Color Doppler Application in Laparoscopic Intraoperative Ultrasonography

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During the past decade, several investigators reported effective application of intraoperative ultrasonography as a new diagnostic modality in surgery. Intraoperative ultrasonography has been successfully applied in the screening of the biliary tract and in the examination of the liver, pancreas, urinary tract, and endocrine organs. It has also been used successfully during vascular surgery.[1-4] With the advent of minimal access surgery, the application of expensive preoperative diagnostic tests has visibly increased, particularly the use of ERCP procedures in patients with cholecystolithiasis. The loss of tactile feedback during laparoscopic surgery for gastrointestinal malignancy stimulated the increasing use of CT and MRI imaging. With our prior experience in intraoperative ultrasonography and in the advent of minimal access surgery, we were stimulated to introduce laparoscopic intraoperative ultrasonography (LIOU) in 1990 for screening the biliary tract for laparoscopic cholecystectomy.[5,6] More reports on the use of laparoscopic intraoperative ultrasonography followed.[7-10]

A recent review of laparoscopic ultrasonography in this new modality implied that LIOU could contribute to surgical decision making during various procedures such as laparoscopic cholecystectomy, staging laparoscopy, and other laparoscopic operations.[6,11] Slow adoption of LIOU resulted from the lack of equipment dedicated to the laparoscopic application of ultrasound and the long learning curve for surgeons not acquainted with the use of diagnostic ultrasound. Fortunately in the past two years, dedicated laparoscopic ultrasound probes and ultrasound systems have become available, and technical considerations on these probes and the basics of ultrasonography have been published.[12] This brief report focuses on the use of equipment involving a new advancement in laparoscopic ultrasonography, the color Doppler feature.

EQUIPMENT FOR LIOU

Ultrasound Scanner

The system currently in use in our hospital fulfills previously published criteria for LIOU.[6,11] The Aloka 2000 SSD

multipurpose ultrasound scanner system provides a high-quality B-mode imaging and incorporates the color Doppler option (Fig. 1). Additional equipment for recording images obtained during examination such as videorecorders, printers, and digital recorders can be connected to the system.

Laparoscopic Transducer Probe

A laparoscopic transducer probe with angulating tip (Aloka UST-5536-7.5) is a dedicated instrument that fulfills the criterium for application in a laparoscopic setting entirely.[6,11,12] Technical data of this probe and a comparison of it with other available transducers are presented in Table 1.

EXAMINATION TECHNIQUE

The examination technique using different types of laparoscopic ultrasound transducers has been previously described.[12] When using the linear-array laparoscopic transducer probe with angulating tip, the screening surface is placed under laparoscopic visualization on the target area (e.g., upon the anterolateral aspect of the common bile duct). The screening maneuver consists of slow back-and-forth movements of the probe (through the trocar) with slight rotation of the transducer. The longitudinal sections of the common bile duct can be seen and easily identified, and the best images are achieved during the slow withdrawal of the transducer towards the examiner. The color Doppler is used for identifying vascular structures and for differentiating between the common bile duct, the portal vein, and the hepatic artery (Figs. 2, 3). When using the color Doppler feature, screening movements must be very slow to avoid motion artifacts. Doppler spectral analysis can be used in combination with the audio signal for the identification of arteries and veins and for confirming the inflow patterns and direction (Figs. 4, 5). Measurements of flow and velocity are possible. In screening the common bile duct, important landmarks are the portal vein (in the background of the common bile duct) and the right hepatic artery, which is seen between the portal vein and the common bile duct in cross section (Fig. 2). To facilitate the examination of certain target areas in some patients, saline solution can be added through one of the access ports until the area examined is emerged in fluid. This enhances acoustic contact between the screening surface, the probe, and the target area.

However, this technique is seldom used when screening the liver. Use of the laparoscopic ultrasound transducers with an angulating tip and relatively large screening surfaces (4 cm) evidently enhances the quality of screening by exactly aligning the transducer screening surface with liver tissue, avoiding compression and enabling optimal imaging. The vascular pattern of the liver, the area of lesions, and the lesion itself can be demonstrated (Fig. 6). In all areas of application, initial examination is performed in B-mode Gray scale, and for further clarification of anatomical structure, the color Doppler is used.

DISCUSSION

The main areas of application of LIOU are presented in Table 2, which demonstrates the predominant use of this modality in the screening of the biliary tract and liver, staging for pancreatic pathology, and guiding dissection during laparoscopic procedures. Use of the laparoscopic ultrasound transducer with an angulated screening surface, in our experience, clearly enhances the examination and its reliability.[6,11,12] A point of new development and current interest is application of color Doppler technology for LIOU. As shown in Table 1, reviewing some of the available ultrasound systems and transducers and ultrasound systems with the color Doppler feature, it is important to understand that these features involve highly technical and specialized types of instruments.

