World J. Surg. 17, 640–646, 1993

WORLD
Journal of
SURGERY

Operative Ultrasonography During Hepatobiliary and Pancreatic Surgery

Junji Machi, M.D., Ph.D., Bernard Sigel, M.D., Howard A. Zaren, M.D., Toshihiko Kurohiji, M.D., and Yuichi Yamashita, M.D.

Department of Surgery, Medical College of Pennsylvania, Philadelphia, Pennsylvania, U.S.A.; and First Department of Surgery, Kurume University School of Medicine Kurume, Fukuoka, Japan

On the basis of our experience with operative ultrasonography during hepatobiliary and pancreatic surgery, its indications, benefits, and disadvantages are summarized. High-resolution operative ultrasound scanning of the liver, biliary tract, and pancreas was performed during 357, 735, and 242 operations, respectively. The benefits of operative ultrasonography were categorized as acquisition of diagnostic information otherwise not available, replacement for or complement to operative radiography, and guidance of surgical procedures. Operative ultrasonography provided beneficial information during 73 of 82 hepatic operations (89.0%), 57 of 69 noncalculous biliary operations (82.6%), and 177 of 242 pancreatic operations (73.1%). Operative ultrasonography was significantly superior (sensitivity 93.3%) to other screening tests for diagnosing liver metastasis from colorectal carcinoma evaluated in 189 patients, and it detected previously unrecognized metastatic tumors in 18 patients (9.5%). For screening common bile duct calculi during 666 operations, operative ultrasonography and operative cholangiography were comparable in all indices of accuracy except for a higher predictability of a positive test of operative ultrasonography (94.8% versus 71.7%). For diagnosing portal vein invasion of pancreatic carcinoma, operative ultrasonography provided better overall accuracy than preoperative studies (89.7% versus 64.1%). On the basis of operative ultrasound findings, previously planned surgical procedures were altered in 32 of 82 hepatic operations (39.0%) and 24 of 145 pancreatic operations for chronic pancreatitis (16.6%). Operative ultrasound guidance of various surgical procedures was performed during 88 hepatic and 84 pancreatic operations, including 40 ultrasound-guided hepatectomies and 42 pancreatotomies. Operative ultrasonography has a number of advantages, such as safety and speed in performance, wide application, high diagnostic accuracy, and ability of guiding procedures. Its disadvantages are the limitation of the fields of view in certain applications, the need for special equipment, and a slow learning curve.

Operative ultrasonography (OUS) is a relatively new technique compared to operative radiography. OUS provides higher resolution images than body scanning because of the use of higher-frequency ultrasound equipment, which can provide valuable information unobtainable with operative radiography or even with surgical exploration. Since 1979 we have performed OUS during more than 2500 operations in various surgical fields [1–3]. Experience with the various applications of OUS of the liver [3, 4], biliary tract [1, 5, 6], and pancreas [1, 5, 7] has been previously published. This report is a review of our experience with OUS of the liver, biliary tract, and pancreas in which the clinical results have been updated and the specific and comparative (to other imaging methods) utility of OUS in each surgical field has been assessed in terms of indications, benefits, and disadvantages.

Offprint requests: J. Machi, M.D., Ph.D., Medical College of Pennsylvania, Department of Surgery, 3300 Henry Avenue, Philadelphia, PA 19129, U.S.A.

Methods

High-resolution real-time B-mode ultrasound systems employing 5 to 10 MHz, most frequently 7.5 MHz, transducers have been used. Recently color Doppler imaging systems have also been employed. A flat linear-array probe with a side-viewing capability was used for operative scanning of the liver. A slender cylindrical pencil-like probe with a front-viewing capability suitable for examining small structures located deep in the operative field was usually used for scanning the extrahepatic biliary tract. The pancreas was scanned with either type of probe, depending on the condition of the operative field and the accessibility of the probe. The probe was either gas-sterilized or covered with a disposable sterile bag.

