Evaluation of Magnetic Resonance Cholangiography
in the Management of Bile Duct Stones

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Hypothesis: Magnetic resonance cholangiography (MRC) offers the potential for accurate, noninvasive detection of common bile duct stones (CBDSs) before cholecystectomy, and for a consequent reduction in the incidence of preoperative negative diagnoses associated with endoscopic retrograde cholangiography (ERC).

Design: Prospective cohort study: MRC results were correlated with ERC (high-risk patients) or intraoperative cholangiography (moderate-risk patients).

Setting: A university hospital providing primary, secondary, and tertiary care.

Patients: Seventy patients with suspected CBDSs scheduled to undergo elective cholecystectomy between April 15, 1997, and September 30, 1998. Forty patients were considered at high risk and 30 at moderate risk for CBDSs, according to results of liver function tests and sonograms of the upper abdomen.

Main Outcome Measures: Confirmation or exclusion of CBDSs by MRC was assessed by a panel of radiologists who were unaware of the ERC results. Results of ERC and intraoperative cholangiography were analyzed by the investigating gastroenterologists or surgeon.

Results: Results of MRC were positive for CBDSs in 21 (52%) of 40 high-risk patients, a finding confirmed by preoperative ERC in 19 (90%) of 21 patients. Results of MRC were positive for CBDSs in 6 (20%) of 30 moderate-risk patients, all of which were confirmed by intraoperative cholangiography. Finally, CBDSs were present in 19 (48%) of 40 high-risk patients and 6 (20%) of 30 moderate-risk patients ($P = .02$). Overall sensitivity and specificity of MRC were 100% and 95.6%, respectively; the positive and negative predictive values were 92.6% and 100%, respectively.

Conclusions: Magnetic resonance cholangiography is a reliable, noninvasive method for the detection or exclusion of CBDSs, and seems to reduce the frequency of negative diagnoses associated with ERC. Magnetic resonance cholangiography revealed no CBDSs in 19 (48%) of 40 patients at high risk for CBDSs. Thus, MRC-based diagnosis has the potential to reduce the number of invasive preoperative diagnostic procedures and their associated risks and overall health care costs.

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PROCEDURES FOR diagnosing common bile duct stones (CBDSs) include intraoperative cholangiography (IOC),1 endosonography,1 and endoscopic retrograde cholangiography (ERC)—the most widely used of these 3 techniques2,3 because it offers the opportunity to provide therapy on determination of the diagnosis, with only a single invasive intervention.4 Intraoperative cholangiography is still considered by some as the criterion standard for diagnosis of CBDSs.5 However, ERC and IOC are associated with a relatively high incidence of negative diagnoses if used routinely on an unselected population.5,6

The most recent technique to be applied is magnetic resonance cholangiography (MRC),7,8 which is distinguished from previous techniques because it is a noninvasive procedure that can be performed before cholecystectomy. Current evidence9 also suggests that MRC might have greater sensitivity and specificity to diagnose CBDSs. Thus, MRC potentially offers the possibility of accurate diagnosis without the risks or the incidence of negative diagnoses associated with invasive techniques.

To evaluate these potential benefits, we prospectively assessed the use of MRC in diagnosing CBDSs in patients scheduled to undergo cholecystectomy, in whom preoperative suggestion of CBDSs was

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PATIENTS AND METHODS

PATIENTS

Between April 15, 1997, and September 30, 1998, we prospectively studied 70 patients with symptomatic cholelithiasis and suspected CBDSs after obtaining their informed consent and approval from the ethics committee of the University Hospital of Basel, Basel, Switzerland. Based on established criteria for diagnostic testing, patients with high probability of CBDSs were studied using ERC and MRC, and those with moderate probability of CBDSs were studied using IOC and MRC. On hospital admission, blood samples were collected to permit laboratory analysis of liver function (serum enzyme levels) before ERC, MRC, and IOC. The number of patients and duration of study were limited only by the availability of the magnetic resonance imaging device for only 2 days during each study week.

