Surg Endosc (1999) 13: 784–788

Surgical Endoscopy
Ultrasound and
Interventional Techniques

A prospective comparison of laparoscopic ultrasound vs intraoperative cholangiogram during laparoscopic cholecystectomy

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Received: 1 May 1998/Accepted: 21 October 1998

Abstract
Background: The laparoscopic ultrasound (US) probe provides a new modality for evaluating biliary anatomy during laparoscopic cholecystectomy (LC).
Methods: We performed a laparoscopic US examination in 65 patients without suspected common bile duct (CBD) stones prior to the performance of a laparoscopic cholangiogram (IOC). We then compared the cost, time required, surgeon's assessment of difficulty, and interpretations of findings.
Results: There was a significant difference in the cost of US versus the cost of IOC ($362 ± 12 versus $665 ± 12; $p <$ 0.05). Surgeons who had performed >10 US (EXP) were compared with those who had performed ≤10 (NOV). There were significant differences between the EXP and NOV groups in ease of examination, visualization of biliary anatomy, and accuracy of measurement of the CBD.
Conclusions: The use of laparoscopic US for the accurate evaluation of the CBD and biliary anatomy requires that the surgeon has surpassed the learning curve, which we have defined as having performed >10 US exams.

Key words: Laparoscopic ultrasound — Intraoperative cholangiography — Laparoscopic cholecystectomy — Choledocholithiasis

Laparoscopic cholecystectomy has become the gold standard for the treatment of symptomatic cholelithiasis and cholecystitis. Although preoperative symptoms and studies including ultrasound (US) and liver function tests have been utilized to detect the presence of choledocholithiasis, the intraoperative cholangiogram remains the treatment of choice to identify common duct stones. The intraoperative cholangiogram has also been used to delineate extrahepatic biliary anatomy and to avoid or identify unintentional ductal injury (0.5–2.7% incidence versus 0.2% in open cholecystectomy) [7].

There has yet to be universal acceptance of the intraoperative cholangiogram (IOC) for routine screening or anatomic verification. Advocates cite the ability of cholangiography to identify occult common duct stones (5–10%) and to define surgically relevant aberrant ductal anatomy (6%) [2, 4], thereby decreasing the incidence of postoperatively retained common duct stones and the likelihood of accidental injury to the common duct. Opponents of routine cholangiography point to the additional expense, false positive results, and the added time and difficulty involved. Performance of cholangiography adds, on average, 15 min of operating time and $500–750 to the cost of the procedure. In addition, it has been estimated that $165,000 worth of routine exams are required to identify one clinically relevant and otherwise missed common duct stone [6]. While most general surgeons can easily perform cholangiography, the rate of success when applied in a routine manner is 90% at best [1]. For these reasons, many surgeons have suggested a selective use of cholangiography [11, 17].

It is readily apparent that a safe and easily performed procedure to diagnose choledocholithiasis and define biliary anatomy would be a useful tool in the general surgeon's armamentarium. In the prelaparoscopic era, intraoperative ultrasonography demonstrated its effectiveness in the evaluation of the extrahepatic biliary anatomy. High sensitivity and specificity have been witnessed in defining anatomy and identifying choledocholithiasis during open cholecystectomy [8, 12, 16]. Recently, surgeons have gained experience with the utilization of laparoscopic US probes for identifying ductal anatomy and choledocholithiasis with positive results [3, 9, 13]. It appears that when performed by an experienced surgeon, this technique is a reliable method

Presented at the annual meeting of the Society of American Gastrointestinal Endoscopic Surgeons (SAGES), Seattle, Washington, USA, 1–4 April 1998

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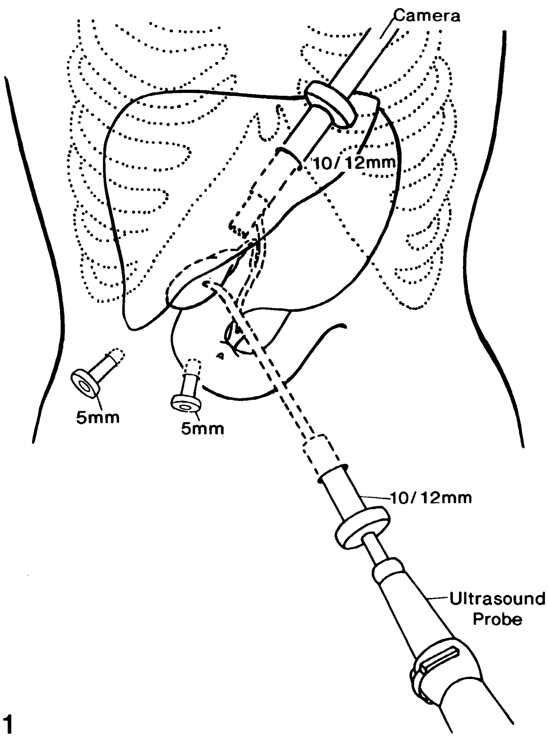

