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Diagnostic value of magnetic resonance cholangiopancreatography for secondary common bile duct stones compared with laparoscopic trans-cystic common bile duct exploration

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ABCDEF 1 Peixin Li
ACD 2 Zhongtao Zhang
AB 1,2 Jianshe Li
B 2 Lan Jin
AC 2 Wei Han
B 3 Jie Zhang

1 Department of Comprehensive Surgery, Medical and Health Center, Beijing Friendship Hospital affiliated to Capital Medical University, Beijing, P.R. China
2 Department of General Surgery, Beijing Friendship Hospital Affiliated to Capital Medical University, Beijing, P.R. China
3 Department of Medical Imaging, Beijing Friendship Hospital Affiliated to Capital Medical University, Beijing, P.R. China

Corresponding Author: Zhongtao Zhang, e-mail: zhangzht@medmail.com.cn
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Background: The aim of this study was to evaluate the diagnostic potential of magnetic resonance cholangiopancreatography (MRCP) in preoperative patients with secondary common bile duct stones during the application of laparoscopic trans-cystic common bile duct exploration (LTCBDE).

Material/Methods: The clinical records of 255 patients were retrospectively analyzed. All patients included in the study were examined by MRCP 3 days prior to LTCBDE.

Results: Secondary bile duct stones were detected in 220 patients using LTCBDE. Of the patients diagnosed by MRCP, 141 were true-positive, 28 were true-negative, 7 were false-positive and 79 were false-negative. The sensitivity, specificity, accuracy, positive predictive value, and negative predictive value of MRCP for secondary common bile duct stones were 64.09%, 80.00%, 66.27%, 95.27%, and 26.17%, respectively. When the cases with muddy stones were excluded, the outcomes were 80.41%, 79.41%, 69.23%, 94.44%, and 48.21%, respectively. When cases with stones <3 mm (inclusive) in diameter were excluded, the outcomes were 93.75%, 79.41%, 86.27%, 93.75%, and 65.85%, respectively. When cases with stones <5 mm (inclusive) in diameter were excluded, the outcomes were 93.10%, 79.41%, 89.26%, 92.05%, and 81.82%, respectively.

Conclusions: The effectiveness of preoperative MRCP is overestimated for the diagnosis of secondary common bile duct stones, particularly for muddy and micro-stones.

MeSH Keywords: Biliary Tract Surgical Procedures • Cholangiopancreatography, Magnetic Resonance • Choledocholithiasis

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Background

Secondary common bile duct stones form in the gallbladder and not the bile duct. Gallbladder stones move into the common bile duct by the expanding cystic duct. Approximately 5% to 15% of patients with gallstones have secondary common bile duct stones [1–3]. The ability to diagnose and treat secondary common bile duct stones is continuously improving with the development of non- and minimally-invasive procedures. As a non-invasive technique, magnetic resonance cholangiopancreatography (MRCP) provides comprehensive morphological diagnostic information of the biliopancreatic duct without contrast agent and is superior to endoscopic retrograde cholangiopancreatography (ERCP) in the diagnosis of obstructive biliary disease [4,5]. This advantage has led to increased clinical utilization of MRCP. Many hospitals have widely used laparoscopic trans-cystic common bile duct exploration (LTCBDE). LTCBDE can accurately diagnose and provide a therapeutic option for secondary common bile duct stones, and it significantly reduces the incidence of postoperative common bile duct stones [6]. Choledochoscope can also be used in some complicated surgical procedures [7].

In recent years, many studies have evaluated the accuracy of MRCP for the diagnosis of secondary common bile duct stones. These studies evaluated the accuracy of MRCP using ERCP or intraoperative cholangiography (IOC) [4,5,8–20]. Using these methods, the authors reported that MRCP has a high accuracy rate. However, to date no studies have evaluated the accuracy of MRCP using LTCBDE as a standardization parameter. Therefore, the purpose of the present study was to evaluate the effectiveness of MRCP for the diagnosis of secondary common bile duct stones utilizing LTCBDE.

Material and Methods

In the present study, patients were selected who had been subjected to LTCBDE from April 2009 to December 2012 at Beijing Friendship Hospital. A total of 255 patients met the criteria listed in Table 1, including 147 men and 108 women aged from 15 to 85 years (median age 57 years). All patients were evaluated on a General Electric (GE) Signa 3.0T system. The experimental protocol was approved by the Institutional Human Ethics Committee.