IMAGING TECHNIQUES

Endoscopic retrograde cholangiography was completed using standard techniques and standard catheters. A balloon catheter was used only when visualization of the bile ducts was insufficient. Intraoperative cholangiography was achieved using standard laparoscopic transcystic techniques.

The magnetic resonance studies were performed using a 1.5-T superconductive unit (Magnetom Vision; Siemens AG, Erlangen, Germany) with a circularly phased array body coil. To optimize the view of the bile ducts, images from the axial and coronal planes were collected. Three standard acquisition techniques known to optimize imaging without increasing costs were routinely used. For anatomical orientation, a true fast imaging with steady-state precession sequence was used, T2/T1 weighted (a standardized mixing of the T1 and T2 sequences, both weighted, to permit better viewing of the blood vessels and bile ducts), a spatial resolution of $1.3 \times 1.3$ mm, a section thickness of 8 mm, and an acquisition time of 14 seconds. To visualize the bile ducts, single-shot turbo spin echo was performed, using an optimized rapid acquisition with relaxation enhancement heavy sequence, T2 weighted, spatial resolution of $1.5 \times 1.4$ mm, section thickness of 10 to 70 mm (thick slab), and image matrix of $240 \times 256$ (acquisition time, 7 seconds). Field of view was 300 mm. Finally, we used a half-Fourier acquisition single-shot turbo spin echo heavy sequence, T2 weighted, spatial resolution of $1.1 \times 1.4$ mm, section thickness of 2 to 4 mm (thin slice), and image matrix of $240 \times 256$ (acquisition time, 18 seconds). Field of view was 280 to 320 mm, depending on patient constitution (ie, to avoid artifact, as small a field of view as possible was preferred, enlarging the field only when patient constitution required it). All 3 acquisition techniques were performed using standard breath-holds of 8 to 14 seconds.

DATA ANALYSIS

All MRC scans were analyzed by a panel of radiologists who were unaware of ERC, IOC, and laboratory test results. In addition, a panel of radiologists who were unaware of MRC and laboratory data participated in the analysis of ERC and IOC data by the investigating gastroenterologists and surgeons. Diagnoses based on MRC and ERC were determined by consensus.

Results of MRC were correlated with preoperative ERC data for patients at high risk (n = 40) and with IOC results for those at moderate risk (n = 30) (Figure 1). Specificity, sensitivity, and positive and negative predictive values were calculated. Sensitivity was the ability to identify patients with CBDSs using the number of positive MRC diagnoses as a percentage of the total number of patients with CBDSs confirmed by ERC or IOC. Specificity was the ability to identify patients without CBDSs using the number of negative MRC diagnoses divided by the total number of patients without ERC or IOC evidence of CBDSs. Positive and negative predictive values of MRC for a population with clinical suggestion of CBDSs were determined by the proportion of MRC diagnoses (positive or negative) confirmed by ERC or IOC.

Differences among the 3 techniques were assessed using t tests and chi² analyses, with P < .05 indicating statistical significance. Values are expressed as mean ± SD.

RESULTS

The 70 study patients were aged 59.6 ± 15.4 years, and the ratio of female-to-male patients was 1:3. Initial diagnoses indicated that 29 patients (41%) had symptomatic cholelithiasis alone, 25 (36%) had cholecystitis, 13 (19%) had biliary pancreatitis, and 3 (4%) had obstructive jaundice. Forty patients were considered at high risk and 30 at moderate risk of CBDSs. The 2 groups were comparable in age (62.6 ± 18.2 vs 55.2 ± 19.7 years; P = .62) and sex (female-to-male ratio, 1:6 and 1:7; P = .93). Comparison of serum enzyme levels in the high- and moderate-risk groups revealed no significant difference between the groups in bilirubin level (29 ± 26 vs 21 ± 19 µmol/L [1.7 ± 1.5 vs 1.2 ± 1.1 mg/dL]; P = .12) but a significantly greater alkaline phosphatase level in the high-risk group (223 ± 219 vs 144 ± 83 U/L; P = .01). Complete laboratory findings and reference values are summarized in Table 2.

