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SURGICAL ENDOSCOPY
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The role of echo-laparoscopy in abdominal surgery: five years' experience in a dedicated center

Domenico Piccolboni, Francesco Ciccone, Anna Settembre, Francesco Corcione

General and Laparoscopic Surgical Department, Monaldi Hospital, Naples, Italy

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Abstract
Background: For more than 20 years intraoperative ultrasonography (IOUS) has been considered an important diagnostic tool in abdominal surgery. In the last few years, with the spread of laparoscopic surgery, echo-laparoscopy (LIOUS) has gradually replaced open ultrasonography, aiming to achieve similar results.
Methods: LIOUS was performed using an ALOKA 5.500 device, provided with a linear flexible laparoscopic probe that was compatible with a 10-mm port. IOUS was performed by means of a linear side-view, T-shaped or microconvex probe. The probes were sterilized with hydrogen peroxide. No water bath was used during the surgical examination, but full contact of the probe with the surface of the involved organ was always attempted. From 2001 to 2005, 36 liver resections, 40 pancreas procedures, 203 procedures for suspected common bile duct calculi, 541 colon and 82 stomach resections, and 82 adrenal surgery procedures were performed. IOUS or LIOUS was performed in 432 patients (43.8%). All livers and pancreases underwent intraoperative ultrasound, while biliary, colonic, gastric, and adrenal pathologies were selectively studied when there were doubts about the location and extension of the disease.
Results: IOUS and LIOUS were valuable diagnostic procedures, supplying relevant clinical information in 65.1% of the patients and modifying the surgical approach in 17.2%. LIOUS was used instead of cholangiography to study bile ducts when lythiasis was suspected, achieving high diagnostic specificity (98%) and accuracy (100%). Surgical anatomy of the bile ducts was correctly identified by LIOUS in every case.
Discussion: In our experience IOUS and LIOUS were of the utmost importance in better defining staging of disease, infiltration of neighboring structures, number and size of nodular lesions, and anatomy of the hepatic pedicle and intrahepatic structures, thus making it possible to more accurately plan surgical procedures.

Correspondence to: Domenico Piccolboni

Key words: Ultrasound (intraoperative) — Laparoscopy — Laparoscopic ultrasound — Hepatobiliary surgery

For more than 20 years intraoperative ultrasonography (IOUS) has been an important tool for diagnosis and staging of abdominal diseases [1–3], and its sensitivity for detecting small hepatic lesions is still considered superior to that of helical computed tomography (CT) [4]. It is currently the gold standard for detecting liver metastases with sensitivities of between 90% and 95%, decreasing to 50% for lesions smaller than 1 cm [5, 6]. Leen et al. [7] recently reported that the addition of contrast imaging to IOUS, with the technique of pulse inversion harmonic scanning, allowed identification of further hepatic lesions with a median size of 0.8 cm, with a minimum of 4 mm, providing further information in 50% of the cases and modifying the surgical attitude in 29.8% of the cases.

Nowadays, with the availability of flexible-tip electronic linear probes located at the end of a rigid shaft and compatible with a 10-mm trocar, echo-laparoscopy has gradually replaced IOUS, achieving almost the same results as the latter in hepatic, biliary, pancreatic, gastric, and adrenal surgery. The purpose of this article is to report our experience in the use of echo-laparoscopy (LIOUS) in abdominal surgery, evaluating the importance of LIOUS in getting more information during surgery and its role in changing the surgical strategy.

Materials and methods

LIOUS and IOUS were performed using an ALOKA 5.500 device (ALOKA Co. Ltd., Tokyo, Japan), provided with a flexible-tip, linear, multifrequency, laparoscopic probe and linear side-view T-shaped or convex electronic probes, sterilized with hydrogen peroxide (Sterrad), located within the operative theatre, and used without any rubber balloon protection. In most cases direct contact of the probe with the involved organ was preferred, without water interposition. Transumbilical access was used in most cases, but subxyphoid or lateral ports

Table 1. IOUS-LIOUS utilization in abdominal surgery

Pathology	No. cases	IOUS-LIOUS
Liver	36	100
Pancreas	40	100
Colon	541	19.9
Stomach	82	34.1
Adrenal	82	47.8
Bile ducts	203	88.6
Total	984	43.8

were also used. LIOUS examination time was 8 min on average (range = 6–10 min). After a learning curve of about 50 cases, all the surgeons involved in the procedures were able to perform the examination, having become familiar with ultrasonic anatomy of the surgical field and become acquainted with intraoperative handling of the probe.

