoscopic ultrasound during exploratory laparoscopy for a pancreatic cancer.

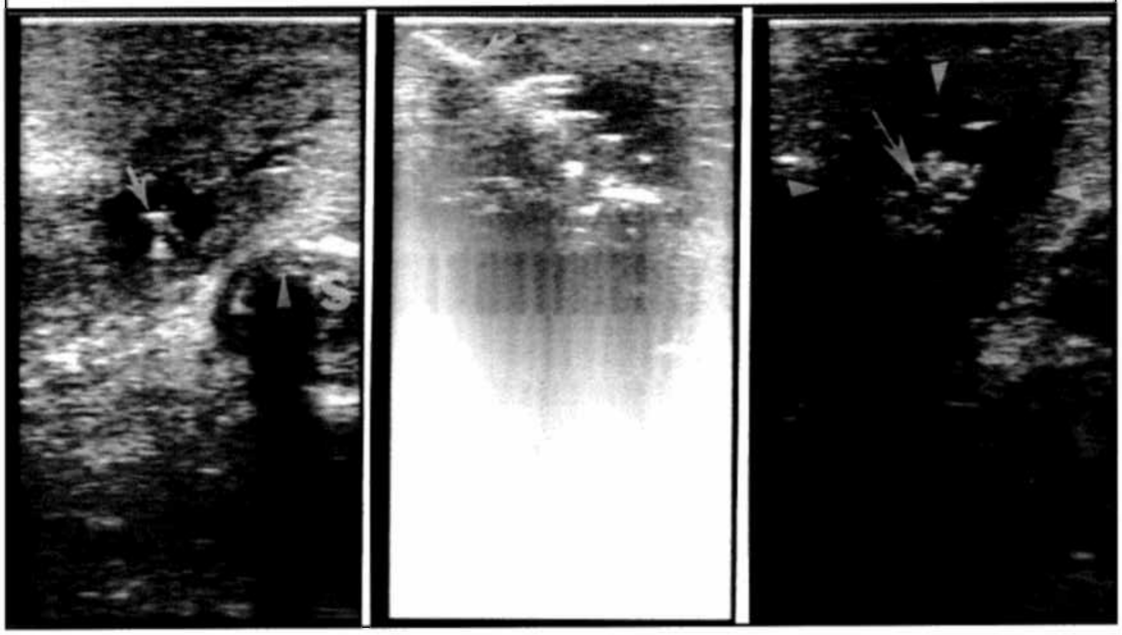


intraoperative ultrasound.[1,2] Certain systems have a capability of duplex ultrasound (B-mode plus Doppler spectrum) or color Doppler imaging (display of blood flow in color on B-mode images), which facilitates quicker identification of blood vessels. A probe consists of transducers mounted on or near the tip of a slender shaft. It is usually 10mm in diameter and 40 to 70cm in length, and is introduced into the peritoneal cavity via a 10mm trocar, after cold gas sterilization. Several types of LUS system-probes are presently available. A system provides linear-array (producing rectangular images), convex or sector (producing pie-or fan-shaped images) transducers. A probe can be either front-viewing (scanning plane parallel to the probe shaft) or side-viewing (scanning plane at the right angle with the shaft). A front-viewing sector probe is suitable for scanning of the extrahepatic bile duct or the pancreas whereas a side-viewing convex or linear-array probe is essential for scanning of the liver. A rigid-shaft probe was originally made by manufactures; currently, a flexible probe is also available. This has a flexible tip that is mobile in two or four directions (Figure 1). Although technically more demanding, a flexible probe facilitates scanning of areas that are difficult to delineate with a rigid probe (e.g., behind the dome of the liver), reduces the number of trocar insertion sites, and decreases the scanning time.

Clinical Applications

It is easily understandable that after rapid widespread performance of laparoscopic cholecystectomy in the early 1990s LUS was first introduced for examination of the biliary tract. Initial experiences demonstrated the technical feasibility of LUS to delineate the biliary anatomy and to detect bile duct calculi.[7-10] Since then, several prospective trials have compared LUS with intraoperative cholangiography (that is a current standard) during laparoscopic cholecystectomy.[11-15] LUS, once learned, required less time than intraoperative cholangiography (5 to 10 minutes versus 10 to 15 minutes). The accuracies (sensitivity and specificity) of both tests in diagnosing bile duct calculi showed no significant difference (Figure 2). An anatomic definition of the biliary tract (e.g., detection of bile duct

Fig 4.– Laparoscopic radiofrequency thermal ablation of a liver tumor guided and monitored by laparoscopic ultrasound. The tumor was detected in the lateral segment by preoperative computed tomography, but was not visible during laparoscopy. Left: The tumor was localized near the posterior surface of the liver, and a cannula (arrow) was inserted in the center of the tumor. S = stomach, arrowhead = a nasogastric tube. Center: During radiofrequency thermal ablation, ablated areas became hyperechoic due to outgassing. A radiofrequency artifact was also seen. Arrow = a shaft of the cannula. Right: After completion of thermal ablation. Arrowheads indicate ablated areas. Arrow = remaining gasses in the center of ablated areas.



