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ORIGINAL ARTICLE

Laparoscopic Ultrasonography Versus Magnetic Resonance Cholangiopancreatography in Laparoscopic Surgery for Symptomatic Cholelithiasis and Suspected Common Bile Duct Stones

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Abstract

Background There continues to be controversy regarding the optimal screening modality in patients with symptomatic cholelithiasis and suspected common bile duct (CBD) stones. The aim of this study was to assess the diagnostic accuracy of laparoscopic ultrasonography (LUS) compared to magnetic resonance cholangiopancreatography (MRCP).

Methods Both LUS and MRCP were performed to evaluate the CBD stones and biliary anatomy in 200 patients undergoing laparoscopic surgery. Pre-, intra-, and postoperative data were collected prospectively and reviewed retrospectively.

Results Coexisting CBD stones were identified in 64 of 200 (32%) patients by surgical exploration or postoperative ERCP. For the detection of CBD stones, LUS yielded a positive predictive value of 100%, a negative predictive value of 99.3%, a sensitivity of 98.4%, and a specificity of 100%. Preoperative MRCP had a positive predictive value of 87.9%, a negative predictive value of 95.5%, a sensitivity of 90.6%, and a specificity of 94.1%. The non-random concordance between MRCP and LUS was considered to be excellent with a kappa coefficient of 0.92 ($p < 0.01$).

Conclusions LUS can reduce the need for MRCP examination and can become the primary imaging method for the evaluation of CBD stones in laparoscopic surgery.

Keywords Laparoscopic ultrasonography · Magnetic resonance cholangiopancreatography · Cholelithiasis · Outcomes

Introduction

The incidence of common bile duct (CBD) stones in patients undergoing elective cholecystectomy for symptomatic gallstones is reported to be 5 to 15%,[1–6] while it is higher in patients with suspected CBD stones based on preoperative imaging or abnormal laboratory findings.[7–9] Treatment options include laparoscopic cholecystectomy (LC) with peri-operative endoscopic biliary sphincterotomy and stone extraction, LC with transcystic or trans-ductal exploration of CBD, and LC alone followed by expectant management.[1,2,10] Preoperative endoscopic retrograde cholangiopancreatography (ERCP), trans-abdominal or endoscopic ultrasonography, magnetic resonance cholangiopancreatography (MRCP), fluoroscopic intraoperative cholangiography (IOC), and laparoscopic ultrasonography (LUS) are the standard procedures in evaluating patients with suspected CBD stones. However, there continues to be controversy regarding the necessity and method of bile duct imaging[11]. Recently, the non-invasive imaging techniques such as MRCP and LUS have been increasingly used as the primary imaging methods to screen the bile duct for stones and to identify the biliary anatomy.[10,12–15] Herein, we report a prospective study of laparoscopic surgery in 200 patients with symptomatic cholelithiasis and suspected CBD stones, with the aim of critically evaluating our experience and results of using LUS as compared with preoperative MRCP.

Patients and Methods

Patients

From January 2013 to July 2016, 1600 consecutive patients with symptomatic cholelithiasis were referred to our institution for laparoscopic surgery. Of them, 200 patients were preoperatively

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suspected with coexisting CBD stones based on clinical history suggestive of jaundice, cholangitis or pancreatitis, elevated serum levels of both conjugated and total bilirubin, or dilated CBD (with or without stones) on trans-abdominal ultrasound. There were 116 men and 84 women, with a median age of 49.5 years (range, 20–85 years). According to our traditional algorithm for management of cholelithiasis, preoperative MRCP was performed in these patients for confirming the presence of CBD stones and avoiding unnecessary exploration of CBD. In January 2013, laparoscopic ultrasound was introduced in our institute, and then we started the study to evaluate the role of LUS in laparoscopic surgery as compared with MRCP. Pre-, intra-, and postoperative data were collected prospectively and reviewed retrospectively. The study was approved by the local ethics committee, and informed consent was obtained from all patients.