Table 1. LIOU transducer - rigid with angulating tip

	Olympus	B&K type 8555	Aloka type UST 5536 7.5
lineary	+	+	
convex		+	
rigid with angulating tip (flexible)	+	+	+
frequency (MHz)	7.5	5 - 6.5 - 7.5	7.5
axial resolution (min)	<1	0.6 - 0.5 - 0.4	<1
penetration depth (mm)	60	130 - 110 - 90	60
contact surface (mm)	38	22	38
diameter (mm)	10	9.8	10 (12)
length (mm)	45	48	45
angulation U/D	90˚/90˚	90˚/90˚	90˚/60˚
angulation R/L	60˚/60˚		60˚/60˚
Doppler spectral analysis		+	+
color Doppler		+	+

Figure 1. The Aloka SSD 2000 Ultrasound System.

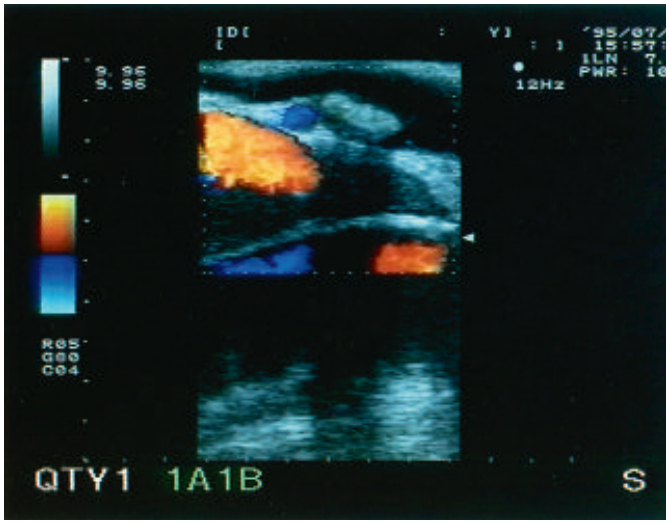

Figure 2. Proximal common bile duct, dilated 11 mm in diameter with a large stone; an acoustic shadow can be seen behind the stone. In the upper left corner of the right hepatic artery (transverse section), are the portal vein and the vena cava in the far field of the vessels, demonstrated clearly by color Doppler.

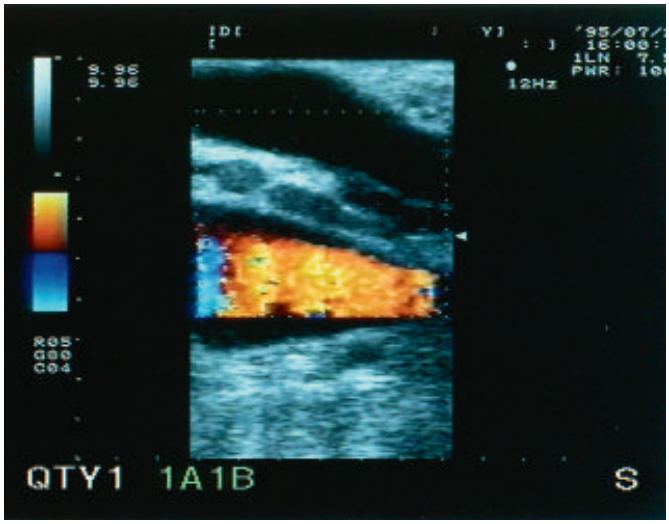

Figure 3. Mid part of the dilated common bile duct, pancreatic tissue in the upper right corner, and the vena cava in the background. The high resolution of the image enables recognition of the mucosal layer of the common bile duct.

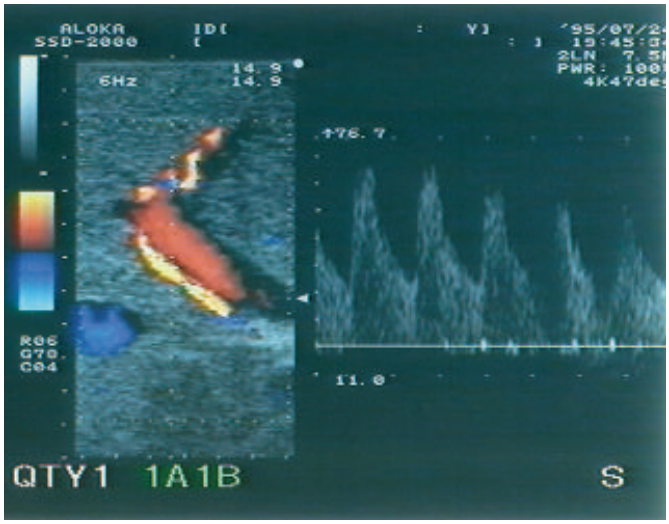

Figure 4. Right portal vein with an accompanying arterial branch is confirmed by spectral imaging plotted from the small artery and is shown in the right segment of the picture.