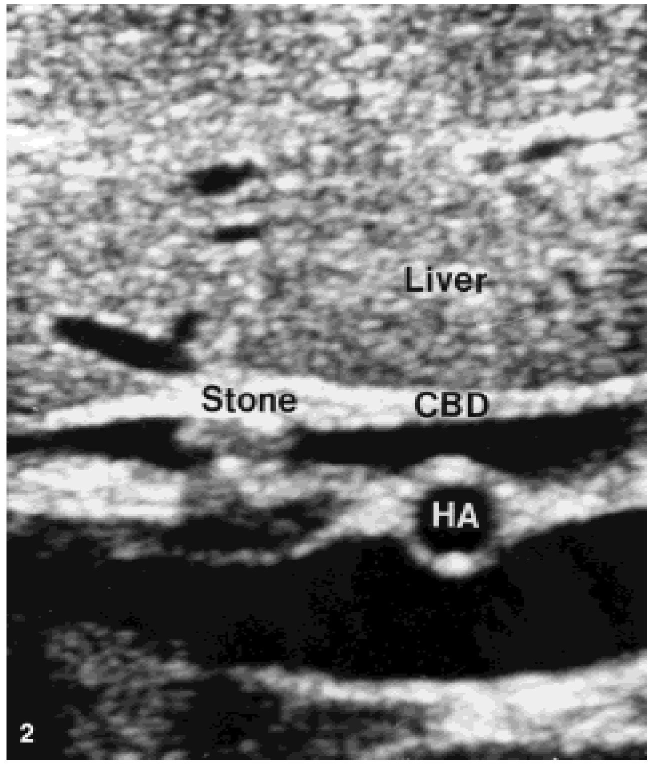

Fig. 1. Schematic diagram of intraoperative placement of trocars and laparoscopic ultrasound probe.

Fig. 2. Ultrasound image of the common bile duct (CBD) with a stone present within the duct (HA, hepatic artery).

for evaluating the extrahepatic biliary ducts that is certainly less invasive than cholangiography. The laparoscopic US probe offers the additional benefit of allowing the use of color Doppler imaging to identify blood vessels and examine suspicious lesions in the gallbladder wall. Furthermore, it can be used repeatedly during a procedure if necessary. Finally, intraoperative US has been reported to take less time than a cholangiogram and it is probably more cost-effective.

There have been few prospective studies comparing laparoscopic intraoperative US to intraoperative cholangiogram, and there have been none evaluating differences in surgeons' experience. We have found that laparoscopic US is a reproducibly accurate and precise method of evaluating the extrahepatic biliary tree for anatomic orientation and the presence of choledocholithiasis once the surgeon has gained adequate experience.

Materials and methods

All patients undergoing laparoscopic cholecystectomy for cholelithiasis or cholecystitis at the University of Cincinnati Medical Center from April 1996 through May 1997 were offered a chance to participate in the study. All patients underwent routine preoperative evaluation, including a complete history and physical examination; particular attention was paid to a history of jaundice or pancreatitis. Routine preoperative blood work included a complete blood count and analysis of liver enzymes including bilirubin and amylase. Additionally, all patients underwent a right upper quadrant US to determine the presence of cholelithiasis, choledocholithiasis, cholecystitis, pancreatitis, common bile duct dilation, or obstruction. Only patients without suspected common bile duct stones were entered into the study group.

Before beginning the study, all surgeons were given a brief in-service demonstration of the proper use of the laparoscopic US probe. Routine laparoscopic cholecystectomy was performed in all patients. Prior to the performance of the intraoperative laparoscopic cholangiography, laparoscopic US examination was performed. Examination of the extrahepatic biliary tree was performed utilizing a Toshiba (Tustin, CA, USA) 7-mHz probe with four degrees of freedom. Once the four standard access ports were placed, but prior to beginning the dissection of the gallbladder, the US examination was performed in the standard manner.

