Endoscopic ultrasound versus magnetic resonance cholangiopancreatography in suspected choledocholithiasis: A systematic review

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ABSTRACT

Background and Objectives: There is a lack of consensus about the optimal noninvasive strategy for patients with suspected choledocholithiasis. Two previous systematic reviews used different methodologies not based on pretest probabilities that demonstrated no statistically significant difference between Endoscopic ultrasound (EUS) and magnetic resonance cholangiopancreatography (MRCP) for the detection of choledocholithiasis. In this article, we made a comparison of the diagnostic ability of EUS and MRCP to detect choledocholithiasis in suspected patients. Methods: We conducted a systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations with all published randomized prospective trials. We performed the systemic review using MedLine, EMBASE, Cochrane, LILACS, and Scopus reviews through May 2015. We identified eight randomized, prospective, blinded trials comparing EUS and MRCP. All the patients were submitted to a gold standard method. We calculated the study-specific variables and performed analyses using aggregated variables such as sensitivity, specificity, prevalence, positive predictive value (PPV) and negative predictive value (NPV), and accuracy. Results: Five hundred and thirty eight patients were included in the analysis. The pretest probability for choledocholithiasis was 38.7. The mean sensitivity of EUS and MRCP for detection of choledocholithiasis was 93.7 and 83.5, respectively; the specificity was 88.5 and 91.5, respectively. Regarding EUS and MRCP, PPV was 89 and 87.8, respectively, and NPV was 96.9 and 87.8, respectively. The accuracy of EUS and MRCP was 93.3 and 89.7, respectively. Conclusions: For the same pretest probability of choledocholithiasis, EUS has higher posttest probability when the result is positive and a lower posttest probability when the result is negative compared with MRCP.

Key words: Cholangiopancreatography, choledocholithiasis, endosonography, magnetic resonance

INTRODUCTION

Choledocholithiasis occurs in 15%-20% of patients with gallbladder stones and can cause numerous complications.[1,2] There is a lack of consensus about
the optimal noninvasive strategies for patients with suspected common bile duct (CBD) stones after a negative transabdominal ultrasound (US) and/or computed tomography. Endoscopic retrograde cholangiopancreatography (ERCP) continues to be considered the standard of reference for detection of bile duct stones with the possibility of simultaneous treatment. Nevertheless, ERCP remains an invasive method. Low-risk tests such as endoscopic ultrasound (EUS) and magnetic resonance cholangiopancreatography (MRCP) have emerged as reliable substitutes for diagnostic ERCP. A few reports have compared the diagnostic ability of CBD stones between EUS and MRCP. Two previous systematic reviews demonstrated no statistically significant difference between EUS and MRCP in terms of the detection of choledocholithiasis although both tests were highly effective. Since the last systematic review, one new prospective study has emerged, accounting for new data with an increased sample population higher than 30%. The aim of this study was to compare the diagnostic ability of EUS and MRCP in cases of suspected choledocholithiasis using data from published comparative studies.

MATERIALS AND METHODS

Protocol and registration
This systematic review of the literature was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations. The review was registered on the PROSPERO international database (www.crd.york.ac.uk/prospero/) under number CRD42014014670.

Eligibility criteria
a. Types of studies: We focused on prospective comparative trials (clinical trials and/or observational studies).
b. Types of participants: Patients in whom choledocholithiasis was suspected with similar population characteristics (age, sex distribution, and clinical indication for the test).
c. Types of intervention: Studies comparing the outcomes in two diagnostic arms: EUS and MRCP. Both EUS and MRCP were performed for the diagnosis of extrahepatic biliary obstruction followed by one or more of the confirmatory criterion standard tests (ERCP or intraoperative cholangiography with or without cholangioscopy) that were accepted as criterion standards in all studies. Both procedures were performed temporally close together (24-72 h in most cases) to minimize the chances of a negative study from stone passage. There were no restrictions regarding different technique modalities in each arm except for the blinding of the endosonographer and the radiologist evaluating the patients.
d. Types of outcome measures: The main outcomes measures were accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV).