Methods

The laparoscopic procedure was performed by the senior authors or by surgical trainees under supervision. The LUS examination was done using a 10-mm flexible probe equipped with a 7.5-MHz side-viewing transducer (Diagnostic Ultrasound System ProSound, Hitachi Aloka Medical Ltd). The LUS probe was inserted initially via the umbilical port and was passed under vision over the capsule of the liver. The liver parenchyma and gallbladder were scanned. The confluence of the right and left hepatic ducts were also viewed through segment IV of the liver. Afterwards, the probe was transferred into the subxiphoid port and was placed directly on the porta hepatis. The transverse scanning was performed from the common hepatic duct to the ampulla of the Vater. Visualization of the distal CBD was achieved by clockwise rotation of the probe. In some cases, saline solution was infused into the right upper quadrant to enhance acoustic coupling. Successful LUS examination was defined as visualization of the entire course of extrahepatic bile duct. Scanning was repeated as clinically required. The notation was made of the diameter of CBD; the presence, location, size, and number of stones or sludge; and the time and completeness of LUS examination.

When both MRCP and LUS showed the presence of CBD stones, the trans-ductal (CBD ≥ 6 cm in diameter) or trans-cystic exploration of the CBD with choledochoscopy was performed for confirmation and removal of stones. If only one imaging investigation showed positive results, the trans-cystic choledochoscopy investigation was attempted for identification of CBD stones. If the trans-ductal or trans-cystic exploration of CBD with stone retrieval was unsuccessful, the patients were converted to open CBD exploration or postoperative ERCP with biliary sphincterotomy and stone extraction. When the findings of the two imaging investigations were negative, the CBD was regarded as free of stones. The patients went on to LC. All patients were followed for more than 6 months postoperatively, with imaging and laboratory tests as clinically indicated. The diagnostic powers of the two imaging investigations were evaluated by calculation of sensitivity, specificity, and positive and negative predictive value. The presence or absence of coexisting CBD stones was identified by trans-cystic or trans-ductal CBD exploration, postoperative ERCP, and clinical follow-up results.

Statistical Analysis

Nonparametric tests were used for statistical analysis. The Mann–Whitney *U* test was used to compare continuous variables, and proportions were compared by chi-square test (SPSS/PC+; SPSS, Inc., Chicago, IL, USA). The diagnostic power of each imaging investigation was cross-tabulated using a contingency table. The Kappa coefficient was calculated to determine the concordance between the two imaging investigations. A p value of less than 0.05 was considered significant.

Results

The demographic and clinical profiles of the 200 patients are shown in Table 1. Coexisting CBD stones were identified in 64 of 200 (32%) patients by surgical exploration ($n = 61$) or postoperative ERCP ($n = 3$). Preoperatively, MRCP showed filling

Table 1 Clinical profiles of the patients according to the presence or absence of common bile duct stones

	With CBD stones ($n = 64$)	Without CBD stones ($n = 136$)
Mean age (years)*	47	41
Gender (male/female)*	36/28	80/56
Elevation of serum bilirubin level (with/without)#	42/22	25/111
Pancreatitis (with/without)#	10/54	4/133
Mean diameter of CBD by MRCP (cm)#	1.0	0.6
Mean diameter of CBD by LUS (cm)#	0.9	0.6
Mean hospital stay (days)#	3.8	2.2

CBD, common bile duct, *MRCP* magnetic resonance cholangiopancreatography, *LUS* laparoscopic ultrasonography

*$p > 0.05$; #$p < 0.05$

defects of CBD in 66 patients, 58 of whom were confirmed with CBD stones by surgical exploration (true positives), and 8 were identified without stones by both LUS and trans-cystic exploration of the CBD intraoperatively (false positives). The sensitivity and specificity of MRCP was 90.6 and 94.1%, respectively. The positive and negative predictive value of MRCP was 87.9 and 95.5%, respectively. The average time interval between MRCP and LC was 6 days (range, 1 to 11 days). Intraoperatively, LUS detected hyperechoic objects with acoustic shadow in 63 patients, all of whom were confirmed with CBD stones by surgical ($n = 60$) or endoscopic ($n = 3$) exploration (true positives). The LUS missed a small stone (2 mm in diameter) lodged in the ampullar region (false negative), which was confirmed and removed by trans-cystic exploration of CBD. The sensitivity and specificity of LUS was 98.4 and 100%, respectively. The positive and negative predictive value of LUS was 100 and 99.3%, respectively (Table 2). The non-random concordance between MRCP and LUS was considered to be excellent with a kappa coefficient of 0.92 ($p < 0.01$).