From January 2001 through December 2005, 984 patients were submitted to surgery in our department for liver (36 patients), pancreas (40 patients), bile ducts (203 patients), stomach (82 patients), colon (541 patients), and adrenal pathologies (82 patients). Three surgeons (FC, DP, and FC) were involved in all the procedures. Four hundred thirty-two patients (43.8%) were submitted to intraoperative ultrasonic examinations; 362 were laparoscopic (LIOUS 83.8%) and 70 were open (IOUS 16.2%) (Table 1). Three surgeons (DP, FC, and AS) performed all the intraoperative ultrasound examinations. We performed intraoperative ultrasound in only 43.8% of the cases, i.e., when doubts remained about diagnosis, resectability, liver involvement, or preoperative staging of the disease.

As for colorectal, gastric, and adrenal pathologies, we decided to perform IOUS or LIOUS rather than MRI and echo-endoscopy when preoperative examinations (ultrasonography, endoscopy, and CT scan) raised doubts about the existence of very small focal hepatic lesions or about resectability of the tumor. All patients with liver or pancreas pathologies were studied by either technique. One hundred eighty patients (88.6%) with suspected bile duct calculi, 108 patients (19.9%) with colon and rectal tumors, 28 patients (34.1%) with gastric malignancies, and 40 patients with adrenal masses (48.7%) were studied.

The main goals of the study were to get better definition of the anatomy and the relationships of the involved organ with respect to the neighboring structures. The anatomy of the hepatic pedicle and location and number of calculi, when present, were increasingly studied by ultrasound instead of by traditional cholangiography.

Results

Thirty-six liver surgery procedures were performed from 2001 to 2005; half of these patients had secondary malignancies that were treated by either laparoscopic or open resective procedures, one-third were primary malignancies, and the rest were benign lesions or hydatid cysts.

IOUS and LIOUS were equally effective in diagnosis and deciding on the surgical procedure to use. More relevant information was given by IOUS in 72.2% of the cases (26 cases), mainly with respect to number, location, and anatomic and vascular relationships of focal lesions. Relevant information was given by LIOUS in 27.8% of the cases (10 cases), deeply affecting surgical decision-making in seven cases (19.4%) (Fig. 1), specifically with respect to the evaluation of laparoscopic resectability or necessity of laparotomy in four patients, while in three cases of primary liver lesions, LIOUS allowed detection of multifocal HCC (Fig. 2), not diagnosed by preoperative imaging, thus ruling out the possibility of radical surgical resection.

Fig. 1. LIOUS: Subglissonian liver metastases of the VIII segment not detected by preoperative imaging.

Fig. 2. LIOUS: Isoechoic capsulated HCC of the V-VIII segment of the liver near the medial portal pedicle.

Fig. 3. Laparoscopic duplex view of pancreatic head neoplasm infiltrating the superior mesenteric vein.

Of 40 pancreatic procedures, 25 were laparoscopic. IOUS or LIOUS was used in every case, either to verify respectability (Fig. 3) before performing laparotomy or to guide the surgical procedure. Differential diagnosis between pancreatic cancer, ampullary cancer, and chronic pancreatitis and/or mesenteric vessel infiltration was the main goal of the ultrasonic study.

Five patients were treated for benign pancreatic lesions: three cystadenomas and two insulinomas (Fig. 4). Anatomic location and relationships to the splenic ves-

Fig. 4. LIOUS: Insulinoma of the pancreatic body adjacent to the portal vein.