Initially, the gallbladder was not retracted but allowed to remain in its subhepatic position. The 30° laparoscope was positioned in the 10/12-mm subxiphoid port. The US probe was then inserted via the 10/12-mm umbilical port (Fig. 1). The examination was begun by placing the probe over the antero-superior segment V of the liver to obtain a transhepatic view of the gallbladder in situ. Determination of cholelithiasis was then made. The probe was passed medially over segment IV so that the common hepatic duct could be seen, as well as any dilation of the intrahepatic ducts. The liver and gallbladder were then retracted superiorly by placing a grasper on the gallbladder fundus with cephalad traction to afford access to the porta hepatis. The US probe was positioned over the hepatoduodenal ligament and dragged along its course. Intraperitoneal instillation of saline was utilized to achieve good sonic conduction. Multiplanar imaging was performed to assess the portal structures, including the common bile duct, the cystic–common duct junction, the portal vein, and the hepatic artery. Color Doppler imaging was used to assist with anatomic orientation. The probe was advanced toward the duodenum, and attempts were made to visualize the intrapancreatic common bile duct. During this time, the presence or absence of choledocholithiasis was documented (Fig. 2). Image quality, ease of examination performance, and ability to distinguish the various anatomical structures and pathology was scored by each surgeon (easy, difficult, or impossible). A staff radiologist blinded to the surgeons' interpretation evaluated the majority of the studies postoperatively to assess the surgeons' ability to identify essential anatomical structures.

Upon completion of the US examination, cholangiography was performed. After a small dochotomy was made in the cystic duct, a cholangiographic catheter was passed into the duct. Instillation of contrast into the biliary tree was viewed using real-time fluoroscopy. The surgeon's subjective assessment of degree of difficulty and ability to visualize anatomic structures by cholangiogram was also recorded. All intraoperative deci-

Table 1. Comparison of perceived difficulty or ease of performing laparoscopic ultrasound versus intraoperative cholangiogram

	Ultrasound ($n = 64$)			Cholangiogram ($n = 63$)		
	Easy	Difficult	Impossible	Easy	Difficult	Impossible
EXP	22/31 70.9%	9/31 29.1%	0/31 0%	24/33 72.7%	4/33 12.1%	5/33 15.2%
NOV	8/33 24.2%[a]	20/33 60.1%[a]	4/33 12.1%	20/30 66.7%	6/30 20%	4/30 13.3%

EXP, surgeons who had performed >10 laparoscopic ultrasound exams; NOV, surgeons who had performed ≤10 ultrasound exams
[a] $p \leq 0.001$ by Student's *t*-test
Only cases in which all information was available were used in this table, yielding an *n* of 64 in the ultrasound group and an *n* of 61 in cholangiogram group

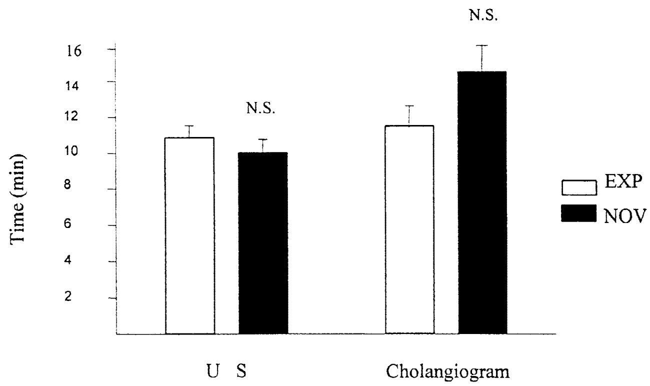

Fig. 3. Time to perform either laparoscopic intraoperative ultrasound or intraoperative cholangiogram between surgeons who had done >10 laparoscopic ultrasound exams (EXP) and those who had performed ≤10 (NOV).

sions were made based upon the cholangiographic images, not the US results.

Time required to perform both procedures was recorded. For the US examination, the procedure time was started when the US probe was placed into the trocar and completed when it was removed from the abdomen. Time to perform the cholangiogram was recorded from incision of the cystic duct to removal of the catheter.

Postoperatively, patients were followed in a routine fashion, with anticipated discharge within 23 h of the procedure. Particular attention was paid to the presence of postoperative choledocholithiasis, jaundice, pancreatitis, cholangitis, and/or the need for ERCP.

Statistical analysis was performed using Student's *t*-test and the chi-square test; $p < 0.05$ was considered significant. Results are reported as percentage (%) or mean ± SEM.

