



THE SIGNIFICANCE OF MAGNETIC RESONANCE CHOLANGIOPANCREATOGRAPHY (MRCP) IN THE DETECTION OF SUSPECTED CHOLEDOCHOLITHIASIS.

Radio-Diagnosis

Dr. Deep Kumar Roy	Professor & Head of the Department, Department of Radiodiagnosis & Imaging Sciences, Jorhat Medical College & Hospital, Jorhat, Assam, India.
Dr. Washim Ahmed Ansari*	Post Graduate Trainee, Department of Radiodiagnosis & Imaging Sciences, Jorhat Medical College & Hospital, Jorhat, Assam, India. *Corresponding Author
Dr. Suresh Killing	Assistant Professor, Department of Radiodiagnosis & Imaging Sciences, Jorhat Medical College & Hospital, Jorhat, Assam, India.

ABSTRACT

Background: Magnetic resonance cholangiopancreatography (MRCP) is a radiation-free test that can be performed quickly and does not expose patients to ionizing radiation or iodinated contrast material. The present study is intended to evaluate the role of MRCP in the detection of Common Bile Duct (CBD) stones in patients with suspected choledocholithiasis. **Materials and Methods:** This prospective study included 64 patients with suspected choledocholithiasis which was based on clinical evaluation and biochemical or ultrasonographic examination. MRCP was done in all patients. All presenting patients underwent open surgery after proper investigation. CBD exploration was performed in all patients, either due to the presence of palpable stones or due to the presence of dilated CBD (≥ 8 mm). Demonstration of CBD stones intra-operatively was considered the 'gold standard' for their presence, defined as stones visualized and extracted or attempted for extraction during surgical CBD exploration. **Results:** Intraoperatively, 45 (70.3%) out of 64 patients had cholelithiasis. 55 (85.93%) out of 64 patients had dilated CBDs. In 43 (67.18%) out of 64 patients, choledocholithiasis was detected intraoperatively. The sensitivity, specificity, and positive and negative predictive value of ultrasonography in detecting CBD stones in the present study were found to be 65.11%, 61.9%, 77.77% and 46.43% respectively. The sensitivity, specificity, positive predictive value and negative predictive value of MRCP in the diagnosis of CBD stones in the present study were 95.35%, 90.47%, 95.35% and 90.48% respectively. **Conclusion:** MRCP is a non-invasive and uncomplicated investigation with high sensitivity, specificity, and positive and negative predictive values for the detection of CBD stones. Hence MRCP is advised in all cases with a suspicion of CBD stones, where facilities and expertise are available.

KEYWORDS

Ultrasonography, MRCP, Cholelithiasis, Dilated CBD, Choledocholithiasis.

INTRODUCTION

Cholelithiasis is the most commonly encountered biliary pathology. In patients with symptomatic cholelithiasis, the incidence of choledocholithiasis varies between 5 to 15 percent, out of which 5 percent are asymptomatic [1]. Although common bile duct (CBD) stones may be silent, major morbidity and mortality are associated with the development of complications such as cholangitis and acute pancreatitis. Therefore, the detection and treatment of common bile duct stones should be considered the most important.

The diagnosis of choledocholithiasis is usually based on a combination of clinical suspicion (biliary colic, jaundice and cholangitis), biochemical analysis (raised alkaline phosphatase and conjugated bilirubin levels) and transabdominal ultrasonographic imaging findings. However, all of these individually have varying diagnostic accuracies and none is a completely reliable method for identifying bile duct stones [2].

During an open cholecystectomy, Intraoperative Cholangiography (IOC) is a standard procedure that can detect CBD stones with a sensitivity of 98% and a specificity of 100%. However, it is an invasive procedure with intra-operative and post-operative morbidities of 6.3% and 15.9% respectively. Its regular use is associated with increased operating time and increased costs [3].