Table 2. Indications for LIOU

-	screening of the biliary tract during laparoscopic cholecystectomy		++
-	staging:	- liver pathology	++++
		- pancreatic pathology	++++
		- guiding dissection	++++
		- biliary tract pathology	++++
		- distal esophagus and gastric	++/-
		- colonic pathology	++/-

On the other hand, these systems have multipurpose design and can be applied in different areas of intraoperative ultrasonography, particularly in vascular surgery, which broadens the spectrum of its applicability in the OR. Encouraging results have been obtained by using intraoperatively a combination of Gray scale B-mode imaging with the color Doppler, as this provides easier identification of anatomic structures and better information on the vascular pattern of tumors.[10] Assessing the blood supply to tissues is an important indicator in evaluating organ function and possibly in enhancing tumor identification and characterization, although the measuring of actual capillary flow is currently beyond reach.

The flow in small nutrient vessels can be well visualized by the different methods, using Doppler, color Doppler technology, and ultrasound contrast-medium-enhanced color Doppler. For the enhancement of the color imaging, different contrast mediums have recently become available. Most contrast agents in the United States are based on the use of microbubbles small enough to cross the capillary vessels. Small CO_2 microbubbles, which resorb rapidly, can be difficult to use unless they are stabilized. Microbubbles, stabilized or coated by a semirigid membrane using lipids or albumin, are effective (Albumex™, Molecular Biosystems, Inc.). Another alternative is to stabilize microbubbles by lowering their surface tension, i.e., by adding a surfactant, as it is the case with Levovist (Schering AG, Berlin). These air microbubbles provide enhanced back scatter during ultrasound examination, improving the accuracy of Doppler recording. This may lead to exciting new diagnostic possibilities, such as the dynamic scanning of liver lesions. Encouraging preliminary experience using SHU 508 (Levovist) as an agent in diagnosing and differentiating hepatic tumors, particularly hepatocellular carcinoma, has been published and suggests the practicality of this technique.

As we do not have experience with ultrasound contrast medium, we focus mainly on high-quality color Doppler imaging and its potential benefit in laparoscopic application. Our experience is encouraging in which 65

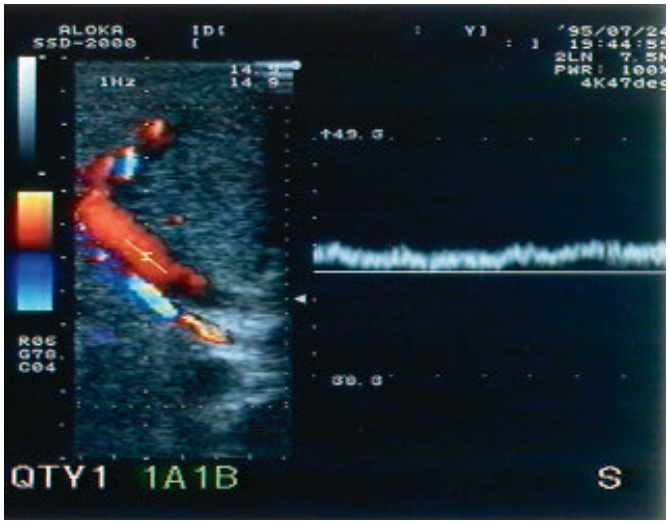

Figure 5. Right portal vein with an accompanying branch of the hepatic artery. The classic venous flow pattern of the portal vein is shown in the right side of the image.

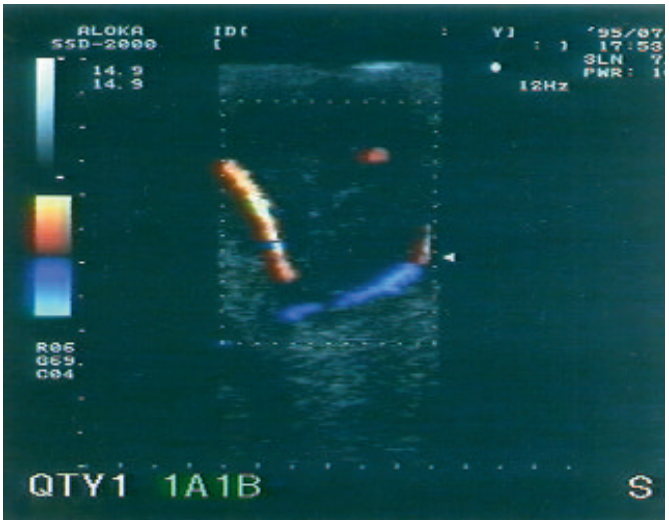

Figure 6. Solitary metastasis of colonic carcinoma. Both portal and hepatic veins are supplying the lesion, as demonstrated by color Doppler.