Information sources
Studies were identified by searching several electronic databases and scanning the reference lists of articles. This search was applied for Medline (inclusive of all years) and EMBASE. The Cochrane, LILACS (via BVS), Scopus, and CINAHL (via EBSCO) databases were also reviewed. A manual search was also conducted for relevant reviews, original articles, and abstract books. The last search was run on May 22, 2015; no language limits were applied.

Search
Comparative trials were identified by conducting a comprehensive search of electronic databases using medical subject headings (MESH) stratified by population — “choledocholithiasis,” intervention — “endosonography,” and comparison — “magnetic resonance cholangiopancreatography.” We further searched the bibliographies of all the included primary studies and existing reviews by hand for additional citations.

Study selection
We performed the eligibility assessment and the selection of screened records independently in an unblended, standardized manner with two reviewers. Disagreements between the reviewers were resolved by a consensus.

To summarize the study selection processes, we used an adapted PRISMA flow diagram [Figure 1].

Data collection process
The method of data extraction from each included study consisted of filling out information sheets after the paper was read. We used a QUADAS-based checklist. One review author extracted the data from the included studies and a second author checked the extracted data. Disagreements were resolved via a discussion between the two review authors.
Data items
The following data items were extracted from each included study:

- Number of patients included in the analysis.
- Clinical and/or laboratory characteristics used as inclusion criteria.
- Number of patients with final diagnoses of choledocholithiasis based on the gold standard.
- These values were calculated from the data provided in the original papers and we excluded patients who did not undergo all three evaluations (EUS, MRCP, and the gold standard). In studies that included patients with diagnoses other than biliary stones, we limited our analysis to biliary stones and treated these other patients as negative cases for biliary stones because they did not show any stone(s) with criterion standard evaluation. Gold standard criteria were used to confirm choledocholithiasis.
- Interval between EUS and MRCP execution.
- Interval between EUS/MRCP and gold standard execution.
- Tests methods in terms of operators characteristics, test sequence, and gold standard distribution.
- Study design.
- EUS and MRCP accuracy, sensitivity, specificity, PPV, and NPV for choledocholithiasis diagnosis.

Risk of bias in individual studies
To evaluate the risk of bias and applicability of the primary diagnostic accuracy studies, we used the QUADAS-2 tool.\[21\]
This tool is structured so that the four key domains are each rated in terms of the risk of bias and the concern regarding applicability to the research question.

The first domain is patient selection, the second is index test, the third is the reference standard, and the fourth is flow and timing.

**Summary measures**

The primary outcome measures that we focused on included sensitivity, specificity, pretest probability, PPV and NPV, and accuracy of EUS and MRCP for the detection of choledocholithiasis.

We performed the analysis using the software Review Manager (RevMan) 5.3 obtained from the website of the Cochrane Informatics and Knowledge Management Department.[23] The average data and standard deviation (SD) were obtained using Microsoft Excel software for Windows version 2013.

**Risk of bias across studies**

QUADAS-2 was applied individually to the selected studies and a global comparative analysis was conducted based on it. Each one of the four key domain tools that included patient selection, index test, reference standard, and flow and timing was filled. We also conducted a comparative analysis of these criteria and checked if the selection of patients, conduct, interpretation of both the index test and reference standard, or patient flow could have introduced bias.

**RESULTS**

**Study selection**

Two thousand and six hundred and forty-three (2,643) studies were screened and the articles assessed for eligibility were selected after the title and abstract were read. Twenty-two studies compared the performance of EUS and MRCP with regard to the detection of choledocholithiasis. Two thousand and six hundred twenty-one (2,621) articles were excluded because they did not include the information outlined above. Fourteen studies were excluded, out of which six did not provide sufficient data, seven were reviews, and one was an editorial. These characteristics are summarized in Figure 1. After the last systematic review, one new study has emerged, accounting for 135 patients.[20] Eight published prospective studies that assessed the diagnostic accuracy of EUS and MRCP for the diagnosis of choledocholithiasis in 538 patients were included in our analyses.