The liver was examined using a contact scanning technique by positioning the probe in contact with the liver surface. The entire liver was systematically imaged to obtain transverse and, at times, longitudinal sections of the liver. Examination of the extrahepatic biliary tract required a probe standoff technique in which the probe was placed 1 to 2 cm away from the surface of the structures. Saline solution was poured into the abdominal cavity to obtain acoustic coupling. The biliary duct was longitudinally scanned from the hepatic hilum to the duodenum. Transverse scanning of the duct and the intrahepatic duct was added whenever necessary (e.g., when the common bile duct was dilated or calculi were detected). The pancreas could be scanned through the stomach, the gastrocolic ligament, or other tissue; however, it was best imaged after exposure of its ventral surface. Operative scanning of the pancreas was performed in both longitudinal and transverse planes. OUS could be performed at any time during the operation. Usually, scanning was first conducted immediately after laparotomy but prior to major tissue dissection to obtain diagnostic information that was not evident during preoperative studies or initial surgical exploration. OUS was also used to guide operative procedures. Such operative ultrasound guidance assisted various surgical manipulations, such as needle placement and tissue incision or resection. OUS was repeated as often as needed.

Operative ultrasound examination was performed during a total of 1334 operations, scanning the liver in 357 operations, the biliary tract in 735 operations, and the pancreas in 242 operations. Statistical analysis was done using the chi-square test.

Results

Operative Ultrasonography of the Liver

Operative ultrasonography of the liver was performed in the following two situations: the first ($n = 82$) was to gain beneficial information and guidance of operative procedures during surgery of hepatic lesions (28 hepatocellular carcinomas, 32 colorectal metastases, 6 other metastases, 3 benign tumors, and 13 cystic lesions); and the second ($n = 275$) was to screen for liver metastasis during surgery for colorectal carcinoma ($n = 206$) and other malignant tumors ($n = 69$).

During the early course of hepatic operations, OUS provided beneficial information. Preoperatively unrecognized daughter nodules (intrahepatic metastases) and intravascular tumor thrombi of primary hepatocellular carcinomas and metastatic tumors from colorectal and other carcinomas were detected. Hepatocellular carcinomas associated with cirrhosis that were frequently nonpalpable were readily localized by OUS. Nonpalpable cavitary lesions, such as cysts and abscesses, were also diagnosed by OUS. Vascular and biliary structures in relation to hepatic lesions were clearly delineated. In particular, OUS was more accurate than preoperative studies for determining the tumor involvement of vessels, such as the portal vein and hepatic vein, and detecting tumor thrombi. The operative ultrasound findings were useful for surgeons when determining the resectability of malignant tumors and for deciding on the most appropriate surgical procedure. During 73 of 82 liver operations (89.0%), OUS provided beneficial information. On the basis of operative ultrasound information, preoperatively proposed surgical procedures were altered in 32 of 82 operations (39.0%). Usually, it meant more or less extensive hepatic procedures than anticipated prior to the use of OUS.

Operative ultrasound guidance was used for various hepatic procedures. Guidance was provided either for placement of needles or during tissue dissection. Ultrasound-guided needle placement facilitated biopsy of the liver ($n = 23$), especially deeply situated, nonpalpable tumors, aspiration of cystic lesions ($n = 6$), injection of contrast or chemotherapeutic agents ($n = 8$), and catheterization of intrahepatic biliary ducts ($n = 4$). During tissue dissection for hepatic resection ($n = 40$) and hepatic incision ($n = 7$), the incised hepatic plane was delineated together with target lesions and vascular structures. Operative ultrasound guidance was used during a total of 88 hepatic operations. Approximately one-half of the time it was for the purpose of performing hepatectomy, which included anatomic segmentectomy, lobectomy, and nonanatomic resection. Of the 55 hepatic resections in this series, 40 (72.7%) were guided by OUS.

Screening of the liver for metastasis was performed using OUS, mostly during operations for colorectal carcinoma. The accuracy of OUS in comparison to preoperative studies and surgical exploration for diagnosing liver metastasis from colorectal carcinoma was reported in detail previously [4]. OUS was performed routinely during colorectal cancer operations in 189 patients, who were followed more than 18 months postoperatively. A total of 104 metastatic tumors were diagnosed. In 18 patients (9.5%), OUS detected 22 tumors that were unrecognized at preoperative studies and surgical exploration. These "occult" tumors were 4 × 4 mm to 15 × 18 mm in size. The sensitivity, predictability of a negative test, and overall accuracy of OUS were significantly superior to those of preoperative ultrasonography, computed tomography, and surgical exploration (Table 1). During the postoperative follow-up period of 18 to 54 months (mean 35.6 months), liver metastases that were not identified by any screening procedures, including OUS, occurred in 13 patients (6.9% of total patients). OUS was also used for screening of liver metastases during 69 laparotomies for other malignant tumors such as gastric carcinoma, ovarian carcinoma, and gastrointestinal and retroperitoneal sarcoma. In eight operations (11.6%), preoperatively unknown nonpalpable metastatic liver tumors were diagnosed solely by OUS.