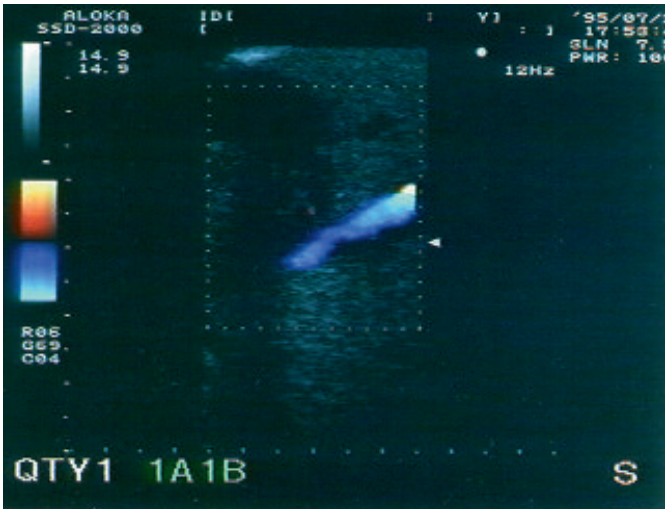

Figure 7. Portal branch of segment 7, supplying the metastasis of colonic carcinoma.

Figure 8. Hemangioma of the liver with scattered vascularization pattern within the lesion.

patients underwent a combination of Gray scale B-mode imaging and color Doppler for screening of the biliary tract, identification of lymph nodes, differentiation between lymph nodes and vessels in staging laparoscopy, and screening of the liver and pancreatic pathology.

Preliminary experience indicates that use of the color Doppler provides quick recognition of vascular structures, significantly enhances the examination of the biliary tract, and avoids misinterpretation of visualized tubular structures, particularly avoiding confusing the duct with the portal vein or hepatic artery of the pancreaticoduodenal artery. This shortens the time of examination even for the inexperienced examiner. In the case of liver screening, the vascular pattern of this organ can be clearly visualized by use of color Doppler (Figs. 6, 7). When using this modality in liver surgery, particularly segmental resection, respective segmental vessels can be visualized and dissected. By using the color Doppler temporarily, one can check whether the correct segmental branch has indeed been dissected; if so, it may be ligated by clamping the respective portal branch. The vascular pattern of tumor or lesion may be helpful in differentiating between a metastatic tumorous lesion and hemangioma (Fig. 8). During a dissection to perform the drainage of kidney or liver cysts, presence of vascular structures and small vessels in the area of dissection can be easily recognized. The procedure can be safely accomplished in a short time without entering vessels of the cyst capsule or its surroundings (which are sometimes difficult to identify by laparoscopy). Use of the color Doppler particularly enhanced our dissection during lymph node biopsy in the area of the hepatoduodenal ligament, as the hepatic artery branches and celiac trunk could be easily localized. Furthermore, they could be recognized without excessive dissection, and the lymph nodes in this area could be safely harvested by combining the laparoscopic images with the ultrasound information.

CONCLUSION

New developments in color Doppler technology are becoming available, as is evident in a new generation of Aloka ultrasound scanners with the so-called Power Flow option. Rapid developments in computer technology can benefit the ultrasound sys-

tems with color Doppler, and result in lowering the cost of this technology. It will enable in the future a wider application of this modality for intraoperative use.

Our current, though limited, experience with the color Doppler is very encouraging and suggests that this option will provide additional dimensions to laparoscopic ultrasonography. LIOU in its current state is facilitated by the use of new dedicated laparoscopic transducer probes with an angulated tip. The color Doppler method is helpful in confirming or excluding the presence of anticipated pathology and the detection of unexpected lesions. LIOU enables precise assessment of the extent of the pathology and its location relative to important anatomical structures.

The spectrum of applications of LIOU is evidently broadening. The method is noninvasive and provides instant information as needed intraoperatively. The cost benefit of laparoscopic ultrasonography is positive, but further evaluation, particularly in view of the use of color Doppler, is still necessary. We do believe that LIOU, in view of current technological advances regarding the probe design and the use of color Doppler, will play an increasing role in providing the surgeon useful diagnostic information necessary for intraoperative decision making and enabling the surgeon to conduct complex procedures, even in situations where the anatomy is difficult to interpret, especially when distorted by disease processes. STI

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