In patients with suspected stones, Endoscopic Retrograde Cholangiopancreatography (ERCP) is able to detect common bile duct stones with high accuracy [1]. It can be applied both as a diagnostic and a therapeutic tool. ERCP also allows direct visualisation of duct anatomy. However, it has a significant mortality and morbidity of 1% and 7%, respectively [1]. Ductal cannulation is difficult or not possible in patients who had undergone previous surgeries, which include a Billroth Type-II gastrectomy and a hepatico-enterostomy.

Nowadays, Magnetic Resonance Cholangiopancreatography (MRCP) is replacing ERCP as a diagnostic procedure in the investigation of benign biliary obstructions and chronic pancreatitis. Because of its technical versatility, multiplanar capability and superior soft tissue resolution, MRCP has an advantage over ERCP. It is non-invasive, can be performed rapidly and does not expose the patients to ionizing radiation or iodinated contrast material.

Considering the recent acceptability of MRCP for diagnostic purposes, the present study was conducted to evaluate the significance of MRCP in detecting CBD stones in patients with suspected choledocholithiasis.

MATERIALS AND METHODS

A prospective study was conducted on 64 patients, from December 2021 to November 2022 in the Department of Radiodiagnosis & Imaging Sciences, Jorhat Medical College & Hospital, Jorhat, Assam, India. Ethical committee clearance was obtained and informed consent for the study was taken from all patients. The procedures were in accordance with the guidelines of the Ethical Committee on Human Experimentation of the institution, which was in accordance with the guidelines of the Helsinki Declaration of 1975 which were revised in 2008.

The study included 64 patients who were suspected of having choledocholithiasis on the basis of any of the following criteria: -

1. A presence or history of any of the following:
 - Intermittent jaundice- Cholangitis which was defined as a fever of $> 37.3^{\circ}\text{C}$, chills, colicky right upper quadrant pain and leucocytosis.
 - Status of post biliary pancreatitis which was defined according to a history of biliary pancreatitis of not more than 2 months prior to admission, with subsided pancreatitis at the time of admission.
 - Post-cholecystectomy status.
2. Total bilirubin which was > 1.3 mg/dL
ALP which was > 126 IU/L
3. A CBD diameter of ≥ 8 mm at sonography, considering the upper limit of normality of CBD diameter as 7.9 mm [4] or CBD stones that were suspected/diagnosed at sonography.

All cases of obstructive jaundice other than CBD stones (e.g. carcinoma head of the pancreas, periampullary carcinoma, CBD strictures, cholangiocarcinoma, etc.) were excluded from the study.

The patients were initially evaluated by taking their detailed history, doing thorough physical examinations and checking complete blood counts & liver function tests reports. Transabdominal ultrasonography

was done on a Samsung RS80A machine with a curvilinear transducer of 1-7 MHz frequency. An ultrasonography scan was done after the patients had undergone an overnight fast for 8 to 12 hours. MRCP was performed for all patients on a 1.5 Tesla GE Signa HDxt MRI machine (by Wipro General Electric Healthcare). The patients fasted for 6 hours before MRCP. Prior to the examination, all external metallic items were removed.

MRCP protocols: 3 plane localizer was taken after proper positioning of the patient. The MRCP protocol consisted of Axial T2 FS BH, Axial T2 BH, Axial T1 FS BH, Axial T1 BH, Axial T2 SSFSE Rtr, Cor FS BH, Cor SSFE Rtr, Thick slab MRCP-BH, Axial 2D FIESTA FS-BH, A 3D image [thick maximum intensity projection (MIP)] was reconstructed to visualize the biliary and pancreatic duct in a 3D view. All patients with choledocholithiasis which were suspected on clinical evaluation or during biochemical or radiological investigations were subjected to open surgeries. All patients during surgery with dilated CBDs of sizes of ≥ 8 mm (which were measured by vernier callipers) or with palpable CBD stones underwent CBD explorations. Demonstration of CBD stones intra-operatively was considered the 'gold standard' for detecting their presence, which included visualization, extraction, or an attempt to extract stones during surgical CBD explorations.