Results of MRC were positive for CBDSs in 27 (39%) of 70 patients, and negative in 43 (61%). In the high-risk group (n = 40), MRC results were positive for CBDSs in 21 patients (52%), and the diagnosis was confirmed by ERC in 19 (90%) of those 21 patients (Table 3), indicating false-positive MRC diagnoses in 2 patients. In the moderate-risk group (n = 30), MRC results were positive for CBDSs in 6 patients (20%), and the diagnosis was confirmed by IOC in all patients. Incidence of CBDSs in high-risk patients was significantly greater than in moderate-risk patients (48% vs 20%; P = .02). There were no false-negative MRC diagnoses.

Overall sensitivity and specificity of MRC were 100% (25/25) and 95.6% (43/45), respectively. Positive and
negative predictive values were 92.6% and 100%, respectively. All MRC images were of good quality (Figure 2).

There were no complications related to MRC, ERC, or IOC. Three patients (1 each with duodenal stenosis, papillary edema, and large duodenal diverticulum) were excluded because ERC was technically not possible.

**COMMENT**

Magnetic resonance cholangiography seems to be a useful, accurate, noninvasive technique for the detection of CBDSs. Sensitivity, specificity, and positive and negative predictive values are comparable to those of the standard invasive techniques of ERC and IOC. In addition, there seems to be good correlation between MRC findings and identified laboratory predictors of CBDSs.

Magnetic resonance imaging was first applied in the diagnosis of biliary disease in 1986, but its use for detection of CBDSs is more recent. Results from a 1998 study of 265 unselected prospective patients show a sensitivity of 100% and a specificity of 98% to 100%. Resolution of MRC for detection of CBDSs is excellent: detected calculi range from 2 to 20 mm, averaging 9 mm (Figure 2). However, calculi smaller than 3 mm might be missed in as many as 29% of patients. In other selected series of patients with suspected CBDSs, a sensitivity of 81% to 100% and a specificity of 85% to 100% have been reported (Table 4). In addition, successful diagnosis of CBDSs by MRC seems to be less investigator dependent than ultrasonography, ERC, or percutaneous transhepatic cholangiography, and patients receive neither radiation nor contrast agents.
Our results demonstrate a sensitivity of 100% and a specificity of 96%, confirming the diagnostic accuracy of MRC. No negative MRC diagnosis was contradicted by ERC or IOC. Moreover, based on our MRC findings, 19 (48%) of 40 preoperative ERC procedures performed in our series could have been avoided. This suggests that use of MRC can reduce the need for invasive diagnostic assessment, thereby decreasing the associated risks and costs.

The overall prevalence of CBDs in patients scheduled to undergo elective cholecystectomy is 1.3% to 13.6%, depending on patient selection.\(^2\) Results of studies\(^3\) of several laboratory predictors of CBDs indicate that the most accurate are serum bilirubin level (positive and negative predictive values, 57% and 66%, respectively; \(P<.01\)), serum alkaline phosphatase level (positive and negative predictive values, 53% and 65%, respectively), and dilated common bile duct (positive and negative predictive values, 64% each; \(P<.01\)).\(^1\) Based on the bilirubin and alkaline phosphatase serum levels in our series, we found a significant difference in the incidence of CBDs in the high- vs moderate-risk groups (48% vs 20%; \(P=.02\)), confirming the value of these laboratory selection criteria.