**Study characteristics**

The important characteristics of the selected studies are summarized in Table 1 including the number of patients used in the final analysis. These values were extracted from a careful reading of the included papers. The design, conduct, and outcomes analyses of these studies were similar. The main objective of these studies was to evaluate the performance of EUS and MRCP for the detection of biliary disease, most commonly choledocholithiasis, against criterion standards of ERCP and/or intraoperative cholangiography. The included studies emphasized performing EUS and MRCP temporally close to each other and then evaluating the same patient group with ERCP or intraoperative cholangiography. The procedures were conducted independently, and the individual operators were blinded to the outcome of the results of the other investigation. One of the studies used two subgroups for analysis: Patients with unexplained CBD dilation in standard ultrasonography (US) (Group 1) and patients with a nondilated CBD and a high probability of having choledocholithiasis (Group 2).[23] We subdivided this investigation into two studies in terms of data and included all relevant studies irrespective of their favoring one or the other technique.

**Risk of bias within studies**

Table 2 lists the risks of bias included in the studies based on the QUADAS-2 tool.

All included studies were similar in terms of patient selection and index test risk of bias.

In terms of the reference standard, the results were not interpreted without knowledge of the results of the index test in two studies: Kondo et al.[15] and Schmidt et al.[17]

de Lédinghen et al.[11] did not report if their reference standard results were interpreted without knowledge of the results of the index test.

The studies by de Lédinghen et al.,[11] Materne et al.,[12] Kondo et al.,[15] and Fernández-Esparrach et al.[20] reported an inappropriate interval between the index test(s) and the reference standard.

In terms of receiving the same reference standard, Ainsworth et al.[14] and Aube et al.[16] did not introduce bias.

There was a high probability that a patient’s flow had introduced bias in the studies of de Lédinghen
Table 1. Characteristics of the studies

| Study            | Patients included in the analysis | Patients with a final diagnosis of choledocholithiasis (gold standard) | Gold standard | EUS × MRCP interval | EUS/MRCP × gold standard interval | Study design                  | Study inclusion criteria                                                                 | Tests methods                                                                                                      |
|------------------|----------------------------------|---------------------------------------------------------------|---------------|---------------------|-----------------------------------|----------------------------------|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| de Lédinghen et al. (1998) | 32                               | 10                                                           | Intraoperative cholangiography/choledochoscopy ERPC | 1 day (0-7 days) | 4 days, 5 days (1-50 days) | Prospective blinded study | Clinical or biochemical signs of choledocholithiasis: Epigastric or RUQ pain with fever or jaundice, elevated ALP/GGT/transaminases, acute pancreatitis and unexplained cholestasis | All patients underwent EUS and MRCP by two different operators blinded for the other investigators, results, followed by either ERCP or surgical treatment for the final diagnosis |
| Materne et al. (2000) | 50                               | 9                                                            | ERCP Intraoperative cholangiography Clinical follow-up | 1 day (0-10 days) | ERCP: 1 day (0-14 days) Surgery: 3 days (0-22 days) Follow-up: 6-18 months | Prospective blinded study | Bile duct obstruction suspected by biochemical markers elevated ALP/GGT > twice normal, clinical symptoms: RUQ pain, fever or jaundice and findings of biliary obstruction at transabdominal US | MRCP was performed before EUS in 31 patients and after EUS in 19 patients. The final diagnosis was established with ERCP in 37 patients, from surgery in 9 patients and from follow-up in 4 patients. EUS and MRCP were performed within 24 h before ERCP; investigators were blinded to the results of the other studies |
| Scheiman et al. (2001) | 28                               | 5                                                            | ERCP          | <24 h               | <24 h                             | Prospective blinded study | Adult patients (>18 years) referred for ERCP on the basis of clinical signs (abnormal liver enzymes, abnormal transcutaneous US) and symptoms (biliary pain) | Each patient was examined on the first day by EUS and MRCP, in that order, and on the following day by ERCP. No investigator had any knowledge of the findings from the other investigations |
| Ainsworth et al. (2003) | 163                             | 60                                                          | ERCP          | <24 h               | <24 h                             | Prospective blinded study | Patients admitted for elective ERCP                                                                                                      | MRCP was always performed first by two investigators. EUS was performed no more than 48 h later; investigators were blinded to the results of the other studies |
| Aube et al. (2005) | 45                               | 16                                                          | ERCP Perioperative cholangiography Clinical follow-up | <48 h           | ERCP and perioperative cholangiography: No data Clinical follow-up: 3 months | Prospective blinded study | Three groups: 1) Patients with biologic cholestasis or subclinical jaundice, with no suspicion of tumoral disease nor obstruction identified by sonography; 2) acute pancreatitis with no history of chronic alcoholism; 3) abdominal pain associated with degrees of cholestasis defined as elevated transaminases or a transitory increase in serum amylase | EUS and MRCP were performed in a random order within two weeks in all patients and the results compared with those of ERCP. Investigators were blinded to the results of the other studies |
| Kondo et al. (2005) | 28                               | 24                                                          | ERCP/IDUS     | <2 weeks            | <2 weeks                         | Prospective unblinded study | Patients who were highly suspected of choledocholithiasis based on clinical symptoms (RUQ pain, fever, jaundice) and biochemical abnormalities (elevated ALP/GGT/transaminases/bilirubin) with or without abnormal findings on abdominal US (high echoic spots in the common bile duct or bile duct dilatation) | EUS and MRCP were performed in a random order within two weeks in all patients and the results compared with those of ERCP. Investigators were blinded to the results of the other studies |
Table 1. (Continued)