In addition, the CBD sludge was detected by LUS in three patients, but was not shown in any patient with MRCP. Two patients were treated by trans-cystic saline flushing, and the other was managed expectantly with no untoward sequelae. Two patients were identified with small stones lodged in cystic duct by LUS. The mean diameters of CBD measured by MRCP and LUS were 1.0 and 0.9 cm, respectively, in patients with CBD stones, and were significantly larger as compared with 0.6 and 0.6 cm in patients without CBD stones ($p < 0.05$). The biliary anatomy was successfully visualized in all patients with MRCP or LUS. Fifteen of 200 patients were preoperatively identified with variations of the hepatic duct confluence ($n = 12$) or the cystic duct confluence ($n = 3$) by MRCP. However, the biliary variations were recognized by LUS in 10 patients only. The average time required to perform LUS was 5.5 ± 3.1 min.

Laparoscopic procedure was successfully undertaken in all patients without requirement of conversion to an open procedure. Sixty-one patients underwent laparoscopic trans-ductal ($n = 49$) or trans-cystic ($n = 12$) exploration of CBD and stone removal. Three patients underwent endoscopic biliary sphincterotomy and stone extraction postoperatively due to failure of trans-cystic exploration (Fig. 1). The average hospital stay was 3.8 days for patients with CBD stones and 2.2 days for patients without CBD stones ($p < 0.05$). None of the patients presented with clinical or biochemical evidence of retained CBD stones after a median follow-up period of 19 months (range, 6–40 months). One patient (2%, 1/49) with LC and trans-ductal exploration developed early postoperative bile leakage and was successfully treated by peritoneal drainage combined with ERCP and bile duct stent. The duration of the leak was 5 days postoperatively. There were no operative mortality and reoperation for all patients.

Table 2 Results and accuracy indices of MRCP and LUS in detection of CBD stones

	MRCP	LUS
True positives	58	63
True negatives	128	136
False positives	8	0
False negatives	6	1
Sensitivity (%)	90.6	98.4
Specificity (%)	94.1	100
Positive predictive value (%)	87.9	100
Negative predictive value (%)	95.5	99.3

MRCP magnetic resonance cholangiopancreatography, *LUS* laparoscopic ultrasonography, *CBD* common bile duct

Discussion

The evaluation of possible concurrent CBD stones is critical in the surgical decision for patients with symptomatic cholelithiasis. Timely removal of CBD stones avoids the development of comorbidities such as cholangitis and pancreatitis. There have been considerable controversies regarding the optimal screening modality for suspected CBD stones in LC. Transabdominal ultrasonography is generally recommended as a preliminary investigation for identification of patients with concurrent CBD stones, but its accuracy is inadequate.[9,13,16] Both ERCP and IOC are the reference standards for diagnosis of CBD stones. It continues to be debated, however, whether a diagnostic procedure based on instrumentation of biliary system should be utilized routinely. Due to the potential risk of severe complications[17–19] and the cost concerns, the ERCP procedure is usually reserved for patients with therapeutic requirements and is not recommended for use only as a diagnostic test in most centers. IOC has been widely used to screen for CBD stones and to delineate bile duct anatomy in open or laparoscopic cholecystectomy. Increasingly, however, some investigators have argued that IOC does little to prevent bile duct injury during LC; increases operation time, costs, and complications; and causes radiation exposure to staff and patients.[20,21] In addition, the failure rate of IOC is around 6–15% in laparoscopic procedure for unselected patients,[22–24] and its utilization has dramatically decreased during the past decades.[25] As the non-invasive imaging techniques, both LUS and MRCP have recently been demonstrated to be equivalent to IOC in screening for CBD stones.[22,26,27] In the present study, therefore, we compared the outcomes of LUS to those of MRCP with the aim to determine an optimal screening modality in patients with symptomatic cholelithiasis and suspected CBD stones.