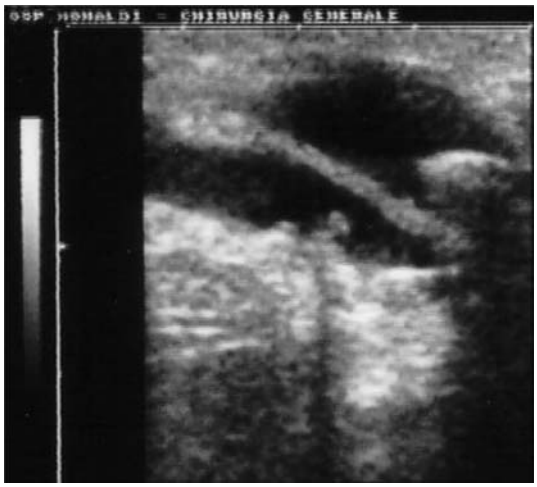

Fig. 5. Mirizzi syndrome: Laparoscopic view of the gallbladder with stones overcoming the main bile duct containing microscopic calculi.

sels and Wirsung duct were sharply outlined thanks to LIOUS. This allowed the surgeons to schedule either laparoscopic segmental resection or distal splenopancreatectomy. LIOUS proved useful in 24 patients (60 %) and determined the surgical procedure in 11 (30%).

Two hundred three patients with suspected main bile duct stones were treated in the same period. During the first two years LIOUS and IOC were performed alternately, with similar diagnostic accuracy (100% for LIOUS vs. 95% for IOC), but sensitivity was significantly better with LIOUS (98% vs. 80%) [8]. Subsequently, LIOUS was preferentially used when the learning curve had reached a plateau, obtaining high diagnostic specificity (98%) and accuracy (100%).

The time required to perform LIOUS was significantly shorter than that for IOC (6 min vs. 8 min on average). Also, with experience more information could be obtained with LIOUS (Fig. 5) than by IOC with respect to thickness of the bile duct wall and abnormalities of the cystic duct confluence and of the biliary papilla. Moreover, ultrasound was preferably done at the beginning of surgery, before any dissection of the hepatic pedicle, thus preventing possible complications in the common bile duct. No cannulation of the cystic duct or contrast injection was required.

Table 2. Comparative results of IOUS-LIOUS in abdominal surgery

Pathology	More information	Change of surgical strategy (%)
Liver	100	19.4
Pancreas	60	30
Colon and stomach	35.3	9.5
Adrenal	—	10
Cumulative results	65.1	17.2

From 2001 through 2005, 541 colonic resections and 82 stomach resections were performed for malignancies, GIST, or neuroendocrine tumors. Only 108 patients (19.9%) with colorectal pathologies and 28 patients (34.1%) with gastric malignancies were studied with intraoperative ultrasound. Nodal involvement in either the right or the left mesocolon and in perigastric or celiac nodes and the number and extension of liver metastases were the additional data supplied by LIOUS, which proved more accurate than preoperative imaging in 48 patients (35.3%) and changed operative management in 13 patients (9.5%).

Our experience included 82 adrenal surgery procedures in the same five year period. Forty patients (47.8%) were studied with LIOUS via a transperitoneal approach. LIOUS was used whenever doubts remained about resectability or the surgical location of the adrenal gland was difficult find and was to evaluate involvement of the kidney. In two cases vena caval adherence or infiltration, not detected by preoperative imaging, was shown. In two cases of left adrenal secondary lesions and pancreatic and/or retroperitoneal involvement, contraindicating surgery was evidenced by LIOUS. Surgery was thus changed in 10% of the cases (Table 2).

Discussion

Liver anatomy is defined by LIOUS as well as by open sonography; the study can be performed by a transumbilical or (for the right lobe) a subxyphoid approach. The hepatic veins appear as longitudinal, thin-walled anechoic structures, while the portal pedicles appear as transversal thick-walled vessels, crossing the hepatic veins and holding them in their bifurcations like a saddle. The laparoscopic probe can be steered up and down to gain perfect adherence to the hepatic surface, thus allowing palpation of the liver parenchyma, in a way much similar to finger palpation.

John et al. [9] reported in 1994 that LIOUS gave additional staging information in 42% of patients and changed surgical strategy in 16%, increasing resectability from 58% to 93%, while Foroutani et al. [10] in 2000 reported increased sensitivity of LIOUS over CT for small hepatic lesions, ranging from 0.3 to 2.7 cm.

Lo et al. [11] reported that exploratory laparotomy was avoided in 63% of patients with unresectable HCC, and Montorsi et al. [12] found that more HCC nodules than expected with preoperative examinations and laparoscopy were detected in 18.5% of cirrhotic patients.