Results

A total of 53 female and 11 male patients with an average age of 44 years old (range, 19–72 years) were enrolled in the study group. Laparoscopic intraoperative US was performed in 60 of 65 patients (92%). The most common reason for inability to perform the US was operator inexperience or inability to interpret the images. In 30 patients (50%), the surgeon described the procedure as easy; in 29 cases (48%), it was described as difficult. Evaluation of ease or difficulty was unrecorded for one successful US. Eighty-six percent (56/65) of the study population had a successful intraoperative cholangiogram performed. In the majority of the failed cholangiograms, a small cystic duct led to the inability to cannulate; one failure was secondary to an impacted stone in a short cystic duct seen on US. According to the operating surgeon, 44 (79%) of the cholangiograms were easy, whereas 10 (18%) were difficult. Assessment of ease or difficulty was unrecorded for two successful cholangiograms.

In order to evaluate the effect of experience on the success of laparoscopic ultrasonography more carefully, the surgeons in the study were then divided into two groups: those who had performed >10 laparoscopic US examinations ($n = 2$; experienced, EXP) and those who had performed ≤10 ($n = 7$; novice, NOV). This somewhat arbitrary division was made based on our retrospective analysis of the data. In analyzing these data, we were able to appreciate several significant differences (Table 1). As shown in the table, surgeons experienced in laparoscopic US found the examination easy to perform in 71% of cases; this rate compares favorably to those less experienced and is approximately the same as the percentage of easy cholangiograms. There were no significant differences between EXP and NOV surgeons in the time to perform either the laparoscopic US or the intraoperative cholangiogram (Fig. 3).

We also compared the ability to visualize important anatomical structures within the porta hepatis between US and cholangiogram and among EXP and NOV (Table 2). As shown in the table, the experienced surgeons (EXP) were able to visualize the cystic common duct junction, the common hepatic duct, and the distal common bile duct significantly more frequently ($p < 0.05$) than the less experienced novice surgeons (NOV). Furthermore, the EXP surgeons were able to visualize anatomical structures via laparoscopic US at least as frequently as both groups visualized similar structures using the gold standard method of intraoperative cholangiogram. In addition, in almost all cases, both the EXP and NOV surgeons were able to successfully visualize the portal vein and hepatic artery, structures impossible to identify using a cholangiogram. In the blinded review, the staff radiologist confirmed the surgeons' identification of anatomic structures 70% of the time. The areas with the poorest correlation between surgeon and radiologist were in the identification of the proximal biliary radicals and the distal common bile duct. These differences were evenly divided between cases in which the radiologist thought that the structure was visualized and the surgeon did not identify it and those in which the reverse was true.

In our patients, we identified four common duct stones using a combination of intraoperative ultrasonography and cholangiogram for diagnosis. Two stones were identified by cholangiogram in cases where the surgeon believed that the US was impossible. One stone was identified by US and subsequently confirmed by cholangiography. The final stone was seen on cholangiogram only, despite an apparently technically successful intraoperative US exam. In this case, despite laparoscopic common duct exploration, no stone was ever retrieved. This common duct stone identification may therefore be considered a false positive cholangiogram.

Recently, Birth et al. [3] reported a series of 516 intraoperative laparoscopic US examinations with the identification of 24 common duct stones and five false positive cholangiograms but no false positive US exams. In our

Table 2. Visualization of portal structures by laparoscopic ultrasound and intraoperative cholangiogram

	Ultrasound (n = 64)		Cholangiogram (n = 61)	
	NOV	EXP	NOV	EXP
Cystic/common duct junction	3/31 (9.7%)[a]	20/33 (60.6%)	26/30 (86.7%)	26/31 (83.9%)
Proximal biliary tree	16/31 (51.6%)	26/33 (78.8%)	26/30 (86.7%)	25/31 (80.6%)
Portal vein	31/31 (100%)	33/33 (100%)	—	—
Hepatic artery	27/31 (87.1%)	33/33 (100%)	—	—
Common hepatic duct	19/31 (61.3%)[a]	32/33 (97%)	25/30 (83.3%)	24/31 (77.4%)
Common bile duct	21/31 (67.7%)	28/33 (84.8%)	25/30 (83.3%)	26/31 (83.9%)
Distal common bile duct	7/31 (22.6%)[a]	24/33 (72.7%)	24/30 (80%)	26/31 (83.9%)