Table 1. Accuracy of four screening procedures for diagnosing liver metastasis from colorectal carcinoma.

Parameter	Preop. US	Preop. CT	Surgical exploration	Operative US	p
Sensitivity (%)	41.3	47.1	66.3	93.3	< 0.0001[a]
Specificity (%)	96.7	94.1	89.5	94.7	
Predictability of a positive test (%)	89.6	84.5	81.2	92.4	< 0.05[b]
Predictability of a negative test (%)	70.7	72.2	79.5	95.4	< 0.0001[a]
Overall accuracy (%)	74.2	75.0	80.1	94.1	< 0.0001[a]

Reproduced with permission of the publisher.
[a]Operative ultrasonography versus each of other three procedures.
[b]Operative ultrasonography versus surgical exploration.
US: ultrasonography; CT: computed tomography.

Operative Ultrasonography of the Biliary Tract

Operative ultrasonography was performed during operations for various diseases or conditions of the biliary tract. Most of the operations were for chronic or acute calculous cholecystitis ($n = 666$), where OUS was employed for screening of common bile duct calculi. Biliary tract tumors examined ($n = 41$) included carcinoma of the bile duct and carcinoma and polyps of the gallbladder. OUS was used to detect biliary fistula, bile duct stricture, and other conditions ($n = 24$) in which the common bile duct was obscured by inflammation, adhesion, or previous surgery. OUS was also performed for congenital biliary duct dilatation ($n = 4$).

Screening for common bile duct calculi by OUS was per-

Table 2. Accuracy of two screening procedures for diagnosing common bile duct calculi.

Parameter	Operative cholangiography	Operative ultrasonography	p
Sensitivity (%)	84.4	92.4	
Specificity (%)	95.5	99.3	
Predictability of a positive test (%)	71.7	94.8	< 0.005
Predictability of a negative test (%)	97.9	99.0	
Overall accuracy (%)	94.2	98.5	

Table 3. Operative ultrasonography of the pancreas.

Pancreatic disease	No. of operations	Operative ultrasonography beneficial	
		No.	%
Pancreatitis	164	121	73.8
Pancreatic carcinoma	65	47	72.3
Islet cell tumor	10	7	70.0
Pancreatic trauma	3	2	66.7
Total	242	177	73.1%

Table 4. Accuracy of two procedures for diagnosing portal vein invasion of pancreatic carcinoma.

Parameter	Preop. studies	Operative ultrasonography	p
Sensitivity (%)	76.5	94.1	
Specificity (%)	54.5	86.4	< 0.05
Predictability of a positive test (%)	56.5	84.2	
Predictability of a negative test (%)	75.0	95.0	
Overal accuracy (%)	64.1	89.7	< 0.01

formed during 666 operations. In 14 of these operations, OUS detected gallbladder calculi in patients without preoperative gallbladder studies who underwent operation for other (than biliary) diagnoses. The common bile duct was also imaged in these operations to exclude bile duct calculi. The remaining 652 operations were undertaken for chronic or acute cholecystitis. During the first 350 operations, both OUS and operative cholangiography were employed for screening of common bile duct calculi for comparison [6]. During the remainder of the operations OUS was performed routinely, and operative cholangiography was used only in selected instances. As a result, operative cholangiography was performed in 401 of the 666 operations. Included in 666 operations were six operations on pregnant patients and 12 operations for patients with allergy to contrast media. The use of operative cholangiography was obviated during these operations. OUS was technically unsuccessful in 8 of 666 operations (1.2%), whereas operative cholangiography was technically unsuccessful in 22 of 401 operations (5.5%). Comparative accuracy of the two tests is summarized in Table 2. The sensitivity, specificity, predictability of a negative test, and overall accuracy of each test were comparable. OUS, however, provided a value for the predictability of a positive test that was significantly superior to that for operative cholangiography. Common bile duct exploration was performed in 86 of 666 operations (12.9%) for the purpose of removing bile duct calculi. The calculi were detected in 77 operations, resulting in a positive common bile duct exploration rate of 89.5%.