The data were recorded in a proforma and statistical analysis was done using Statistical Package for the Social Sciences (SPSS). All patients were followed up for any complications and outcomes.

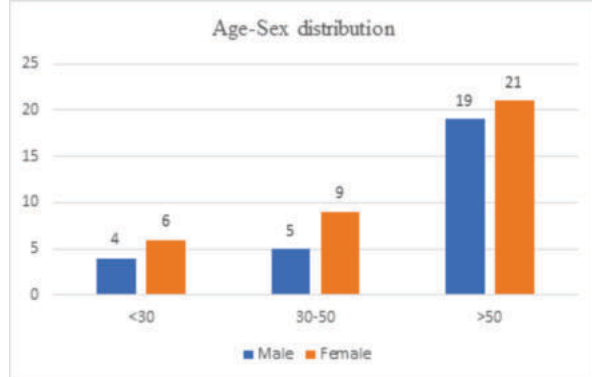
RESULTS

The present study included 64 patients with clinical, biochemical or radiological suspicions of choledocholithiasis.

Their ages ranged from 25 years to 75 years, with a mean age of 55 years. A majority of the patients 40 (62.5%) were above 50 years of age. Out of 64 patients, 36 (56.25%) were females and 28 (43.75%) were males. A female preponderance was observed in the study. [Table-1/Graph-1].

Table 1: Age And Sex Distribution Of The Study Population.

Age-Sex distribution			
Age (Years)	Male (n)	Female (n)	Total (n)
<30	4	6	10
30-50	5	9	14
>50	19	21	40
Total (n)	28	36	64



Graph 1: Age-Sex Distribution.

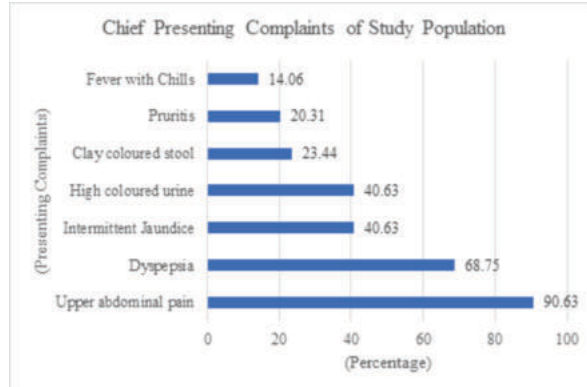
The most common presenting complaint was upper abdominal pain, which was present in 58 (90.63%) patients. The next common complaint was dyspepsia which was present in 44 (68.75%) patients. 26 (40.63%) patients had complaints of intermittent jaundice and highly coloured urine. 15 (23.44%) patients complained of clay-coloured stool and 13 (20.31%) patients had pruritis. Fever with chills was present in only 9 (14.06%) patients [Table-2/Graph-2].

7 (10.93%) patients had a past history of cholecystectomy. 14 (21.87%) patients had a past history of cholangitis.

Table 2: Chief Presenting Complaints Of The Study Population.

Presenting Complaints	Total (n)	Percentage (%)
Upper abdominal pain	58	90.63

Dyspepsia	44	68.75
Intermittent Jaundice	26	40.63
Highly coloured urine	26	40.63
Clay coloured stool	15	23.44
Pruritis	13	20.31
Fever with Chills	9	14.06



Graph 2: Chief Presenting Complaints.

The total leukocyte count (TLC) was raised in 15 (23.44%) out of 64 patients and it ranged from 11000 to 14345/mm³. The most common biochemical abnormality was a raised serum alkaline phosphatase (ALP) level, which was raised in 47 (73.44%) patients and it ranged from 220 to 2150 IU/L. Total serum bilirubin was elevated in 22 (34.38%) patients, which ranged from 4.1 to 16.8 mg%. Serum ALT and AST were elevated in 34 (53.13%) and 38 (59.38%) patients respectively and serum amylase was raised in only 7 (10.94%) patients [Table 3].