Our study indicated that the results of both LUS and MRCP compare favorably with the previous reports of IOC in terms of sensitivity and specificity for the detection of CBD

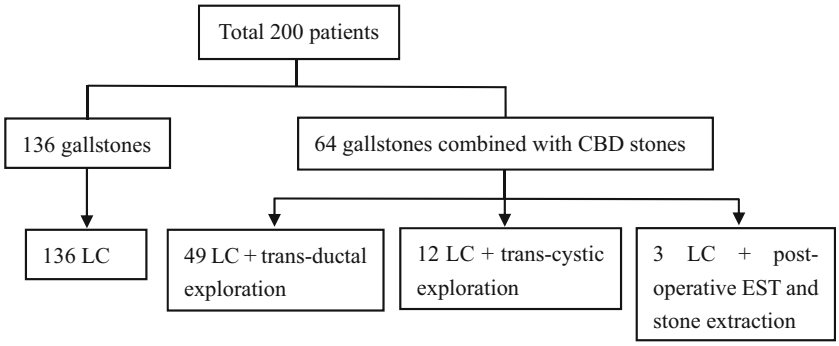

Fig. 1 Flow diagram of patient results. Laparoscopic procedure was successfully undertaken in 200 patients who were preoperatively diagnosed with symptomatic cholelithiasis and suspected CBD stones. Of them, 64 patients were identified with coexisting CBD stones by surgical exploration or postoperative ERCP. Abbreviations: CBD common bile duct, LC laparoscopic cholecystectomy, EST endoscopic sphincterotomy

stones.[20,21,26] The non-random concordance between the two investigations was excellent with a kappa coefficient of 0.92. LUS yielded a sensitivity and specificity of 98.4 and 100% respectively for the detection of CBD stones, which appeared to be superior to MRCP (90.6 and 94.1%, respectively). However, it should be noted that the false-positive rate of MRCP is difficult to be well defined due to the possible passage of stones during the interval between MRCP and laparoscopic procedure. In this study, 8 of 66 (12.1%) patients, who were considered positive on preoperative MRCP, were diagnosed false positive by the intraoperative LUS and trans-cystic choledochoscopy investigation. According to several clinical reports, more than one third of patients with CBD stones might pass the stones spontaneously especially after biliary colic, pancreatitis, cholecystitis, and jaundice.[6,28] To avoid unnecessary CBD exploration, therefore, an accurate intraoperative imaging of bile duct such as IOC or LUS is mandatory in these patients with suspected concurrent CBD stones. Another concern is whether LUS can accurately identify biliary anatomy compared with MRCP. In our experience, LUS was inferior to MRCP in the demonstration of the whole biliary tree and its variations. Other clinical reports have suggested the usefulness of LUS in preventing the bile duct injury;[24,29–31] however, we could not prove the potential advantage of LUS due to the small size of this study. The advent of superior probe may improve the capacity of LUS in identification of biliary anatomy especially during the difficult dissection of an inflamed Calot triangle.

Other advantages of LUS include speed, ease of performance, and more imaging information. In this study, a trained operator could perform complete LUS investigation in an average time of 5 min, which was significantly faster than IOC investigation as shown by others.[7,22,26] There is no restriction on the type of patient in which LUS could be utilized. In addition, LUS detected the sludge in CBD and small stones lodged in cystic duct intraoperatively, whereas MRCP did not. The clinical course of biliary sludge varies, but it may progress to choledocholithiasis and cause symptoms or complications including biliary colic, acute cholangitis, and acute pancreatitis.[32,33] Whether LUS should be utilized routinely in LC procedure requires the cost-effectiveness analysis based on the prevalence of the concurrent CBD stones in the population, the management strategies and outcomes, and the costs of the screening modality.

In summary, both MRCP and LUS are reliable and effective in screening for bile duct stones and in visualizing biliary anatomy. In our practice, LUS has significantly reduced the need for preoperative MRCP and has been the primary imaging method in patients with cholelithiasis and suspected CBD stones because of its excellent accuracy and safety. However, both modalities are acceptable depending on local practice patterns, equipment availability, and surgeons' preference.

Author Contributions Ying Luo proposed and performed the study and wrote the paper. Tao Yang performed the study and revised the paper, Qiang Yu performed the study and collected data, and Yu Zhang performed the study. All the authors contributed to the design and interpretation of the study and to further drafts. Ying Luo is the guarantor.

Compliance with Ethical Standards

Ethical Approval The study was conducted according to the ethical guidelines of the Helsinki Declaration and was approved by the Ethics Committee of Chinese PLA General Hospital, Beijing, China.

Competing Interest The authors declare that they have no conflict of interest.

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