During operations for tumors and benign diseases of the biliary tract, OUS provided beneficial information prior to extensive tissue dissection. For examination of gallbladder and bile duct carcinomas, it was possible to more precisely assess tumor invasion of the liver parenchyma and blood vessels, such as the portal vein and hepatic artery, and metastasis to the liver and regional lymph nodes. OUS was able to readily identify gallbladder polyps as small as 1 to 2 mm that were not detected by preoperative studies. During operations in which the anatomy around the biliary tract was distorted because of inflammation, tumors, or adhesions due to previous operations, OUS helped to localize the obscured biliary duct and to evaluate surrounding structures including the vasculature. The size of biliary duct, either extrahepatic or intrahepatic, was measured accurately on the ultrasound monitor. OUS facilitated placement of a needle or catheter in the obscured biliary duct for operative cholangiography. OUS guided the resectional procedures for biliary carcinoma and was most helpful when these operations included hepatic resection. OUS was deemed beneficial to complete biliary surgery in 32 of 41 operations (78.0%) for biliary tumors and 25 of 28 operations (89.3%) for benign biliary diseases—a total of 57 of 69 operations (82.6%).

Operative Ultrasonography of the Pancreas

Pancreatic diseases for which OUS was performed are shown in Table 3. Operations for pancreatitis consisted of 145 operations for chronic pancreatitis (including 66 operations for pseudocysts) and 19 operations for acute pancreatitis (including 10 operations for pancreatic abscesses). Islet cell tumors included five insulinomas, three gastrinomas, and two nonfunctioning tumors.

Beneficial information provided by OUS varied with the pancreatic disease. OUS detected, localized, or excluded the stigmata of pancreatitis, such as pseudocyst, pancreatic duct dilation, abscess, bile duct stenosis, and splenic or portal vein thrombosis. Dense inflammation caused by pancreatitis often made surgical exploration and examination of these lesions difficult. Dilated pancreatic ducts or cystic lesions that were not palpable were quickly localized by OUS. Previously unknown small pseudocysts and abscesses were diagnosed. During operations for pancreatic carcinoma, the extent of tumor (e.g., vascular invasion and liver and lymph node metastasis) was determined by OUS more accurately than by the preoperative studies. In 39 operations, the accuracy of OUS for diagnosing portal vein invasion was compared with preoperative studies, including percutaneous ultrasonography, computed tomography, and superior mesenteric angiography (portal phase). Portal vein invasion was present in 22 operations and absent in 17 operations, confirmed by gross or microscopic examination. The comparison of tests in these 39 operations revealed that OUS was significantly better than the combination of preoperative studies in terms of the specificity and overall accuracy (Table 4). Islet cell tumors as small as 3 to 4 mm were detected or precisely localized by OUS on the basis of their characteristic hypoechoic features [1, 7]. When a nodule was palpated during operation, OUS helped to confirm or exclude it as an islet cell tumor. As summarized in Table 3, OUS assisted surgeons by providing beneficial imaging information in a total of 177 of 242 pancreatic operations (73.1%).

During 145 operations for chronic pancreatitis, on the basis of OUS findings previously planned surgical procedures were altered in 24 operations (16.6%): pancreatic resection was changed to internal drainage of the pancreatic duct in eight operations or vice versa in six operations, and the drainage sites (i.e. jejunum, stomach, or duodenum) of pseudocyst were changed in 10 operations.

In a manner similar to hepatic procedures, various pancreatic procedures were performed under the guidance of OUS. Needle placement was appropriately guided by OUS to perform biopsy of tumors ($n = 18$), to aspirate cystic lesions ($n = 13$), and to inject contrast medium into ducts ($n = 3$). OUS also assisted resection of pancreatic carcinoma and enucleation of islet cell tumors ($n = 8$). OUS was most frequently used for guidance of pancreatic incisions for opening the pancreatic duct. The duct that was nonpalpable owing to inflammation was readily found and opened with ultrasound-guided pancreatotomy during 42 operations for chronic pancreatitis [8].

Operative Color Doppler Imaging

Color Doppler imaging has been used during 14 hepatic, 13 biliary tract, and 15 pancreas operations. In comparison to B-mode imaging, operative color Doppler imaging had a capability of delineating much smaller blood vessels. For example, blood vessels that were detected and localized solely by operative color Doppler imaging before surgical tissue dissection included distal intrahepatic branches of the hepatic artery and the portal vein, biliary cystic artery, pancreaticoduodenal artery, small collateral portal tributaries, and intra-tumoral vessels. During cancer operations, the relation of tumors to blood vessels was more clearly determined. Needle visualization during performance of needle placement was enhanced by its motion display in color [9]. Color Doppler imaging also helped to distinguish blood vessels from other hypoechoic or sonolucent areas, such as the ducts or tissue spaces seen on B-mode imaging.