The results of LTCBDE were utilized as a standardization parameter because the technique can intuitively and clearly explore the biliary system and significantly reduce the incidence

Table 1. Study inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
• With common bile duct exploration indications (obstructive jaundice; alkaline phosphatase (ALP), and (or) γ-glutamyltransferase (GGT) increased; CBD diameter ≥8 mm; repeated episodes of biliary colic and cholangitis; previous history of obstructive jaundice; previous history of biliary pancreatitis)	• Hepatolithiasis as a complication
• Diagnosed by MRCP 72 hours preceding surgical procedures	• Hepatic duct stones as a complication
• Potential small gallstones visualized during surgical procedures possibly entering common bile duct through cystic duct	• Mirizzi's syndrome
• With muddy stones or turbid purulent bile by incising cystic duct during operation	• Tumor
• Demonstration of CBD diameter ≥8 mm or significant thickened CBD wall	• Unsuccessful choledochoscope exploration caused by anatomic variations (the confluence part of cystic duct and common bile duct is too low, the cystic duct is too thin,etc.)
	• Choledochal cyst
	• Subjected to emergency surgery, such as perforation caused by ERCP
	• Diagnosed by MRCP in other hospitals
	• MRCP non-applicable as a result of severe claustrophobia or the usual contra-indications (such as for instance pacemakers, some vascular clips in brain surgery and the presence metal fragments in critical positions)

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Table 2. Comparison of MRCP with LTCBDE for the detection of secondary common bile duct stones.

MRCP	LTCBDE		Total
	Positive	Negative	
Positive	141	7	148
Negative	79	28	107
Total	220	35	255

Table 3. Overall accuracy of MRCP evaluated using LTCBDE in secondary common bile duct stones.

	%
Sensitivity	64.09
Specificity	80.00
Accuracy	66.27
Positive predictive value	95.27
Negative predictive value	26.17

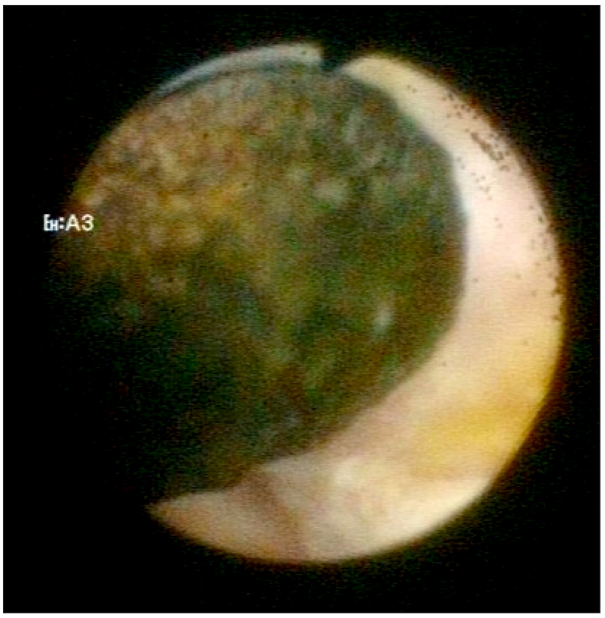

Figure 1. Large stone.

Figure 2. Small stone.

of postoperative common bile duct stones with success rates from 85% to 95% [6]. Because 2.8 mm and 4.9 mm choledochoscopes (Olympus CHF-CB30S, CHF-P60, CHF-V) were used, the success rate for LTCBDE in our hospital ranges from 94.2% to 95.1%. The mean operation time was 83.2±36.5 min. The results of MRCP and LTCBDE were compared for sensitivity, specificity, accuracy, positive predictive value, and negative predictive value to evaluate the diagnostic value of MRCP in secondary common bile duct stones using the following parameters:

Sensitivity = True-positive / (True-positive + False-negative)
Specificity = True-negative / (True-negative + False-positive)
Accuracy = (True-positive + True-negative) / Total cases
Positive predictive value = True-positive / (True-positive + False-positive)
Negative predictive value = True-negative / (True-negative + False-negative)

All data were recorded and analyzed using SPSS 13.0 software.