Table 3: Pattern Of Biochemical Abnormalities.

Biochemical Parameters (Normal range)	No. of patients with abnormal values of Biochemical Parameters n (Range)	Percentage (%)
TLC (4000-11000/mm ³)	15 (11000-14345)	23.44
Serum Bilirubin (0.2-1.3 mg%)	22 (4.1-16.8)	34.38
Serum ALP (38-126 IU/L)	47 (220-2150)	73.44
Serum ALT (4-50 IU/L)	34 (42-215)	53.13
Serum AST (15-46 IU/L)	38 (40-238)	59.38
Serum Amylase (0-175 IU/L)	7 (190-610)	10.94

On ultrasonography, cholelithiasis was diagnosed in 41 (64.06%) patients and dilated CBD (≥ 8 mm) in 49 (76.56%) patients. Choledocholithiasis was diagnosed in 28 (43.75%) patients [Table 4/Figure 1]. MRCP diagnosed cholelithiasis in 43 (67.18%) patients and dilated CBD in 53 (82.18%) patients. Choledocholithiasis was diagnosed in 41 (64.06%) patients [Table 4/Figure 2].

Table 4: Percentage Of Cholelithiasis And Choledocholithiasis Detection On Ultrasonography And MRCP In The Study Population.

Investigations	Normal n (%)	Cholelithiasis n (%)	Dilated CBD n (%)	Choledocholithiasis n (%)
Ultrasonography				
Male	6	15	21	11
Female	8	26	28	17
Total	15 (23.43%)	41 (64.06%)	49 (76.56%)	28 (43.75%)
MRCP				
Male	4	18	23	17
Female	6	25	30	24
Total	11 (17.18%)	43 (67.18%)	53 (82.18%)	41 (64.06%)

Intra-operatively, 45 (70.3%) out of 64 patients had cholelithiasis. 55 (85.93%) out of 64 patients had dilated CBD. In 43 (67.18%) out of 64 patients, choledocholithiasis was detected intra-operatively [Table 5]. Cholelithiasis and choledocholithiasis were most commonly seen in patients who were above 50 years of age [Table 5].



Figure 1: Transabdominal Ultrasonography showing small hyperechoic focus (white arrow) in the distal CBD, measuring 4.8mm in size causing posterior acoustic shadowing, suggestive of calculus.

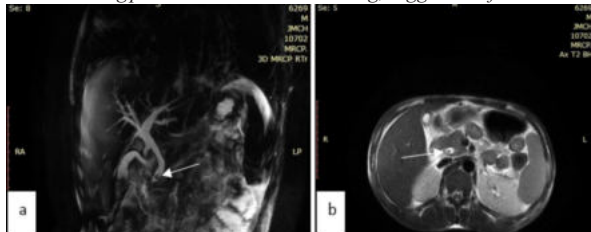


Figure 2: 3D MRCP (a) and Axial T2 BH (b) images show a small hypointense focus (filling defect) measuring 5mm in size in the distal CBD, suggestive of calculus. Marked by white arrows in images a and b.

Table 5: Intraoperative Findings.

Age	Normal n (%)	Cholelithiasis n (%)	Dilated CBD n (%)	Choledocholithiasis n (%)
<30	2	6	8	4
30-50	2	7	11	7
>50	4	32	36	32
Total	9(14.06%)	45(70.3%)	55(85.93%)	43(67.18%)

The correlation between various clinical, biochemical and imaging findings and intra-operative findings was studied and tabulated [Table 6]. Among the 43 patients with choledocholithiasis, 19 (44.18%) patients presented with a history of jaundice and 37 (86.04%) presented with a history of upper abdominal pain. Serum alkaline phosphatase had the highest sensitivity (65.1%) in the diagnosis of choledocholithiasis among the biochemical parameters which were studied. Ultrasonography could diagnose choledocholithiasis in 28 (65%) out of 43 patients with choledocholithiasis. MRCP demonstrated CBD stones in 41 (95.3%) out of 43 patients who were found to have choledocholithiasis intraoperatively [Table 6].