Preoperative ERC is now commonly used to detect CBDs.\(^2\) However, with normal liver function test results, unexpected CBDs will be found by preoperative ERC in only 1.3% to 1.7% of patients.\(^3\) In a study\(^4\) of 5000 unselected patients with cholelithiasis, CBDs were suspected in 10% but diagnosed by ERC in only 5%. Overall, ERC findings are negative in up to 98% of unselected patients with cholelithiasis;\(^2\) in our series, 48% (19/40) of ERC findings were negative. Moreover, the complication rate after ERC is 2.6% to 9.8% (cholestangitis or stone recurrence) and, therefore, should not be underestimated.\(^4\) Late complication rates as high as 10% have been reported\(^1\) (eg, chronic cholangitis or stone recurrence). Preoperative ERC also might increase from 2.7% to 27.0% the risk of developing pancreatitis in patients younger than 59 years, in whom no CBDs are found at investigation.\(^2\) Furthermore, up to 15% of patients treated for CBDs by preoperative ERC might present with a residual stone at the time of surgery.\(^5\) Accordingly, up to 50% of preoperative ERC procedures are purely diagnostic and, therefore, might easily be replaced by a noninvasive diagnostic approach such as MRC, reducing the frequency of invasive negative diagnoses and the risks associated with the ERC procedure, per se.\(^6\)

In selected patients, intraoperative ERC is possible, but the procedure is not yet standardized and prolongs surgical time. Publications are scarce,\(^6\) and the reported failure rate is 9% to 15%. Postoperative ERC has also been recommended in selected patients, but failure for anatomical reasons has been described\(^8\) in up to 6% of patients, necessitating reoperation.

Intraoperative cholangiography was standard procedure during open cholecystectomy to detect CBDs. With a sensitivity of 98% and a specificity of 100%, it remains a criterion standard\(^7\) but is also associated with a high rate of negative findings, ie, up to 98% of unselected patients.\(^2\) With the appearance of laparoscopy, routine performance of IOC probably is no longer justified. However, of 1300 unselected cases of laparoscopic cholecystectomy,\(^8\) postoperative ERC was recommended and performed in 2.5% of patients, but CBDs were found in only 1.3% (\(n=17\)). Similarly, in another 1000 cases of laparoscopic cholecystectomy,\(^8\) CBDs were detected in only 1.7% of patients. Moreover, complete management of CBDs through laparoscopy—although possible (and sometimes recommended)—is expensive, requires extensive skill and experience, and has a failure rate of up to 10%.\(^9\)

We propose a diagnostic algorithm based on MRC that preserves ERC as a therapeutic procedure for proven CBDs (Figure 3). In other words, although proven CBDs should be treated by preoperative ERC, MRC should be used to identify and select patients who might benefit from a therapeutic ERC when the suggestion of CBDs is moderate or high. This would eliminate the need for IOC during cholecystectomy.

A general limitation of MRC for detection of CBDs is that the instrument and technology are expensive and, therefore, not widely available. (Examination costs, per se, are lower than those for ERC—\(\$280 vs \$480\).) In fact, the sparse availability of the MRC instrument limited the performance of the present study, ie, we could study patients only twice a week. Consequently, MRC...
and ERC were occasionally performed within 24 hours of each other. Moreover, MRC was performed only in patients with clinical suggestion of CBDSs, resulting in a high percentage of CBDS diagnoses (39%) in this selected population. Looking at the general population a high percentage of CBDS diagnoses (39%) in this patients with clinical suggestion of CBDSs, resulting in of each other. Moreover, MRC was performed only in study were excluded because the diagnostic workup detected a malignant stenosis. Finally, of the surgeons, gastroenterologists, and radiologists who were analyzing the ERCP and IOC data, only the radiologists were unaware of the MRC results.

We conclude that MRC is an excellent primary tool for detecting or excluding CBDSs before cholecystectomy, and could replace ERC as a diagnostic instrument. Use of ERC should be reserved only for patients who require therapeutic intervention (Figure 3). In our series, use of MRC would have permitted purely noninvasive negative diagnosis for 19 (48%) of 40 patients in whom suggestion of CBDSs was high. Use of MRC would, therefore, spare these patients an invasive preoperative exploratory procedure and likely reduce overall surgical costs. However, the potential application of MRC to detection of CBDSs is limited by the expense and availability of the technology.

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