Discussion

A number of reports describing the value and indications of OUS during hepatobiliary and pancreatic surgery have been published [10–20]. From our experience with more than 1300 operations, we have summarized the indications for OUS. OUS of the liver is indicated to detect and localize hepatic lesions for planning and selecting the operation, to guide various hepatic procedures, and to screen for liver metastasis. OUS of the biliary tract is indicated to screen for common bile duct calculi, to assess the extent of biliary tumor, and to localize and evaluate obscured biliary ducts. OUS of the pancreas is indicated to detect, localize, or exclude the stigmata of pancreatitis, to assess the extent of pancreatic carcinoma, to localize islet cell tumors, and to guide various pancreatic procedures.

The benefits provided by OUS of the liver, biliary tract, and pancreas are provision of new diagnostic information not previously available, as a replacement for or a complement to operative radiology, and for direct guidance of operative manipulations, such as needle placement and surgical tissue dissection [2]. During operation for malignant diseases, OUS helps to evaluate the tumor spread and thereby determine tumor staging. The resectability of tumor can be determined, and the most appropriate surgical operation can be decided at an early stage of the operation [5, 7, 10–13]. Previously planned surgical procedures are changed on the basis of operative ultrasound findings. Other surgeons have reported that OUS altered the surgical management of hepatic tumors in 30% to 50% of operations [14, 15], similar to our results. Precise localization of nonpalpable hepatic tumors and islet cell tumors of the pancreas facilitates selection of appropriate operations [10–12, 14–18]. OUS is more accurate for diagnosing liver metastasis than conventional preoperative studies and surgical exploration [4, 19]. By providing new information, OUS is also helpful during operations for benign diseases, particularly evaluating the complications of pancreatitis or locating obscured biliary ducts in which surgical exploration is difficult owing to inflammation or adhesion [3, 7]. In our series, beneficial imaging information was acquired by OUS in more than 70% to 80% of hepatobiliary and pancreatic operations.

Compared to operative cholangiography, OUS demonstrates equal or superior accuracy [5, 6, 20]. In our study, the predictability of a positive test of OUS was significantly higher, likely contributing to the high positive common bile duct exploration rate. In addition, OUS is able to delineate the anatomy of surrounding structures or organs, whereas operative cholangiography reveals the biliary tract only. For these reasons, we believe that during biliary calculous operation OUS can replace traditional operative cholangiography as a first or routine screening test for common bile duct calculi. Operative cholangiography can be selectively employed when the findings of OUS are inconclusive or insufficient.

Not only does OUS provide diagnostic information, it provides therapeutic assistance as operative ultrasound guidance during operations on the liver, biliary tract, and pancreas [2, 10, 12, 21]. It is an ability unique to OUS that cannot be substituted by operative radiography. We have categorized surgical procedures guided by OUS into two groups: intraoperative needle placement and surgical tissue dissection [21]. OUS guidance enables surgeons to perform surgical procedures more safely and to undertake certain procedures that are impossible otherwise. For example, deeply located tumors such as small nonpalpable hepatic tumors can be biopsied or approached only with the assistance of OUS. Furthermore, new surgical operations, such as ultrasound-guided systematic subsegmentectomy, have been developed as a result of operative ultrasound techniques [12, 22].

In comparison to operative radiography, OUS has a number of advantages: safety, speed, more imaging information, and the ability to guide procedures. In the present study there were no known complications associated with the use of OUS, such as organ injury or infection. Because of its safety, OUS can be used repeatedly during the course of an operation. Because of its provision of multiple imaging information, OUS is applicable to operations of various diseases or conditions. Initially, OUS may extend operating time by 5 to 10 minutes. Persistence beyond this time span is usually counterproductive. OUS examination, once learned, can be performed in a short time and actually reduces overall operating time. For example, initial evaluation of hepatobiliary and pancreatic cancer or screening of common bile duct calculi and screening of liver metastasis can be completed within 5 minutes. Guidance of needle placement or other surgical procedures requires less than 10 minutes, which is usually faster than blind procedures without OUS. Although further experience and assessment are required, operative color Doppler imaging may provide more ultrasound information and thus may widen hepatobiliary and pancreatic applications.