Table 6: Correlation Of Clinical, Biochemical And Imaging Findings With Intraoperative Findings.

Clinical Features and Investigations	Intraoperative findings (n=total number of patients with positive intraoperative findings)		
	Cholelithiasis No. of patients (%)	Dilated CBD No. of patients (%)	Choledocholithiasis No. of patients (%)
Clinical features			
Pain	43 (95.6%)	51 (92.7%)	37 (86.0%)
Jaundice	9 (20.0%)	24 (43.6%)	20 (46.5%)
Biochemical			
Serum alkaline phosphatase >126 IU/L	26 (57.8)	41 (74.54%)	28 (65.1%)
Imaging			
USG	41 (91.1%)	49 (89.0%)	28 (65.1%)
MRCP	43 (95.6%)	53 (96.36%)	41 (95.3%)

Ultrasonography could diagnose choledocholithiasis in only 28 (65.11%) out of 43 patients with choledocholithiasis, which was found intraoperatively, giving a sensitivity of 65.11%. USG correctly

diagnosed the absence of choledocholithiasis in 15 out of 21 patients, i.e., the specificity of USG for choledocholithiasis in the present study was 61.9%. The positive predictive value of USG in the detection of choledocholithiasis in the present study was 77.77% and the negative predictive value was 46.43%.

MRCP diagnosed choledocholithiasis in 41 (95.35%) out of 43 patients with choledocholithiasis, which was found intraoperatively, giving a sensitivity of 95.35%. MRCP correctly diagnosed the absence of choledocholithiasis in 19 out of 21 patients without choledocholithiasis. The specificity of MRCP in diagnosing choledocholithiasis in the present study was 90.47%. The positive predictive value of MRCP in diagnosing choledocholithiasis in the present study was 95.35% and the negative predictive value was 90.48%. [Table 7].

Table 7: Statistical Analysis Of Ultrasonography And MRCP In The Detection Of Choledocholithiasis.

Imaging tests of Choledocholithiasis	Intraoperative Choledocholithiasis		
	Present	Absent	Total
Ultrasonography			
Present	28	8	36
Absent	15	13	28
Total	43	21	64
MRCP			
Present	41	2	43
Absent	2	19	21
Total	43	21	64

DISCUSSION:

Each clinical predictor of CBD stones in the current study had a different level of diagnostic accuracy, and none was 100 percent accurate at detecting bile duct stones. An age of above 50 years, as a predictor of choledocholithiasis, had a sensitivity of 62.5% in predicting CBD stones. Female sex as a predictor of choledocholithiasis had a sensitivity of 56.25%. The inability to predict the rates at which gallstones passed from the gallbladder and the lack of knowledge regarding the length of time that stones remained in the CBD and how they passed from the CBD into the duodenum, whether or not there were symptoms or other signs of cholestasis, may have contributed to the lack of accuracy. It is still mostly unknown how CBD stones evolved naturally [5].

Serum alkaline phosphatase had the highest sensitivity (65.1%) in the diagnosis of choledocholithiasis among the biochemical parameters which were studied. The biliary ductular epithelium secretes hepatobiliary alkaline phosphatase. Back diffusion causes the elevated serum levels that are seen in acute biliary obstruction [6]. It has been stated that raised serum bilirubin levels are more significant, although evidence suggests that high serum levels of alkaline phosphatase more correctly predict the chance of choledocholithiasis.

Alkaline phosphatase was found to be a stronger predictor of common duct stones than bilirubin in the study done by Saltzstein et al., and the authors noted that the higher the level of alkaline phosphatase, the greater its predictive value [7]. Alkaline phosphatase had a sensitivity of 74.7%, total bilirubin had a sensitivity of 73.6%, and aspartate aminotransferase (AST) had the lowest sensitivity in the study by JC Pereira-Lima et al. [8]. Alkaline phosphatase and total bilirubin were found to be independent predictors of CBD stones in research by Yang et al., but alkaline phosphatase had better sensitivity than total bilirubin [9].