| Study                          | Patients included in the analysis | Patients with a final diagnosis of choledocholithiasis (gold standard) | Gold standard | EUS × MRCP interval | EUS/MRCP × gold standard interval | Study design | Study inclusion criteria                                                                                                                                                                                                 | Tests methods                                                                                                                                                                                                 |
|-------------------------------|----------------------------------|---------------------------------------------------------------|---------------|----------------------|-----------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Schmidt et al. (2006)         | 57                               | 18                                                           | ERCP          | 1 day, 9 days (0-5 days) | ERCP and intraoperative cholangiography: 4 days, 1 day (0-9 days) Clinical follow-up: 123 days (17 days-10 months) | Prospective blinded study   | Adult patients with suspected choledocholithiasis: RUQ or epigastric pain, fever and jaundice with associated increase of ALP/GGT/Bilirubin; acute pancreatitis of suspected biliary origin; biological cholestasis with acute fever or jaundice; acute abdominal pain and clinical history suggestive of biliary stones disease | Prospective evaluation comparing MRCP versus EUS performed by different operators blinded to the results of the other method used within a delay of 5 days; final diagnosis was established by ERCP, cholangiography during cholecystectomy or clinical follow-up |
| Fernández-Esparrach et al. (2007) | 63                               | 31                                                           | ERCP          | <24 h                | ERCP: 11±13 days (1-73 days) Surgery/Intraoperative cholangiography: 30±31 days (1-106 days) EUS: <24 h Clinical follow-up: 6 months | Prospective blinded study   | Patients with unexplained common bile duct dilation in standard US (Group 1)                                                                                                                                              | EUS and MRCP were performed within a 24-h period after inclusion and the sequence of the examinations was randomly assigned. To ensure blinding, each examination was performed by a different operator unaware of the result of the other procedure; final diagnosis was established by ERCP, intraoperative cholangiography, surgery, EUS-FNA or clinical follow-up |
| Fernández-Esparrach et al. (2007) | 72                               | 30                                                           | ERCP          | <24 h                | ERCP: 11±13 days (1-73 days) Surgery/Intraoperative cholangiography: 30±31 days (1-106 days) EUS: <24 h Clinical follow-up: 6 months | Prospective blinded study | Patients with a nondilated common bile duct and a high probability of having choledocholithiasis: Cholangitis, jaundice, nonsevere pancreatitis and increased ALP/GGT/transaminases (Group 2)                                           | EUS and MRCP were performed within a 24-h period after inclusion and the sequence of the examinations was randomly assigned. To ensure blinding, each examination was performed by a different operator unaware of the result of the other procedure; final diagnosis was established by ERCP, intraoperative cholangiography, surgery, EUS - FNA or clinical follow-up |