Results

MRCP correctly diagnosed 141 patients with CBD stones, matching the results of LTCBDE. Seven patients were misdiagnosed for CBD stones using MRCP. This study revealed 141 true-positive, 28 true-negative, 79 false-negative, and 7 false-positive cases (Table 2). McNemar Test (P=0.00, <0.01) indicated that the detection of CBD stones by LTCBDE was statistically different compared to MRCP. The sensitivity of MRCP was 64.09%, specificity 80%, accuracy 66.27%, positive predictive value 95.27% and negative predictive value 26.17% for the detection of CBD stones (Table 3).

To further analyze the accuracy of MRCP, this study defined stones with diameters >5 mm as large stones (Figure 1), between 3 and 5 mm (inclusive) as small stones (Figure 2), and <3 mm (inclusive) as micro-stones (Figure 3). The remaining stones were classified as muddy stones (Figure 4). Among the 220 patients identified with CBD stones by LTCBDE, 121 patients (55.00%) had large stones, 32 (14.55%) had small stones, 29 (13.18%) had micro-stones, and 73 (33.18%) had

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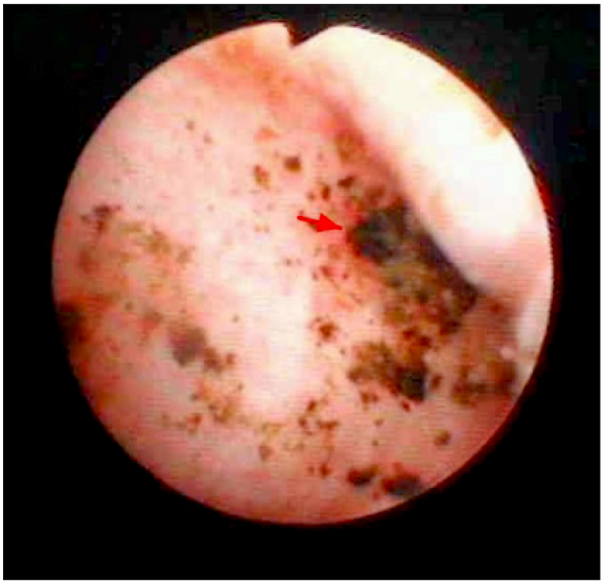

Figure 3. Micro-stones.

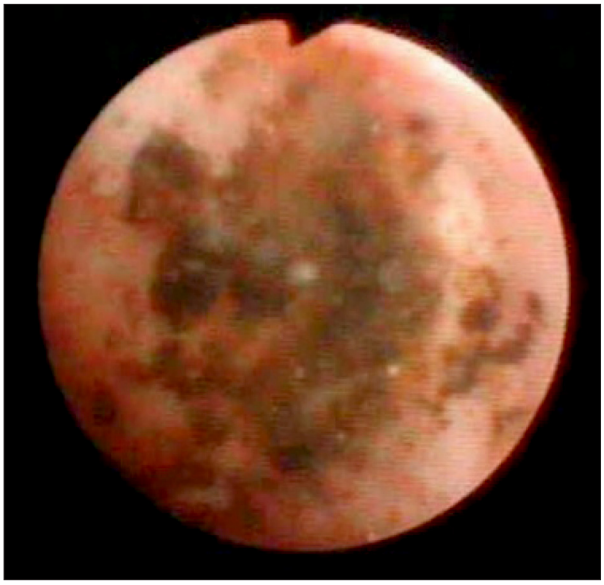

Figure 4. Muddy stones.

Table 4. Overall accuracy of MRCP evaluated using LTCBDE in secondary common bile duct stones (%).

	Accuracy of MRCP evaluated by LTCBDE in CBD stones	Accuracy of MRCP evaluated by LTCBDE in CBD stones (excluding muddy stones cases)	Accuracy of MRCP evaluated by LTCBDE in CBD stones (excluding stones less than 3mm (inclusive) in diameter)	Accuracy of MRCP evaluated by LTCBDE in CBD stones (excluding stones less than 5mm (inclusive) in diameter)
Sensitivity	64.09	80.41	93.75	93.10
Specificity	80.00	79.41	79.41	79.41
Accuracy	66.27	69.23	86.27	89.26
Positive predictive value	95.27	94.44	93.75	92.05
Negative predictive value	26.17	48.21	65.85	81.82

muddy stones. Among the 79 false-negative cases indicated by MRCP, 6 patients (7.59%) had large stones, 8 (10.13%) had small stones, 15 (18.99%) had micro-stones, and 50 (63.29%) had muddy stones.