Ultrasonography is the initial imaging test that is used in the evaluation of patients with suspected bile duct stones. The sensitivity of transabdominal ultrasonography in the diagnosis of choledocholithiasis is operator dependent and it varies between 20 and 80% [10-13]. The quantity, size, and location of the stones, the patient's body habits, and the presence of underlying intestinal gas are all patient-related factors that affect the stone detection rate. The sensitivity, specificity and positive and negative predictive values of ultrasonography in detecting CBD stones in the present study were 65.11%, 61.9%, 77.77% and 46.43% respectively.

The relatively poor ultrasonography detection of common bile duct stones can be attributed to two different factors. First, gas from the duodenum or colon frequently covers the distal region of the common bile duct, where impacted stones typically occur, in both dilated and

non-dilated ducts. By putting the patient in the Trendelenburg position and watching the stone move cephalad towards the liver, one can sometimes still see the stone in dilated ducts. Second, the detection of obstructing stones is hampered by the absence of bile pools in the dilated and non-dilated distal ducts. A system that is not dilated makes the issue worse. In actuality, it is likely that the stone that was sonographically discovered in a dilated system was a more proximal stone rather than the stone that was obstructing the distal duct [10].

MRCP has recently been created as a non-invasive, very sensitive approach for identifying biliary tract disorders. In the present study, MRCP had a sensitivity of 95.35% (41 of 43 patients) in the demonstration of common duct stones and a specificity of 90% (19 of 21 patients). The positive predictive value of MRCP was 95.35%, whereas the negative predictive value was 90%. There were two false positives and two false negatives in the MRCP diagnosis of choledocholithiasis. The mistaken identification of a prominent ampullary sphincter for a lower bile duct stone led to the false positive finding on the MRCP. The MRCP had missed several tiny intrahepatic duct stones, leading to a false negative diagnosis. The lack of contrast between the stones and the surrounding liver and the absence of high-signal bile outlining the stones made it likely that they were missed.

Even with modern imaging methods, MRCP's ability to accurately diagnose CBD stones varies considerably. In the majority of the large series, diagnostic accuracies for the MRCP diagnosis of choledocholithiasis varied from 89 to 100%, specificities from 85 to 100%, and sensitivities from 81 to 100%. [14-18]. In a prospective study, **Fulcher et al.** [19] found that MRCP had an outstanding resolution with 100% sensitivity and 98–100% specificity for the identification of CBD stones. According to an official meta-analysis of 67 published controlled trials published in 2003 by **Romagnuolo et al.** [20], MRCP has an excellent overall sensitivity of 95% and a specificity of 97% for identifying CBD stones. The present study, with sensitivity and specificity of 95.35% and 90.47% respectively for demonstrating CBD stones, are, therefore, in line with these previous studies.

The sensitivity of MR cholangiography in the identification of CBD stones has been reported to vary from 57% to 92% in studies in which an MR cholangiography was done with a two-dimensional fast or turbo spin-echo sequence and a standard body coil. A prior study had the lowest sensitivity (57.7%) for detecting CBD stones, with patients with tiny stones making up more than half of the study population. [21]. However, the detection of small stones that may also move during MRCP when lengthy acquisition times are necessary would be challenging due to motion artifacts and blurring associated with the long acquisition times in the non-breath hold approach that is used. Using a phased array coil and the breath-hold single-shot half-Fourier sequence, an improved MR cholangiographic performance was made possible. This method's reported sensitivity ranged from 92% to 100%. [16]. The results of the present study, which used a single-shot half-Fourier sequence and a phased-array coil on all patients, were consistent with those of prior studies that employed a similar approach. The majority of the time, the source images and traditional cross-sectional imaging detected calculi that are missed on MRCP (MIP images) as minor filling defects within the bile-filled dilated common duct.