*Group 1, †Group 2, ERCP: Endoscopic retrograde cholangiopancreatography, IDUS: Intraductal ultrasound, EUS: Endoscopic ultrasound, MRCP: Magnetic resonance cholangiopancreatography, RUQ: Right-upper quadrant, ALP: Alanine aminotransferase, GGT: Gamma-glutamyltransferase, US: Ultrasonography, FNA: Fine-needle aspiration*
Table 2. Risk of bias within included the studies based on the QUADAS-2 tool

| Patient selection | Signaling questions | Was a consecutive or random sample of patients enrolled? | de Lédinghen | Materne | Scheiman | Ainsworth | Aube | Kondo | Schmidt | Fernández-Esparrach |
|-------------------|---------------------|---------------------------------------------------------|--------------|---------|----------|-----------|------|-------|---------|----------------------|
|                   |                     | Was a case-control design avoided?                      | Yes          | Yes     | Yes      | Yes       | Yes  | Yes   | Yes     | Yes                  |
|                   |                     | Did the study avoid inappropriate exclusions?           | Yes          | Yes     | Yes      | Yes       | Yes  | Yes   | Yes     | Yes                  |
| Risk of bias      |                     | Could the selection of patients have introduced bias?  | Low          | Low     | Low      | Low       | Low  | Low   | Low     | Low                  |
|                   |                     | Are there concerns about the included patients not matching the review question? | Low          | Low     | Low      | Low       | Low  | Low   | Low     | Low                  |
| Index test        | Signaling questions | Were the index test results interpreted without knowledge of the results of the reference standard? | Yes          | Yes     | Yes      | Yes       | Yes  | Yes   | Yes     | Yes                  |
|                   |                     | If a threshold was used, was it properly defined?       | Yes          | Yes     | Yes      | Yes       | Yes  | Yes   | Yes     | Yes                  |
| Risk of bias      |                     | Could the conduct or interpretation of the index test have introduced bias? | Low          | Low     | Low      | Low       | Low  | Low   | Low     | Low                  |
|                   |                     | Concerns regarding applicability                        | Low          | Low     | Low      | Low       | Low  | Low   | Low     | Low                  |
| Reference standard| Signaling questions | Is the reference standard likely to correctly classify the target condition? | Yes          | Yes     | Yes      | Yes       | Yes  | Yes   | Yes     | Yes                  |
|                   |                     | Were the reference standard results interpreted without knowledge of the results of the index test? | Unclear      | Yes     | Yes      | Yes       | Yes  | No    | No      | Yes                  |
| Risk of bias      |                     | Could the reference standard, its conduct, or its interpretation have introduced bias? | Low          | Low     | Low      | Low       | Low  | Low   | Low     | Low                  |
|                   |                     | Concerns regarding applicability                        | Low          | Low     | Low      | Low       | Low  | Low   | Low     | Low                  |
| Flow and timing   | Signaling questions | Was there an appropriate interval between the index test(s) and the reference standard? | No           | No      | Yes      | Yes       | Yes  | No    | Yes     | No                   |
|                   |                     | Did all patients receive a reference standard?          | Yes          | Yes     | Yes      | Yes       | Yes  | Yes   | Yes     | Yes                  |
|                   |                     | Did all patients receive the same reference standard?   | No           | No      | Yes      | Yes       | Yes  | No    | No      | No                   |
|                   |                     | Were all patients included in the analysis?             | Yes          | Yes     | Yes      | Yes       | Yes  | Yes   | Yes     | Yes                  |
| Risk of bias      |                     | Could the patient flow have introduced bias?           | High         | High    | Low      | Low       | Low  | High  | Low     | High                 |
et al.,[11] Materne et al.,[12] Kondo et al.,[13] and Fernández-Esparrach et al.[20]

Results of individual studies

Table 3 lists the reported accuracies, sensitivities, specificities, prevalence (pretest probability), and PPV and NPV (posttest probability) in the included studies.

