Magnetic Resonance Cholangiopancreatography (MRCP) in Patients with Gall Stone Diseases and its Correlation with USG Findings

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Abstract: ***Background**: Gallstone disease is a common hepatobiliary disorder. Ultrasonography (USG) is the first-line imaging modality, whereas Magnetic Resonance Cholangiopancreatography (MRCP) provides comprehensive evaluation of the biliary system and associated anatomical variations. **Objectives**: To evaluate the diagnostic role of MRCP in gallstone disease and correlate its findings with ultrasonographic findings. **Materials and Methods**: A prospective cross-sectional analytical study was conducted at a tertiary care teaching hospital over a period of 18 months. Sixty patients with clinically suspected gallstone disease underwent both transabdominal ultrasonography and MRCP. Gallstone detection, gallbladder volume, common bile duct (CBD) diameter, biliary tract abnormalities, stone distribution, and hepatic and cystic duct anatomical variants were evaluated. Statistical analysis was performed using SPSS version 26.0, with $p < 0.05$ considered statistically significant. **Results**: The study population comprised 42 females (70%) and 18 males (30%), with a mean age of 47.8 ± 7.6 years. Gallstones were detected in 50 patients (83.3%), including multiple calculi in 63.3% and single calculi in 20.0%. MRCP showed perfect agreement with USG for gallstone detection ($\kappa = 1.0$). Gallbladder volume and CBD diameter measured by MRCP were significantly higher than those measured by USG ($p < 0.001$), with excellent correlations ($r = 0.985$ and $r = 0.993$, respectively). MRCP identified extra-gallbladder bile duct stones in 34% of patients and hepatic/cystic duct anatomical variants in 20% of cases, findings that were frequently missed on USG. For CBD pathology, MRCP demonstrated 100% sensitivity and specificity, compared with 71.4% sensitivity for USG. **Conclusion**: USG remains an excellent first-line modality for gallstone detection. However, MRCP provides superior evaluation of choledocholithiasis, biliary tract abnormalities, and anatomical variants, making it a valuable complementary imaging tool for preoperative assessment and management of gallstone disease.*

Keywords: Gallstone disease, MRCP, Ultrasonography, Choledocholithiasis, Common bile duct, Biliary anatomy

1. Introduction

Gallstone disease is a very common GI disorder worldwide, causing a significant burden on healthcare systems and significantly impairing HRQOL for a large percentage of the world's population. [1] A considerable variation is observed in the prevalence of this condition across racial groups, for whom the highest prevalence is observed among Punjabis, residing in North India, and the lowest is observed among South Indians. [2]

Magnetic Resonance Cholangiopancreatography (MRCP) has emerged as a revolutionary non-invasive imaging technique that uses magnetic resonance imaging to visualize the biliary and pancreatic ducts, slowly replacing endoscopic retrograde cholangiopancreatography (ERCP) as the investigation of choice.[3] The technique utilizes heavily T2-weighted MRI pulse sequences that show high signal in static or slow-flowing fluids within the gallbladder, biliary ducts and pancreatic duct, with low signal of surrounding tissue.[4] This technique takes advantage of the natural contrast between the fluid in the ducts and the surrounding soft tissues to create high-resolution images without the need for contrast agent administration or endoscopic procedures. Additionally, MRCP has the advantage of offering complete visualization of the biliary tree, making it very valuable in the assessment of complications such as choledocholithiasis, biliary strictures, and pancreatic involvement that may not be evident on sonographic assessment.