There are many limitations which are associated with MRCP. Smaller CBD calculi can be missed on MRCP [22]. However, normally, stones of sizes of up to 2–3 mm are visible. Papilla can only be seen in about 40% of patients [22]. There may also be difficulty in depicting minor narrowing of the cystic duct and the pancreatic ducts [23]. Another issue with MRCP is that the pictures produced by maximum intensity projection (MIP) reconstruction may fully hide minor filling defects and may show respiratory motion artifacts. Always check source images to ensure that this is not a problem in actual use. Respiratory misregistration is the main issue with a multislice MRCP for MIP. T2 weighting is another problem, which might change with different MRI sequences and affect the results. The MRCP is simply a diagnostic method, it should be noted. The effect of this is that an MRCP could have been avoided and patients could have started their treatment right away if an ERCP was required later as a therapeutic intervention.

This study shows that MRCP has a diagnostic accuracy that is similar to that of direct cholangiography, in the diagnosis of choledocholithiasis. It is non-invasive, can be performed rapidly, and

provides images similar to those of ERCP without the use of a contrast agent or anesthesia. It also avoids the complications associated with ERCP. In the diagnosis of bile duct stones, it may take the place of ERCP. To compare MRCP with diagnostic ERCP, high-quality research is required, particularly randomized controlled trials that specify inclusion/exclusion criteria and pertinent patient characteristics. Additional study is required on patient satisfaction as well as methods for decreasing claustrophobia-related issues.

CONCLUSION

MRCP is an effective primary tool for detecting or excluding CBD stones before cholecystectomy. In the present study, the use of MRCP permitted a purely non-invasive negative diagnosis for 90.48% of patients in whom the probability of CBD stones was high. By using MRCP, these patients could avoid invasive preoperative endoscopic treatments, which would likely result in lower overall surgical expenditures. However, due to its high cost and restricted availability, MRCP's potential use in the detection of CBD stones is constrained. We suggest MRCP as the preferred technique for bile duct calculi diagnostic imaging. When screening patients for possible bile duct stones, ultrasonography needs to be utilised as the initial imaging test.