When cases with muddy stones were excluded, MRCP correctly diagnosed 119 patients with CBD stones and 27 patients without CBD stones, while MRCP misdiagnosed 29 false-negative patients and 7 false-positive patients. McNemar Test (P=0.00, <0.01) indicated that there is a statistical difference between MRCP and LTCBDE for the detection of CBD stones. The sensitivity, specificity, accuracy, positive predictive value, and negative predictive value of MRCP for secondary common bile duct stones were 80.41%, 79.41%, 69.23%, 94.44%, and 48.21%, respectively.

When cases with stones <3 mm (inclusive) in diameter were excluded, MRCP correctly diagnosed 105 patients with CBD stones and 27 patients without CBD stones, while MRCP misdiagnosed 14 false-negative patients and 7 false-positive patients. The McNemar test (P=0.189, >0.05) indicated that there was no statistical difference between MRCP and LTCBDE for the detection of CBD stones. The sensitivity, specificity, accuracy, positive predictive value, and negative predictive value of MRCP for secondary common bile duct stones were 93.75%, 79.41%, 86.27%, 93.75%, and 65.85%, respectively. When cases with stones <5 mm (inclusive) in diameter were excluded, MRCP correctly diagnosed 81 patients with CBD stones and 27 patients without CBD stones, while MRCP misdiagnosed 6 false-negative patients and 7 false-positive patients. The McNemar test (P=1.000, >0.05) indicated that there was no statistical difference between MRCP and LTCBDE for the detection of CBD stones. The sensitivity, specificity, accuracy, positive predictive value, and negative predictive value of MRCP for secondary common bile duct

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Table 5. Overall accuracy of MRCP in secondary CBD stones from various references.

Author	Sensitivity	Specificity	Accuracy	Positive predictive value	Negative predictive value
Bret PM (1997)	90.00	100.00	97.00		
Hochwald SN (1998)	95.00	89.29	91.67	86.36	96.15
Stiris MG (2000)	87.50	94.44	90.00	96.55	80.95
Boraschi P (2002)	90.24	96.30	93.68	94.87	92.86
Topal B (2003)	94.74	100.00	98.55	100.00	98.04
Kats J (2003)	82.76	95.65	88.46	96.00	81.48
Ke ZW (2003)	100.00	96.30	97.38	91.76	100.00
Makary MA (2005)	94.12	97.92	98.44	94.12	97.92
Ausch C (2005)	94.55	98.32	98.05	81.25	99.57
Hallal AH (2005)	100.00	91.00	92.00	50.00	100.00
Dalton SJ (2005)	93.33	96.23	95.65	87.50	98.11
De Waele E (2007)	82.60	97.50	94.20	90.50	95.20
Schmidt S (2007)	94.90	94.40	94.70	97.40	89.50
Eshghi F (2008)	81.80	87.50		94.70	63.30
Srinivasa S (2010)	62.00	97.90		86.70	92.00
Current study	64.09	80.00	66.27	95.27	26.17

Figure 5. False-positive MRCP image. The false stone image may be caused by the thickened CBD wall.

stones were 93.10%, 79.41%, 89.26%, 92.05%, and 81.82%, respectively. Overall accuracy of MRCP in various patient cohorts is displayed in Table 4.

Discussion

Secondary common bile duct stones frequently occur in middle-aged and elderly people. Secondary common bile duct stones can cause jaundice, acute obstructive suppurative cholangitis, acute pancreatitis, toxic shock, and death, which make early diagnosis and treatment critical for positive outcomes. Since the presence of secondary common bile duct stones in patients with cholelithiasis at preoperative stages play a role in determining the choice of treatment, accurate imaging techniques is key to improving diagnostic accuracy.