Accurate biliary anatomy mapping is crucial for more than detecting stones; pre-operative MRCP assessment can greatly improve laparoscopic cholecystectomy outcomes. [5] The comparative evaluation of magnetic resonance cholangiopancreatography and ultrasonography in gallstone diseases highlights the potential for these techniques to be used together to improve diagnostic accuracy. Ultrasonography is considered a preliminary tool for evaluating patients, as this technique is easy to use and quite effective for diagnosing patients with gallstones, while magnetic resonance cholangiopancreatography is considered to be more effective for complete evaluation of the biliary system and for diagnosing complications of gallstones.[6]

The study was conducted to assess the diagnostic accuracy of MRCP and ultrasonography in the diagnosis of gallstone disease for the improvement of patient outcomes, development of evidence-based guidelines for the evaluation of patients with suspected biliary disease, and for the eventual reduction of preventable morbidity associated with gallstone disease and its surgical management.

2. Materials and Methods

The cross-sectional analytical study was conducted at the Department of Radiodiagnosis, Index Medical College Hospital and Research Centre, Indore, Madhya Pradesh, India, over a period of 18 months. Using a consecutive sampling method, 60 patients fulfilling the inclusion and exclusion criteria were selected for the study. Ethical clearance was obtained from the Institutional Ethics Committee before the commencement of the study.

Inclusion Criteria

Clinically suspected cases presenting with right hypochondriac pain, jaundice, dyspepsia, or other symptoms suggestive of biliary pathology, Ultrasound diagnosed cases of gallstone disease, known cases of previously treated gallstone disease presenting with recurrent symptoms.

Exclusion Criteria

Patients who are not willing to undergo MRCP after being diagnosed by ultrasound, contraindications to MRI, those with cardiac pacemakers, cochlear implants, intracranial aneurysm clips, metallic intraocular foreign bodies, certain metallic prostheses, or implanted drug infusion pumps, claustrophobia who are unable to tolerate the MRI examination, not meeting the requirement of minimum 6-8 hours of fasting prior to imaging.

Patients who were referred to the Department of Radiodiagnosis for the evaluation of right hypochondriac pain or suspected gallstone disease were screened for the study eligibility criteria. Patients who qualified for the study underwent an informed consent procedure, during which the details of the study, including its aims, methods, risks, and benefits, were explained in detail. Written informed consent was obtained from all patients (or their parents/guardians in the case of minors) before participation in the study. The patients' clinical history, symptoms, and examination findings were recorded using a pre-structured proforma.

Ultrasonography was performed first in all study subjects with suspected gallbladder pathology. The ultrasonographic examination was conducted in both the supine and left lateral decubitus positions to optimize visualization of the gallbladder. Following ultrasonography, all patients diagnosed with gallstone disease or those with a high clinical suspicion of gallstone disease underwent magnetic resonance cholangiopancreatography (MRCP). MRCP imaging was performed using a 1.5T GE SIGNA EXPLORER scanner with a phased-array body coil. All the study subjects underwent fasting for at least 6-8 hours before they undergo the ultrasonography and MRCP examination.

Data was collected prospectively using a pre-structured proforma and entered into Microsoft Excel for statistical analysis. Statistical analysis was conducted using the SPSS 26.0 version. Categorical variables were expressed as frequencies and percentages, while continuous variables were summarized as mean ± standard deviation (SD).

3. Result

Table 1: Demographic Characteristics of Study Population (N=60)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	18	30.0
	Female	42	70.0
Age Groups	35-40 years	12	20.0
	41-50 years	28	46.7
	51-60 years	17	28.3
	>60 years	3	5.0
Mean Age ± SD		47.8 ± 7.6 years	
Age Range		35-64 years	

Table 1. below highlights the demographic profile of the 60 study participants recruited for this study. The study participants have a clear female preponderance, with a female to male ratio of 2.3:1 (70% female, 30% male), consistent with the established increased incidence of gallstone disease in females, due to estrogen-induced cholesterol supersaturation. The study participants' age range was predominantly 41-50 years (46.7%), with a mean age of 47.8 ± 7.6 years, consistent with the expected demographic distribution in symptomatic cholelithiasis.