All studies reported an EUS accuracy higher than that of MRCP except for Fernández-Esparrach et al.[20] These authors reported the same accuracy for both methods in Group 1 (95%) and a higher accuracy for MRCP in Group 2 (92% vs. 86%).

All studies reported EUS sensitivity higher than that of MRCP.

The MRCP specificity was higher than EUS in four studies. Scheiman et al.,[13] Aube et al.[16] and Schmidt et al.[17] reported the same specificities in both methods (96.0%, 96.5%, and 94.4%, respectively.) The EUS specificity was higher than that of MRCP in de Lédinghen et al.[11] and Ainsworth et al.[14]

In terms of pretest probability, the values varied from 18 to 86.

The EUS PPVs were higher than those of MRCP in four studies. Schmidt et al.[17] reported the same PPVs in both methods (97%).

In terms of the NPVs, those of EUS were higher than those of MRCP in all studies except for de Lédinghen et al.[11]

Synthesis of results

Figure 2 graphically shows the EUS sensitivities and specificities variance for the diagnosis of choledocholithiasis in the included studies.

Figure 3 graphically shows the variance of MRCP sensitivities and specificities for the diagnosis of choledocholithiasis in the included studies.

Table 3. Performance of EUS and MRCP for evaluation of choledocholithiasis

| Study          | de Lédinghen | Materne | Scheiman | Ainsworth | Aube | Kondo | Schmidt | Fernández-Esparrach* | Fernández-Esparrach† |
|----------------|--------------|---------|----------|-----------|------|-------|---------|-----------------------|----------------------|
| Accuracy       | EUS          | 97      | 92       | 93        | 93   | 95    | 93      | 96                    | 95                   | 86                   |
|                | MRCP         | 81      | 88       | 86        | 91   | 93    | 86      | 95                    | 95                   | 92                   |
| Sensitivity    | EUS          | 100     | 89       | 80        | 90   | 94    | 100     | 97                    | 100                  | 93                   |
|                | MRCP         | 100     | 78       | 40        | 87   | 87    | 88      | 95                    | 90                   | 87                   |
| Specificity    | EUS          | 95      | 95       | 96        | 99   | 96    | 50      | 94                    | 91                   | 81                   |
|                | MRCP         | 73      | 98       | 96        | 97   | 96    | 75      | 94                    | 100                  | 95                   |
| Pretest probability |          | 31      | 18       | 18        | 37   | 35    | 86      | 32                    | 49                   | 42                   |
| Positive predictive value |          | 91      | 80       | 80        | 98   | 94    | 92      | 97                    | 91                   | 78                   |
|                | MRCP         | 63      | 88       | 66        | 95   | 93    | 95      | 97                    | 100                  | 93                   |
| Negative predictive value |          | 100     | 98       | 96        | 94   | 96    | 100     | 94                    | 100                  | 94                   |
|                | MRCP         | 100     | 95       | 88        | 93   | 93    | 50      | 89                    | 91                   | 91                   |

EUS: Endoscopic ultrasound, MRCP: Magnetic resonance cholangiopancreatography, *Group 1, †Group 2
A comparison between EUS and MRCP is shown in Table 4. For the detection of choledocholithiasis, the sensitivity of EUS was superior to that of MRCP; the former showed an average of 93.7 and SD of 7.1; the latter was characterized by an average of 83.5 and SD of 18.6. The specificity of EUS was slightly inferior to that of MRCP with an average value of 88.5 and SD of 16.1 versus 91.5 and SD of 10.7. In terms of pretest probability, the mean value was 38.7 with a SD of 21.8. The mean PPV of EUS was 89 with SD of 6.9. For MRCP, the mean value was 87.8 with SD of 14.4. The mean NPV of EUS was 96.9 with SD of 2.6 and the corresponding values for MRCP were a mean value of 87.8 and SD of 15.5. Finally, the aggregated accuracies of EUS were slightly superior to those of MRCP: An average of 93.3 and SD of 1.7 versus 89.7 and SD of 5.0.