Table 5 summarizes the overall accuracy of MRCP for the detection of secondary CBD stones in other studies [4,5,8–20]. Sensitivity ranged from 62.00% to 100% (on average, 90.10%). Specificity ranged from 87.50% to 100% (on average, 95.62%). Accuracy ranged from 88.46% to 99.28% (on average, 94.62%). Positive predictive value ranged from 50.00% to 100% (on average, 90.45%). Negative predictive value ranged from 39.39% to 100% (on average 88.96%).

There were 7 false-positive cases identified in the present study. The thickened CBD wall may have been detected as a false stone image (Figure 5), therefore resulting in the false signal of MRCP, especially in cases having only RARE (Rapid

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Acquisition with Relaxation Enhancement) sequences or a single-level HASTE (Half-Fourier Acquisition Single-shot Turbo spin Echo) sequence. In all 7 patients, stone residues were found in CBD during the LTCBDE procedure. It is possible that gallstones passed through the ampulla post-MRCP or during LTCBDE or prior to LTCEBDE. Stone passage is a hurdle for all studies that focus on the prediction of secondary common bile duct stones. Thus, the accuracy of MRCP in all published studies is questionable because gallstones may have passed through the ampulla or entered the CBD from the gallbladder while clinicians waited for the results of confirmatory tests such as ERCP, IOC, and LTCBDE [9,13,14,21]. If stones passed through the ampulla, patients usually suffer from severe cholecystalgia. Thus, when patients suffered from severe cholecystalgia, a new MRCP would be needed.

This study also showed 107 MRCP negative cases. All the 107 patients had indicators for common bile duct exploration, so LTCBDE were performed, although MRCP did not report the stone images. Among the 79 false-negative cases, there were 50 cases (63.3%) with muddy stones, 15 (19.0%) with micro-stones, 8 (10.1%) with small stones, and 6 (7.6%) with large stones. Forty-three (54.4%) of the stones were found in the distal CBD, and the remaining 36 (45.6%) patients had muddy stones that were spotted in whole CBD. The false-negative cases might originate from the low resolution of MRCP. In the present study, we found that the false-negative cases were related to the micro and muddy stones, which were usually found in the distal CBD or near the ampulla. Small stone size is a major factor that potentially prevents MRCP from correctly diagnosing secondary CBD stones [13,22].

In our study, sensitivity, specificity, accuracy, positive predictive value, and negative predictive value of MRCP for secondary common bile duct stones were 64.09%, 80.00%, 66.27%, 95.27%, and 26.17%, respectively. Compared with previous studies [4,5,8–20], the sensitivity and specificity of this study are within the same scope but lower than the mean value; accuracy and negative predictive value are lower than the minimum value; and positive predictive value was in the same range but higher than the mean value. Lower accuracy is relative to a higher false-negative rate, which indicates a lower negative predictive value. However, the difference between the current study and other published studies is the diagnostic standard, which in this study was LTCBDE, while the other studies utilized ERCP or IOC [4,5,8–20]. When cases with muddy stones were excluded, sensitivity, specificity, accuracy, positive predictive value, and negative predictive value of MRCP for secondary bile duct stones were 80.41%, 79.41%, 69.23%, 94.44%, and 48.21%, respectively, which is consistent with other studies [4,5,8–20]. When cases with stones <3 mm (inclusive) in diameter were excluded, the diagnostic accuracy of MRCP and LTCBDE was not statistically different. Generally speaking, ERCP and IOC require X-ray imaging to diagnose secondary CBD stones. However, the imaging results could be affected by many variables such as bubbles, dense of contrast agent, and experience of the operator. Compared with ERCP and IOC, LTCBDE enables surgeons to visually detect the stones during the surgical process, which is visually perceived to be an accurate diagnosis method. Thus, our findings indicate that LTCBDE is superior to ERCP and IOC as a diagnostic standard of secondary common bile duct stones. Therefore, the results of this study are more convincing than the results of previous studies.

Conclusions

MRCP is not a highly accurate method for the diagnosis of secondary bile duct stones, especially considering the accuracy and negative predictive value. Muddy and micro-stones were misdiagnosed at high rates. Alternatively, LTCBDE is a more accurate method for the diagnosis and treatment of secondary common bile duct stones. Patients whose pre-operation MRCP is negative, but with common bile duct exploration indications, are still suggested to receive LTCBDE.

Conflicts of interest

There are no relevant conflicts of interest for any author.

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