Table 2: Gallstone Detection by MRCP (N=60)

MRCP Findings	Frequency (n)	Percentage (%)	95% CI
Multiple Calculi	38	63.3	50.1-75.0
Single Calculus	12	20.0	10.8-32.3
Total Calculi Present	50	83.3	71.5-91.7
No Calculus	10	16.7	8.3-28.5
GB Sludge	18	30.0	18.8-43.2

Table 2. shows the findings of gallstone detection by MRCP in all 60 patients. MRCP also detected calculi in the same 50 patients (83.3%) as USG, with an identical distribution. This shows perfect agreement between USG and MRCP for the detection of intraluminal gallstones (Cohen's Kappa = 1.0). However, the key benefit of MRCP lies not only in the detection of gallstones but also in its ability to reveal extrahepatic duct pathology, hepatic and cystic duct anomalies, and bile duct stones, which are not visible on USG.

Table 3: Comparison of Gallbladder Volume Measurements (N=60)

Parameter	USG (ml)	MRCP (ml)	Mean Difference	Paired t-test	p-value
Mean ± SD	31.2 ± 7.8	34.1 ± 8.4	2.9 ± 1.2	t = 18.74	<0.001
Median	30.0	33.0			
Range	19-47 ml	21-51 ml			
95% CI	29.2-33.2	31.9-36.3	2.6-3.2		

Table 3. shows a comparison of the gallbladder volume measurements done by ultrasonography (USG) and magnetic resonance cholangiopancreatography (MRCP). The volumes measured by MRCP were higher (mean 34.1 ± 8.4 ml) compared to USG (mean 31.2 ± 7.8 ml) by a statistically significant difference of 2.9 ± 1.2 ml ($p < 0.001$). However, there is a very strong positive correlation between the two methods ($r = 0.985$). The slightly higher volumes measured by MRCP can be attributed to its higher contrast resolution and multi-planar imaging.

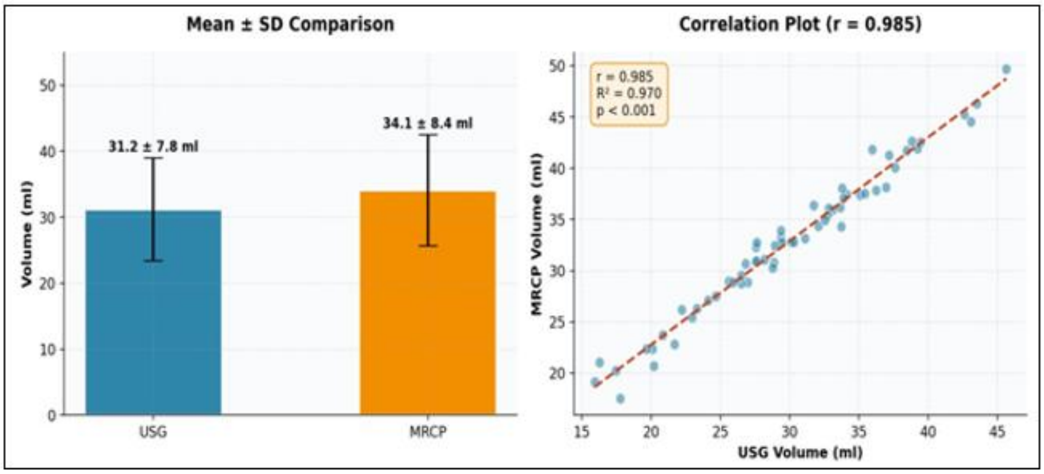

Figure 3: Gallbladder Volume Comparison (N=60)

Table 4: Comparison of Common Bile Duct (CBD) Diameter Measurements (N=60)

Parameter	USG (mm)	MRCP (mm)	Mean Difference	Paired t-test	p-value
Mean ± SD	6.5 ± 1.8	6.8 ± 1.9	0.3 ± 0.2	t = 11.62	<0.001
Median	6.0	6.3			
Range	4.2-10.5 mm	4.1-10.8 mm			
95% CI	6.0-7.0	6.3-7.3	0.2-0.4		