The disadvantages or limitations of OUS include an inability of simultaneous delineation of an entire duct system, difficulty diagnosing or localizing small biliary or pancreatic fistulas, limitation to identifying small tumors, requirement of special ultrasound instruments, and a slow learning curve [1, 2]. The learning curve depends on the purpose of OUS, the target organ, and the complexity of the imaging procedures. For example, for screening the liver for metastasis and the common bile duct for calculi, about 25 examinations are usually needed. For guidance of pancreatic and hepatic operations, about 25 to 40 and about 50 examinations, respectively, are probably required. Unlike operative radiography, OUS cannot display the entire biliary tree or pancreatic ductal system at the same time. Visualization of small biliary or pancreatic fistulas often requires operative radiography. Although OUS can detect much smaller hepatic or pancreatic tumors than preoperative imaging methods, tumors less than 3 to 5 mm are unrecognizable even with high-resolution ultrasonography. The problems related to instruments and learning can be resolved by realization of the benefits of OUS and the willingness to commit resources and time to the application of OUS.

In summary, we have defined indications, benefits, and disadvantages of OUS of the liver, biliary tract, and pancreas based on our experience in more than 1300 operations. OUS provided beneficial information during more than 70% to 80% of hepatobiliary and pancreatic operations. OUS is indicated during operation for a wide variety of malignant and benign diseases for various purposes, from simple screening of lesions (e.g., screening for liver metastasis or common bile duct calculi) to sophisticated guidance of procedures (e.g., ultrasound-guided hepatectomy or pancreatotomy). OUS has many advantages (i.e., safety, speed, more imaging information, wide application, high accuracy, and guidance ability), which we believe outweigh its disadvantages (limitation of certain imaging capabilities, special equipment requirements, and slow learning curve). Because of its numerous benefits and advantages, OUS has made a favorable impact on hepatobiliary and pancreatic surgery, including contributing to surgical decision-making, and reducing surgical tissue dissection, operating time, and the need for operative radiography.

Résumé

Basés sur une expérience personnelle, les indications, les avantages et les inconvénients de l'échographie peropératoire dans la chirurgie hépatobiliaire sont résumés. Une échographie peropératoire à haute résolution a été pratiquée au niveau du foie, des voies biliaires et du pancréas au cours de, respectivement, 357, 735, et 242 interventions. Un bénéfice a été défini lorsque cet examen a permis de faire un diagnostic non décélé par les moyens habituels, de replacer or d'ajouter de l'information acquise par la radiologie préopératoire ou d'influencer l'acte opératoire. Ceci a été le cas dans 73 des 82 interventions hépatiques (89.0%), dans 57 des 69 interventions biliaires non lithiasiques (82.6%) et dans 177 des 242 interventions sur le pancréas (73.1%). La sensibilité de l'échographie peropératoire a été de 93.3%, supérieure à celle des autres examens pour faire le diagnostic de métastases hépatiques d'origine colorectale chez 189 patients; cet examen a, entre autres, permis de détecter des métastases hépatiques non vues par les examens habituels chez 18 patients (9.5%). En ce qui concerne les calculs de la voie biliaire principale, explorée pendant 666 interventions, la précision de l'échographie peropératoire a été tout à fait comparable à celle de la cholangiographie peropératoire, exception faite de la valeur prédictive positive (94.8% vs 71.7%). Dans le diagnostic de l'envahissment de la veine porte par les cancers pancréatiques, l'échographie peropératoire était plus précise que les autres examens préopératoires (89.7% vs 64.1%). Basé sur les données de l'échographie peropératoire, la tactique opératoire a été modifiée dans 32 des 82 interventions hépatiques (39.0%) et dans 24 des 145 opérations pour pancréatite chronique (16.6%). L'échographie peropératoire a été utilisée pour guider les gestes opératoires dans 88 et 84 interventions hépatiques et pancréatiques, respectivement, y compris 40 hépatectomies et 42 pancréatectomies. L'échographie peropératoire présente beaucoup d'avantages, une précision diagnostique élevée et la possibilité de guider des gestes opératoires. Ses inconvénients sont une limitation du champ de vision dans certaines applications, le besoin d'un équipement spécialisé et une courbe d'apprentissage lent.