anomalies) was slightly better provided by intraoperative cholangiography, while the surrounding structures such as the hepatic artery and portal vein were imaged only by LUS. Overall, LUS and intraoperative cholangiography are considered complementary to each other. Because of its safety and quickness, LUS can be the first-choice method for screening bile duct calculi; intraoperative cholangiography can be used selectively when LUS is incomplete or inconclusive or when the biliary anatomy needs to be clearly defined (e.g., suspicion of bile duct anomaly).

Laparoscopic exploration provides diagnostic information not obtainable by preoperative studies, and is considered an effective modality for diagnosing and staging abdominal malignancies. In many recent studies, laparoscopy has been shown to more correctly predict resectability of malignancies including hepatobiliary, pancreatic, and gastrointestinal cancers, and thereby to decrease remarkably the incidence of unnecessary laparotomy for unresectable cancers. Because of the known limitation of diagnostic laparoscopy, LUS has been lately introduced as an adjunct to laparoscopy for various abdominal malignancies. LUS provides surgeons with information that cannot be obtained by laparoscopic exploration alone. LUS can detect lesions located deeply in an organ such as the liver and pancreas; for example, invisible metastatic liver tumors can be diagnosed (Figure 3). Tumor invasion into surrounding structures, mainly major blood vessels, can be evaluated. Prior to extensive tissue dissection, LUS can identify enlarged or suspicious lymph nodes; this is difficult with laparoscopic visual examination alone. The information regarding cancer spread provided by LUS is similar to that by intraoperative ultrasound during open surgery. Several studies reported during the last few years demonstrated that LUS provided staging information in addition to that derived from laparoscopy alone in 10 to 40% of patients with liver, biliary, pancreatic and gastroesophageal cancers.[16-22] In these studies, because of better LUS staging the predicted resectability was higher than 90 to 95%, confirmed by subsequent laparotomy.

There are a number of other applications suggested by recent reports of LUS during laparoscopic exploration or laparoscopic surgery. These include evaluation of gallbladder polyps, detection or definition of pancreatic pseudocysts, localization of pancreatic islet cell tumors, assistance during surgery of liver cysts, assistance during adrenal tumor resection, and evaluation of retroperitoneal tumors.

Intraoperative ultrasound has been used for guidance of various surgical procedures such as needle, cannula or probe placement and tissue dissection or resection. Such guidance techniques (so-called interventional ultrasound) can be used with LUS. LUS can guide a needle into target lesions for biopsy of tumors (e.g., liver or pancreatic tumors) or lymph nodes and for aspiration of cystic lesions. Non-resectional treatment of liver tumors such as laparoscopic cryoablation or thermal ablation that has been developed recently cannot be completed without LUS.[23-25] In these procedures, cannula or probe placement is guided by LUS, and the treatment process is monitored by LUS images (Figure 4). LUS-guided laparoscopic resection of tumors (e.g., partial hepatic resection) has been reported.

Perspective

Although technically more demanding than intraoperative ultrasound during open surgery, LUS, when appropriately performed, can provide versatile information and compensate for the limitation of laparoscopy. During laparoscopic cholecystectomy, LUS can be used as complement or alternative to intraoperative cholangiography: By using LUS as a first-choice screening method, the requirement for intraoperative cholangiography will be significantly reduced. During exploratory laparoscopy immediately prior to planned laparotomy for abdominal malignancies, in particular liver and pancreatic cancers, LUS can extend the diagnostic staging ability of laparoscopic surgeons, and thus can eliminate the need for laparotomy in many patients with unresectable cancers. In selected patients with liver tumors who are not candidates for surgical resection, laparoscopic ablation treatment with LUS guidance can be offered. At present, laparoscopic cancer surgery (e.g., laparoscopic colectomy for colon cancer) is being investigated by clinical trials. Once patients undergo laparoscopic resection of primary abdominal cancers, LUS will have a role, especially in examining the liver for metastasis.

Laparoscopic technology continues to advance rapidly, and laparoscopic surgery continues to apply to the larger numbers and various types of abdominal diseases. As well, ultrasound technology is advancing, e.g., 3-dimensional ultrasound and ultrasound contrast enhancement; such a technology may soon be introduced to intraoperative ultrasound, and possesses a variety of potentials. As technology is evolving and its applications are expanding in both laparoscopy and ultrasound, LUS as a new modality must be assessed carefully to better define its role (and also its limitation) in improving laparoscopic operations and patient outcome. LUS, when appropriately utilized, will show great promise as a valuable adjunct to laparoscopic surgery.

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