REFERENCES

- Topal B, Van de Moortel M, Fieuws S, Vanbeckevoort D, Van Steenberghe W, Aerts R, Penninckx F. The value of magnetic resonance cholangiopancreatography in predicting common bile duct stones in patients with gallstone disease. *Journal of British Surgery*. 2003 Jan;90(1):42-7.
- Varghese JC, Liddell RP, Farrell MA, Murray FE, Osborne H, Lee MJ. The diagnostic accuracy of magnetic resonance cholangiopancreatography and ultrasound compared with direct cholangiography in the detection of choledocholithiasis. *Clinical radiology*. 1999 Sep 1;54(9):604-14.
- Demartines N, Eisner L, Schnabel K, Fried R, Zuber M, Harder F. Evaluation of magnetic resonance cholangiography in the management of bile duct stones. *Archives of Surgery*. 2000 Feb 1;135(2):148-52.
- Lal N, Mehra S, Lal V. Ultrasonographic measurement of normal common bile duct diameter and its correlation with age, sex and anthropometry. *Journal of clinical and diagnostic research: JCDR*. 2014 Dec;8(12):AC01.
- Abboud PA, Malet PF, Berlin JA, Starosick R, Cabana MD, Clarke JR, Shea JA, Schwartz JS, Williams SV. Predictors of common bile duct stones prior to cholecystectomy: a meta-analysis. *Gastrointestinal endoscopy*. 1996 Oct 1;44(4):450-7.
- Townsend CM, Beauchamp RD, Evers BM, Mattox KL. Biliary tract. In: *Sabiston Textbook of Surgery*. 17th ed. Amsterdam: Saunders; 2004; 1597-641.
- Saltzstein EC, Peacock JB, Thomas MD. Preoperative bilirubin, alkaline phosphatase and amylase levels as predictors of common duct stones. *Surgery, gynecology & obstetrics*. 1982 Mar 1;154(3):381-4.
- Pereira-Lima JC, Jakobs R, Busnello JV, Benz C, Blaya C, Riemann JF. The role of serum liver enzymes in the diagnosis of choledocholithiasis. *Hepato-gastroenterology*. 2000 Nov 1;47(36):1522-5.
- Yang MH, Chen TH, Wang SE, Tsai YF, Su CH, Wu CW, Lui WY, Shyr YM. Biochemical predictors for absence of common bile duct stones in patients undergoing laparoscopic cholecystectomy. *Surgical endoscopy*. 2008 Jul;22:1620-4.
- Cronan JJ, Mueller PR, Simeone JF, O'Connell RS, VanSonnenberg E, Wittenberg J, Ferrucci Jr JT. Prospective diagnosis of choledocholithiasis. *Radiology*. 1983 Feb;146(2):467-9.
- Einstein DM, Lapin SA, Ralls P, Halls JM. The insensitivity of sonography in the detection of choledocholithiasis. *American journal of roentgenology*. 1984 Apr 1;142(4):725-8.
- Laing FC, Jeffrey RB, Wing VW. Improved visualization of choledocholithiasis by sonography. *American journal of roentgenology*. 1984 Nov 1;143(5):949-52.
- Cronan JJ. US diagnosis of choledocholithiasis: a reappraisal. *Radiology*. 1986 Oct;161(1):133-4.
- Reinhold C, Taourel P, Bret PM, Cortas GA, Mehta SN, Barkun AN, Wang L, Tafazoli F. Choledocholithiasis: evaluation of MR cholangiography for diagnosis. *Radiology*. 1998 Nov;209(2):435-42.
- Guibaud L, Bret PM, Reinhold C, Atri M, Barkun AN. Diagnosis of choledocholithiasis: value of MR cholangiography. *AJR. American journal of roentgenology*. 1994 Oct;163(4):847-50.
- Regan F, Fradin J, Khazan R, Bohlman M, Magnuson T. Choledocholithiasis: evaluation with MR cholangiography. *AJR. American journal of roentgenology*. 1996 Dec;167(6):1441-5.
- Becker CD, Grossholz M, Becker M, Mentha G, de Peyer R, Terrier F. Choledocholithiasis and bile duct stenosis: diagnostic accuracy of MR cholangiopancreatography. *Radiology*. 1997 Nov;205(2):523-30.
- Soto JA, Yucel EK, Barish MA, Chuttani R, Ferrucci JT. MR cholangiopancreatography after unsuccessful or incomplete ERCP. *Radiology*. 1996 Apr;199(1):91-8.
- Fulcher AS, Turner MA, Capps GW, Zfass AM, Baker KM. Half-Fourier RARE MR cholangiopancreatography: experience in 300 subjects. *Radiology*. 1998 Apr;207(1):21-32.
- Romagnuolo J, Bardou M, Rahme E, Joseph L, Reinhold C, Barkun AN. Magnetic resonance cholangiopancreatography: a meta-analysis of test performance in suspected biliary disease. *Annals of internal medicine*. 2003 Oct 7;139(7):547-57.
- Zidi SH, Prat F, Le Guen O, Rondeau Y, Rocher L, Fritsch J, Choury AD, Pelletier G. Use of magnetic resonance cholangiography in the diagnosis of choledocholithiasis: prospective comparison with a reference imaging method. *Gut*. 1999 Jan 1;44(1):118-22.
- Kalra M, Sahani D, Ahmad A, Saini S. The role of magnetic resonance cholangiopancreatography in patients with suspected biliary obstruction. *Current Gastroenterology Reports*. 2002 Apr;4:160-6.
- Fulcher AS, Turner MA. Pitfalls of MR cholangiopancreatography (MRCP). *J Comput Assist Tomogr*. 1998;22:845-50.