As for metastatic lesions, Goletti et al. [13] found LIOUS to be of value for detecting further liver lesions in 10%–30% of the cases and changing the surgical program in 12%, while Hartley et al. [14] found that it helped diagnosis in only 2.6% of the treated patients.

IOUS has proven useful in pancreas surgery as well: Staging of neoplasms and infiltration of the superior mesenteric vein have been the main topics of this pathology. Machi et al. [2] reported the correct definition of mesenteric vessel infiltration in 89.7% of the cases with IOUS compared with 64.1% with preoperative examinations. Kaczmarek [15] reported that IOUS was helpful in 50% of the procedures in patients with complicated chronic pancreatitis and pancreas adenocarcinoma and it was essential for decision-making in 22.9%.

John et al. [16] evaluated the effects of laparoscopic ultrasonography in the management of pancreatic head and periampullary tumors, reporting further information in addition to laparoscopy alone in 53% of the patients and change in decisions regarding resectability in 25%. However, the importance of LIOUS is not limited to malignant disease: It extends to potentially benign pancreatic pathologies like cystadenomas and endocrine tumors such as insulinomas.

In a recent review by Falconi et al. [17], the problem of localization of endocrine tumors is still unresolved in 10%–20% of the cases, even when using advanced preoperative imaging techniques. Thus, intraoperative ultrasound allows the identification of 88% of insulinomas, 91% of pancreatic gastrinomas, and approximately 30% of duodenal gastrinomas. Atypical resection or regulated surgery can be scheduled according to nodule location and relationships to vessels and the Wirsung duct.

Serous and mucinous cystadenomas, which represent only 10%–13% of all pancreatic cystic lesions and less than 1% of tumors of the pancreas, are accurately defined by LIOUS, which can give further information on laparoscopic resectability and risks of postoperative pancreatic fistula.

The role of ultrasound in biliary surgery has been appreciated since the early 1980s when Machi et al. [2] reported IOUS to be the most accurate and cost-effective tool in the diagnosis of CBD lythiasis. In a subsequent study by Jakimowicz et al. [1], accuracy of IOUS was 97.5% compared with 94.4% for intraoperative cholangiography (IOC), allowing one to cut useless CBD surgery from 10% to 2.7%. Nowadays, laparoscopic cholecystectomy has almost completely replaced open surgery and hence LIOUS has been gaining acceptance among biliary surgeons as a means of reducing bile duct lesions during surgery [18] or to detect CBD stones with a high sensitivity (96% vs. 86% for IOC) and specificity (100% vs. 99%), as in the experience of Tranter et al. [19]. Some specialized teams have been using LIOUS successfully since the mid-1990s [20, 21].

Fig. 6. LIOUS: Distal hepatic pedicle showing the ''triple rail'' image consisting of the CBD, portal vein, and inferior vena cava.

The updated laparoscopic probes have a flexible tip, are multifrequency scanners, and can be steered up to a 90° angle to perfectly fit the hepatic pedicle by direct contact. Access can be effected through the umbilical or the subxyphoid port, allowing either a longitudinal or a transverse view of the anatomic structures. Using umbilical access, a '' triple rail'' image (Fig. 6) is seen by the examiner in the distal pedicle, consisting of the CBD, the portal vein, and inferior vena cava (sometimes a twin image of bile ducts is seen in case of low cystic duct confluence). More proximally, a ''coffee bean'' image (Fig. 7) is clearly detected, consisting of the hepatic duct, right hepatic artery, and portal vein. The subxyphoid approach gives a ''Mickey Mouse'' appearance in which the ears are the CBD and the hepatic artery, while the mouth is the portal vein. Both access routes are recommended to rule out suspected bile duct lythiasis, giving special attention to the diameter of the bile duct (7 mm is considered the cutoff for the presence of stones) and to the thickness of bile duct wall and the presence of biliary sludge. All these signs are poorly detected by IOC. Also, the presence of papillary edema or duodenal mucosa irregularities can be appreciated, and tiny stones of up to 3 mm can be visualized in a few minutes of examination and without any contrast medium. Color Doppler can be used to better differentiate vessels from bile ducts, and the operative field can be irrigated with sterile saline to get better acoustic coupling. LIOUS is best done before any surgical dissection because the presence of air can create artifacts and, moreover, the plan of surgery can be determined at the start of the procedure.