Magnetic resonance cholangiopancreatography (MRCP) measurements were marginally larger (mean 6.8 ± 1.9 mm) than ultrasonography (USG) (mean 6.5 ± 1.8 mm) measurements, with a statistically significant mean difference of 0.3 ± 0.2 mm ($t = 11.62$, $p < 0.001$). The very high correlation coefficient ($r = 0.993$) indicates a close agreement between the two methods. The larger measurements by MRCP are due to its higher spatial resolution and the lack of acoustic shadowing artifacts, which may limit USG measurements.

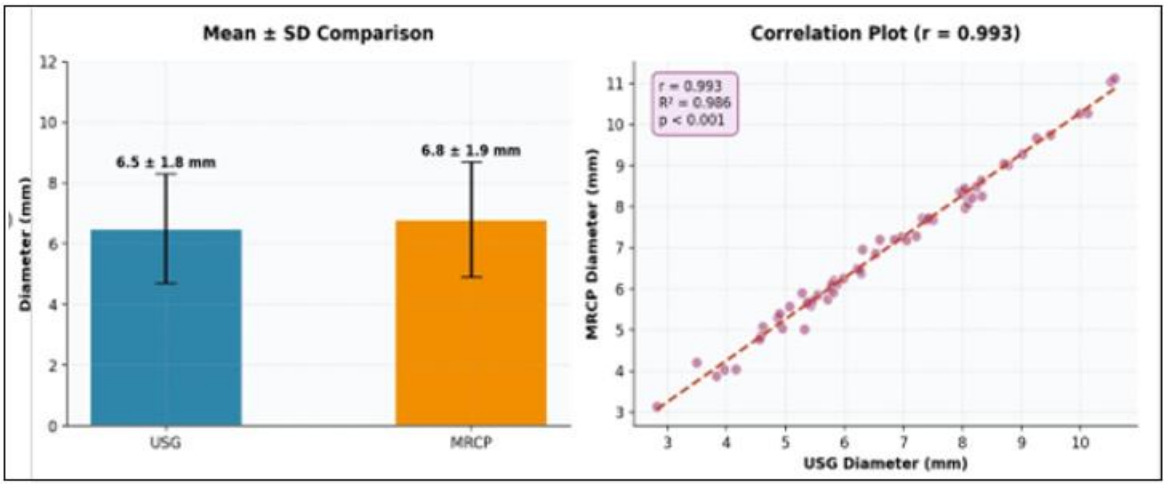

Figure 1: CBD Diameter Comparison (N=60)

Table 5: Concordance Analysis between USG and MRCP for Gallstone Detection

USG Finding	MRCP Positive	MRCP Negative	Total	Agreement (%)
Single Calculus	12	0	12	100
Multiple Calculi	38	0	38	100
No Calculus	0	10	10	100
Total	50	10	60	

Table 5. shows the concordance study between ultrasound sonography (USG) and magnetic resonance cholangiopancreatography (MRCP) for the detection of gallstones. It was noted that there was complete concurrence between the two tests for all categories, i.e., solitary calculus, multiple calculi, and no calculi. Therefore, there was a perfect concordance between USG and MRCP (Kappa = 1.0), showing that both tests were equally effective for the detection of intraluminal gallstones. Thus, USG is recommended for the initial screening for gallstones, while MRCP is recommended as a valuable tool for the assessment of the bile duct.