EXP, surgeons who had performed >10 laparoscopic ultrasound exams; NOV, surgeons who had performed ≤10 ultrasound exams

[a] $p < 0.05$ by Student's *t*-test

Only cases in which all information was available were used in this table, yielding an *n* of 64 in the ultrasound group and an *n* of 61 in cholangiogram group

study group, there were two false positive US exams, both performed by less experienced surgeons and described as difficult by the surgeons. In these two cases, the cholangiogram was negative, the ducts were not explored, and the patients suffered no postoperative complications. Ultrasound common duct diameter was significantly greater ($p < 0.05$) with the presence of a stone (8.1 ± 2.1 mm) than without a stone (3.9 ± 0.27 mm).

The average cost of a laparoscopic ultrasound exam ($362 ± 12) was significantly less ($p < 0.0001$) than the cost of an intraoperative cholangiogram ($665 ± 59). The bulk of the cost differential was secondary to the need for disposable catheters for cholangiography and the cost of real-time fluoroscopy in the operating room. The difference in cost would probably be even greater secondary to decreased operating room costs if, as in other studies [3, 13–15], the time to perform US was significantly shorter than the time to perform cholangiography.

Discussion

It is frequently necessary during laparoscopic cholecystectomy to evaluate the anatomy of the biliary tree. During open cholecystectomy, the use of intraoperative ultrasound has been shown to be as reliable as a cholangiogram in evaluating the bile ducts [8, 10, 12]. For both laparoscopic cholecystectomy and open cholecystectomy, the debate continues over the need for routine versus selective cholangiography [2, 4, 5, 7, 11, 17]. Some of the factors weighing against routine cholangiography are the cost and time to perform the exam, as well as the failure rate associated with the exam. Laparoscopic US examination is a reliable means of assessing the bile ducts and portal anatomy that has been shown to eliminate some of these problems [3, 9, 13–16, 18].

One of the commonly reported limitations of laparoscopic ultrasound's usefulness has been the long learning curve required to perform and interpret an intraoperative US examination [8–10, 14–16]. In the current study, we have demonstrated that after as few as 10 laparoscopic US examinations, the ease of examination, visualization of anatomic structures, and identification of common duct stones compares favorably to the intraoperative cholangiogram. Given a slightly longer learning curve, we may also have been able to demonstrate a decreased time to complete the intraoperative sonography.

Laparoscopic US has several advantages over the routine or selective use of intraoperative cholangiography. The use of US allows the surgeon to begin evaluating anatomy, including major vascular structures, prior to any dissection in Calot's triangle, it eliminates an unnecessary radiation, and it avoids the measurable failure rate of cholangiograms. In addition, unlike cholangiography, the US exam is easily repeated during the cholecystectomy if further questions of anatomical orientation or complications arise.

In this study, a further advantage of intraoperative ultrasonography was demonstrated—a decreased cost of examination. Although the initial cost to purchase the ultrasound probe was $28,500, given the ~$300 per patient savings over the cost of intraoperative cholangiography, the expense of the probe will be recaptured after ~95 exams. Although the cost of a standard color Doppler US machine is significant, at our institution this machine is shared with radiology and is also used for all other intraoperative US needs. Therefore we did not include the cost in our analysis. Similarly, the cost of a C-arm fluoroscopic machine was not included.

In the present series, surgeons who performed >10 laparoscopic US examinations were able to visualize the common hepatic duct (97%), the common bile duct (85%), and the distal common bile duct (73%) in the majority of cases. This success rate compares favorably with other reported series [3, 13] as well as with the ability to visualize similar structures using cholangiography. Furthermore, the experienced surgeons encountered no cases in which the US exam was impossible; by contrast, the failure rate for cholangiogram by the same group of surgeons was 15%. Although the experienced surgeons identified only one true positive common duct stone by both US and cholangiography, the sensitivity and specificity of laparoscopic US compared favorably to cholangiogram in several studies and may even have a positive predictive advantage over cholangiography [3, 13, 16].