Smith et al. [22] in 1999 published a study in which he showed that the use of laparoscopy could avoid unnecessary open surgery in 19% of patients with esophagogastric cancer and LIOUS further identified 8% of nonresectable patients in whom unnecessary surgery was avoided. LIOUS helped in establishing the T stage of the tumor and the regional, celiac, and hepatic pedicle lymph nodes (N stage), and the liver was

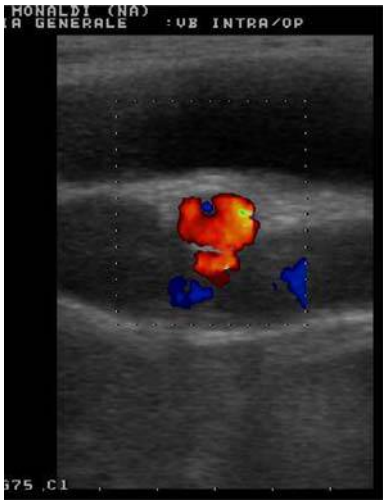

Fig. 7. LIOUS: Proximal hepatic pedicle showing the "coffee bean" image consisting of the hepatic duct, right hepatic artery, and portal vein.

scanned for metastases, thus providing a sharp classification of tumor extension. In our experience LIOUS allowed a good definition of stomach wall invasion and lymph nodes could be classified as involved when they were more than 10 mm, spherical, and had a hypoechoic pattern.

In the case of benign gastric wall tumors such as leiomyoma and stromal tumors, LIOUS has been found useful as a complement to endoscopic ultrasound in exactly localizing the nodule, which is generally located in the posterior wall of the stomach near the esophagogastric junction, and typically has a well-defined fibrotic capsule and a homogeneous pattern.

Since the development of laparoscopic resection for colorectal cancer, intraoperative staging during the laparoscopic procedure is limited and LIOUS represents the only real alternative to manual palpation. As with gastric cancer, the examination starts with localization of the neoplsm and local staging, then the mesocolic and para-aortic nodes are explored and the lymph nodes surrounding the inferior mesenteric artery and vein are detected. Finally, the liver is scanned for metastases. In 1998 Goletti et al. [13] reported that laparoscopy and LIOUS changed the therapeutic plan in 21% and 12% of the patients with colon cancer, respectively, mainly by detecting undiagnosed liver metastases. LIOUS compared favorably with preoperative diagnostic means and laparoscopy alone in the evaluation of liver metastases and peritoneal effusion, with a sensitivity of 100% vs. 62.5% and 75%, respectively. Nodal involvement was correctly defined in 94% of the cases, but specificity was low mainly because of the difficulty in differentiating benign hyperplastic from malignant nodes.

Since laparoscopic adrenalectomy has become the gold standard for most adrenal primary and secondary tumors, there has been growing evidence that LIUOS has relevance, both for outlining the vascular supply by using color and power flow techniques and for evaluating resectability, adherence to the liver, and infiltration of the vena cava on the right side and pancreatic tail involvement on the left.

In our experience IOUS and LIOUS were selectively used in 43.8% of the patients when doubts about disease extension and staging, resectability, and/or the surgical approach (open or laparoscopic) remained after preoperative evaluation. For these patients the end points of our study were (1) to evaluate the importance of IOUS and LIOUS to get further information or reveal undetected lesions, and (2) to find out the impact of IOUS and LIOUS on surgical decision-making for several different abdominal pathologies. The cumulative results were 65.1% and 17.2%. The most important application fields were the liver (100% and 19.4%, respectively) and the pancreas (60% and 30%, respectively), while colonic and gastric pathologies seemed to be less ultrasound dependent (35.3% and 9.5%, respectively) and adrenal surgery was affected in only 10%.

We found that the role of LIOUS in biliary surgery was extremely important, gradually replacing intraoperative cholangiography for detection of bile ducts stones. More experience is required so general surgery teams can take advantage of these techniques to better fit patient requirements and reduce surgical risks.

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