Resumen

Con base en nuestra experiencia, se resumen las indicaciones, beneficios y desventajas de la ultrasonografía operatoria en el curso de cirugía biliar y pancreática. Se realizó escanografía ultrasonográfica de alta resolución del hígado, del tracto biliar y del páncreas en el curso de 357, 735 y 242 operaciones, respectivamente. Los beneficios de la ultrasonografía operatoria fueron categorizados como: adquisición de nueva información diagnóstica no disponible en otra forma, reemplazo o complemento de radiografías operatorias y guía de los procedimientos operatorios. La ultrasonografía operatoria aportó información benéfica en 73 de 82 operaciones hepáticas (89.0%), en 57 de 69 operaciones biliares para entidades no asociadas con cálculos (82.6%) y en 177 de 242 operaciones pancreáticas (73.1%). La ultrasonografía operatoria demostró ser significativamente superior (sensibilidad: 93.3%) a otras pruebas escanográficas en el diagnóstico de metástasis hepáticas de carcinoma colorrectal en 189 pacientes valorados, y logró detectar tumores metastásicos previamente no identificados en 18 pacientes (9.5%). En cuanto a la pesquisa de cálculos en el colédoco en el curso de 666 operaciones, la ultrasonografía operatoria y la colangiografía operatoria aparecieron comparables en todos los índices de certeza, excepto una más alta capacidad de predicción de resultado positivo en la ultrasonografía operatoria (94.8% versus 71.7%), la cual, además, permite delinear la anatomía de los órganos vecinos, en tanto que la colangiografía revela el tracto biliar solamente. En el diagnóstico de invasión de la vena porta por parte de carcinoma

pancreático, la ultrasonografía operatoria probó ser de mayor certeza, globalmente, que los estudios preoperatorios (89.7% versus 64.1%). Con base en los hallazgos ultrasonográficos operatorios, se modificó el plan quirúrgico previo en 32 de 82 operaciones hepáticas (39.0%) y en 24 de 145 operaciones pancreáticas por pancratitis crónica (16.6%). La guía ultrasográfica de diversos procedimientos fue realizada en el curso de 88 operaciones hepáticas y de 84 operaciones pancreáticas, incluyendo 40 hepatectomías y 42 pancreatectomías guiadas por ultrasonografía. La ultrasonografía operatoria exhibe un número de ventajas, tales como seguridad y velocidad, amplia aplicación, elevada certeza diagnóstica y capacidad de guiar diversos procedimientos. Sus desventajas son la limitación de determinados campos visuales en algunas circunstancias, la necesidad de equipos especiales y una lenta curva de aprendizaje.