The development of specialized US scanners with real-time imaging and color Doppler scanning facilitates the use of laparoscopic ultrasonography by surgeons with relatively little ultrasonographic experience. Although the use of laparoscopic US does not eliminate the possibility of duct injury or missed common duct stones, it does provide a fast, reproducible, reliable, and cost-effective means by which the surgeon, after a short learning curve, can screen the biliary anatomy. Ultrasound must always be used in conjunction with the surgeon's visual anatomic clues. Identifying aberrant anatomy by US alone, such as a high insertion of the cystic duct into the right hepatic duct, is still difficult, and careful dissection is still the rule. If questions concerning choledocholithiasis, aberrant anatomy, or bile duct injury remain after US examination, selective intraoperative cholangiogram should be utilized. Continued experience with intraoperative laparoscopic US examination by surgeons skilled in laparoscopy is likely to lead to further improvements in the sensitivity of the exam. Indeed, it may one day surpass the intraoperative cholangiogram as the screening method of choice during laparoscopic cholecystectomy.

Acknowledgments. This work has been supported by a SAGES grant made possible by Ethicon Endo-Surgery. Dr. R. A. Falcone, Jr., is the recipient of a SAGES Resident Research Award. We thank Laura James for her gracious assistance in performing the statistical analyses and Jean Loos for her talented art work for this manuscript. We also acknowledge the ongoing support of the operating room and radiology support staff.

References

1. Berci G, Sackier JM (1991) The Los Angeles experience with laparoscopic cholecystectomy. Am J Surg 161: 382–384
2. Berci G, Sackier JM, Paz-Parlow M (1991) Routine or selected intraoperative cholangiography during laparoscopic cholecystectomy? Am J Surg 161: 355–360
3. Birth M, Ehlers KU, Delinikolas K, Weiser HF (1998) Prospective randomized comparison of laparoscopic ultrasonography using a flexible-tip ultrasound probe and intraoperative dynamic cholangiography during laparoscopic cholecystectomy. Surg Endosc 12: 30–36
4. Cantwell DV (1992) Routine cholangiography during laparoscopic cholecystectomy. Arch Surg 127: 483–484
5. Clair DG, Carr-Locke DL, Becker JM, Brooks DC (1993) Routine cholangiography is not warranted during laparoscopic cholecystectomy. Arch Surg 128: 551–554
6. Gerber A (1986) A requiem for the routine operative cholangiogram. Surgery 163: 363–364
7. Hunter JG (1991) Avoidance of bile duct injury during laparoscopic cholecystectomy. Am J Surg 162: 71–75
8. Jakimowicz JJ, Rutten H, Jürgens PJ, Carol EJ (1987) Comparison of operative ultrasonography and radiography in screening of the common duct for calculi. World J Surg 11: 628–634
9. Kubota K, Bandai Y, Sano K, Teruya M, Ishizaki Y, Makuuchi M (1995) Appraisal of intraoperative ultrasonography during laparoscopic cholecystectomy. Surgery 118: 555–561
10. Lane RJ, Coupland GAE (1982) Ultrasonic indications to explore the common bile duct. Surgery 91: 268–274
11. Lillemore KD, Yeo CJ, Talamini MA, Wang BH, Pitt HA, Gadacz TR (1992) Selective cholangiography: current role in laparoscopic cholecystectomy. Ann Surg 215: 669–676
12. Mosnier H, Roullet Audy JC, Boche O, Guivarc'h M (1992) Intraoperative sonography during cholecystectomy for gallstones. Surgery 174: 469–473
13. Ohtani T, Kawai C, Shirai Y, Kawakami K, Yoshida K, Hatakeyama K (1997) Intraoperative ultrasonography versus cholangiography during laparoscopic cholecystectomy: a prospective comparative study. J Am Coll Surg 185: 274–282
14. Rothlin MA, Schlumpf R, Largiader F (1994) Laparoscopic sonography: an alternative to routine intraoperative cholangiography? Arch Surg 129: 694–700
15. Rothlin MA, Schob O, Schlumpf R, Largiader F (1996) Laparoscopic ultrasonography during cholecystectomy. Br J Surg 83: 1512–1516
16. Sigel B, Machi J, Beitler JC, Donahue PE, Bombeck CT, Baker R, Duarte B (1983) Comparative accuracy of operative ultrasonography and cholangiography in detecting common duct calculi. Surgery 94: 715–720
17. Traverso LW, Hauptmann EM, Lynge DC (1994) Routine intraoperative cholangiography and its contribution to the selective cholangiographer. Am J Surg 167: 464–468
18. Yamamoto M, Stiegmann GV, Durham J, Berguer R, Oba Y, Fujiyama Y, McIntyre RC (1993) Laparoscopy-guided intracorporeal ultrasound accurately delineates hepatobiliary anatomy. Surg Endosc 7: 325–330