The receiver operating characteristic (ROC) curve graphically shows the highest accuracy of EUS for diagnosis of choledocholithiasis as well as the sensitivity values according to the specificity of EUS and MRCP [Figure 4].

**Risk of bias across studies**

In terms of patient selection, index test, and reference standard, all studies reported a low risk of bias. However, in terms of flow and timing there was a high risk of bias in the studies of de Lédinghen et al.,[11] Materne et al.,[12] Kondo et al.,[15] and Fernández-Esparrach et al.[20]

**DISCUSSION**

There has been much recent interest in performing an initial evaluation of patients with suspected choledocholithiasis with less invasive or noninvasive modalities such as EUS and MRCP.

There have been two previous systematic reviews that conducted different methodologies not based in PRISMA recommendations. These reviews demonstrated no statistically significant difference between EUS and MRCP in terms of the detection of choledocholithiasis. Despite a high aggregated diagnostic accuracy being shown for both modalities, there is no superiority between the tests with respect to sensitivity, specificity, PPV, and NPV.

ERCP is at present a well-established method for the treatment of pancreatobiliary disease. Since it is associated with a small risk of significant morbidity and mortality, including severe complications such as acute pancreatitis, bleeding, perforation, sepsis, and even but rarely death, its use must be dedicated to treatment instead of diagnosis.[4]

We have compared the diagnostic ability of EUS and MRCP to detect choledocholithiasis in suspected patients. This study demonstrated a high diagnostic accuracy of both methods, with the highest sensitivity for EUS and the highest specificity for MRCP.

The major advantage of MRCP is its completely noninvasive nature compared with EUS, perhaps making it a better test for high-risk patients such as the elderly or the severely ill. This study reported a mean MRCP specificity of 91.5 for the detection of choledocholithiasis, demonstrating a very low failure rate. Nevertheless, a high level of technical expertise is crucial to ensure an accurate review of MRCP images and this method requires a high level of patient cooperation.[24] The presence of air bubbles inside the bile duct it is one contributing factor to EUS false negative results.

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**Table 4. Average and variance of diagnostic variables**

|            | EUS          | MRCP         |
|------------|--------------|--------------|
| SN         | 93.7 SD 7.1  | 83.5 SD 18.6 |
| SP         | 88.5 SD 16.1 | 91.5 SD 10.7 |
| PP         | 38.7 SD 21.8 | 87.8 SD 14.4 |
| PPV        | 89 SD 6.9    | 87.8 SD 15.5 |
| NPV        | 96.9 SD 2.6  | 87.8 SD 5.0  |
| Accuracy   | 93.3 SD 1.7  | 89.7 SD 5.0  |

SN: Sensitivity, SD: Standard deviation, SP: Specificity, PP: Pretest probability, PPV: Positive predictive value, NPV: Negative predictive value.
EUS yields very high-resolution images because of the proximity of the endoscope probe to the internal structures. This high resolution, which exceeds that of MRCP, makes EUS extremely sensitive to small stones. This systematic review demonstrated a mean EUS sensitivity of 93.7 to detect choledocholithiasis. If stones are demonstrated by EUS, therapeutic ERCP can potentially be performed immediately after the completion of EUS while the patient is still sedated. However, EUS brings with risks of sedation, bleeding, and perforation.

Both EUS and MRCP demonstrated a high posttest probability, with the advantage going to EUS (PPV 89 and NPV 96.9). Given that both tests are highly accurate, additional large-scale trials may be required to elucidate a difference.

**Limitations**
The gold standard used in a variety of studies has been ERCP although its accuracy is not 100%. Another limitation could be the long interval between EUS and MRCP executions and between EUS/MRCP and the reference standard reported in some tests, which can favor the passage of stones and disagreement between tests.

An evaluation concerning microlithiasis could not be made because the studies did not contain enough data about the number and sizes of the stones.

**CONCLUSION**
We have demonstrated that for the same pretest probability of choledocholithiasis, EUS exhibits a higher posttest probability when the result is positive and a lower posttest probability when the result is negative compared to MRCP.

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**Conflicts of interest**
There are no conflicts of interest.

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