References

1. Sigel, B.: Operative Ultrasonography (2nd ed.). Philadelphia, Raven Press, 1988
2. Machi, J., Sigel, B.: Overview of benefits of operative ultrasonography during a ten-year period. J. Ultrasound Med. *8*:647, 1989
3. Machi, J., Sigel, B., Zaren, H.A., et al.: Operative ultrasound: ten years of experience. Surg. Annu. *23*:73, 1991
4. Machi, J., Isomoto, H., Kurohiji, T., et al.: Accuracy of intraoperative ultrasonography in diagnosing liver metastasis from colorectal cancer: evaluation with postoperative follow-up results. World J. Surg. *15*:551, 1991
5. Sigel, B., Coelho, J.C.U., Machi, J., et al.: The application of real-time ultrasound imaging during surgical procedures. Surg. Gynecol. Obstet. *157*:33, 1983
6. Sigel, B., Machi, J., Beitler, J.C., et al.: Comparative accuracy of operative ultrasound and cholangiography in detecting common bile duct calculi. Surgery *94*:715, 1983
7. Sigel, B., Machi, J., Ramos, J.R., Duarte, B., Donehue, P.E.: The role of imaging ultrasound during pancreatic surgery. Ann. Surg. *200*:486, 1984
8. Machi, J., Sigel, B., Kodama, I., Zaren, H.A.: Ultrasound-guided pancreatotomy for opening the pancreatic duct. Surg. Gynecol. Obstet. *173*:59, 1991
9. Kurohiji, T., Sigel, B., Justin, J., Machi, J.: Motion marking in color Doppler ultrasound needle and catheter visualization. J. Ultrasound Med. 9:243, 1990
10. Castaing, G., Emond, J., Bismuth, H., Kunstlinger, F.: Utility of operative ultrasound in the surgical management of liver tumors. Ann. Surg. *204*:600, 1986
11. Brower, S.T., Dumitrescu, O., Rubinoff, S., McElhinney, J.A., Aufses, A.H., Jr.: Operative ultrasound established resectability of metastases by major hepatic resection. World J. Surg. *13*:649, 1989
12. Makuuchi, M., Hasegawa, H., Yamazaki, S., Takayasu, K., Moriyama, N.: The use of operative ultrasound as an aid to liver resection in patients with hepatocellular carcinoma. World J. Surg. *11*:615, 1987
13. Plainfosse, M.C., Bouillot, J.L., Rivaton, F., Vancamps, P., Hernigon, A., Alexandre, J.H.: The use of operative sonography in carcinoma of the pancreas. World J. Surg. *11*:654, 1987
14. Parker, G.A., Lawrence, W., Horsley, J.S., et al.: Intraoperative ultrasound of the liver affects operative decision making. Ann. Surg. *209*:569, 1989
15. Rifkin, M.D., Rosato, F.E., Branch, H.M., et al.: Intraoperative ultrasound of the liver: an important adjunctive tool for decision making in the operating room. Ann. Surg. *205*:466, 1987
16. Angelini, L., Bezzi, M., Tucci, G., et al.: The ultrasonic detection of insulinomas during surgical exploration of the pancreas. World J. Surg. *11*:642, 1987
17. Charboneau, W.J., James, F.M., Van Heerden, J.A.: Intraoperative real-time ultrasonographic localization of pancreatic insulinoma: initial experience. J. Ultrasound Med. *2*:251, 1983
18. Norton, J.A., Sigel, B., Baker, A.R., et al.: Localization of an occult insulinoma by intraoperative ultrasound. Surgery *97*:381, 1985
19. Boldrini, G., Gaetano, A.M., Giovannini, I., Castagneto, M., Colagrande, C., Castiglioni, G.: The systematic use of operative ultrasound for detection of liver metastasis during colorectal surgery. World J. Surg. *11*:622, 1987
20. Jakimowicz, J.J., Rutten, H., Jurgens, P.J., Carol, E.J.: Comparison of operative ultrasonography and radiography in screening of common bile duct for calculi. World J. Surg. *11*:628, 1987
21. Machi, J., Sigel, B., Kurohiji, T., Zaren, H.A., Sariego, J.: Operative ultrasound guidance for various surgical procedures. Ultrasound Med. Biol. *16*:37, 1990
22. Makuuchi, M., Hasegawa, H., Yamazaki, S.: Ultrasonically guided subsegmentectomy. Surg. Gynecol. Obstet. *161*:345, 1985

Invited Commentary

Giuseppe Gozzetti, M.D.

Institute of Clinical Surgery and Cardiosurgery, University of Bologna, Bologna, Italy

Since the first applications of operative ultrasonography (OUS) at the beginning of the 1980s by Makuuchi and Hasegawa in Japan and the authors of the present paper in the United States, the procedure has been rapidly accepted in centers of hepatic and pancreatic surgery worldwide.

After 10 years of personal experience in this field, I can confirm that OUS is a useful tool in liver surgery. OUS is indispensable in resective surgery of the cirrhotic liver, where most neoplastic nodules are not palpable within the fibrous parenchyma and are thus identifiable only by OUS [1].

What is the place of OUS in surgery of the noncirrothic liver today? It is a matter of fact that in recent years an improvement in preoperative radiographic investigations has been achieved. In my own experience, the sensitivity of preoperative investigations—including computed tomography (CT) with new devices, angio-CT, CT after intraarterial lipiodol injection, and RMN—has been greatly improved. More recently in my department, the gap between the data obtained from preoperative investigations and that from OUS has been radically reduced. Personally, I would like to stress the importance of an extensive preoperative investigation in order to achieve an accurate assessment of any hepatic lesions.

If I had to quantify the utility of OUS in choosing or modifying the surgical strategy for noncirrhotic liver, I would say that currently it is not more than 15% to 20% [2]. Also, the search for occult hepatic metastases of digestive tract cancer has provided results that are slightly inferior to those reported by Machi et al. in the present article, with an overall percentage of less than 5%. On the other hand, the use of OUS cannot be questioned in the cases of pancreatic tumors with cholestasis