Table 6: Biliary Tract Anomalies and Variants Detected (N=60)

Finding	Detection by USG	Detection by MRCP	Total Cases	Percentage
Normal Anatomy	51	51	51	85.0
CBD Dilatation	4	5	5	8.3
CBD Stone	0	2	2	3.3
Phrygian Cap GB	1	1	1	1.7
Septate GB	1	1	1	1.7
Folded Fundus GB	1	1	1	1.7
Total Anomalies	7	10	10	15.0

Table 6. shows the biliary tract anomalies and variants identified. Normal anatomy was identified in 51 patients (85.0%), and anomalies were identified in 9 patients (15.0%). Dilatation of the common bile duct (CBD) was the most common anomaly identified (8.3%), and one more case was identified by MRCP than by USG. CBD stones were identified only by MRCP in 2 patients (3.3%). Gallbladder morphological variants included Phrygian cap (1.7%), septate gallbladder (1.7%), and folded fundus (1.7%). Notably, MRCP identified additional hepatic and cystic duct anatomical variants that were not visible at all on USG.

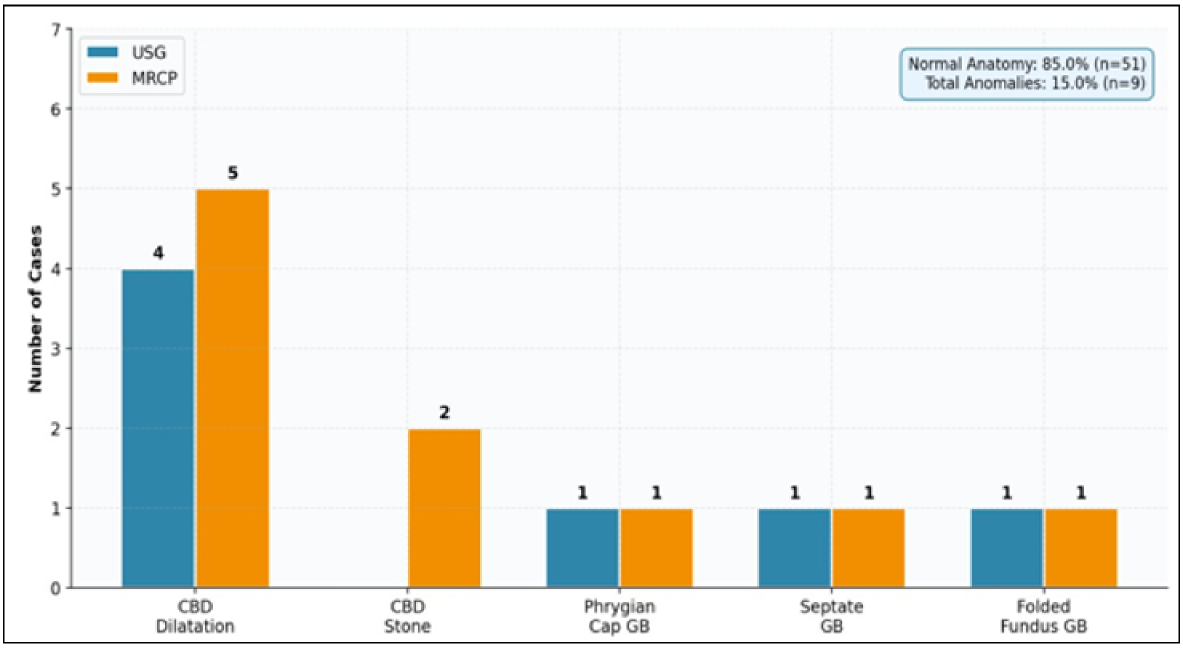

Figure 2: Biliary Tract Anomalies- USG vs MRCP (N=60)

Table 7: Diagnostic Performance Metrics - USG vs MRCP (N=60)

Metric	USG for Gallstones	USG for CBD Pathology	MRCP for Gallstones	MRCP for CBD Pathology
Sensitivity	100% (50/50)	71.4% (5/7)	100% (50/50)	100% (7/7)
Specificity	100% (10/10)	100% (53/53)	100% (10/10)	100% (53/53)
PPV	100%	100%	100%	100%
NPV	100%	96.4%	100%	100%
Accuracy	100% (60/60)	96.7% (58/60)	100% (60/60)	100% (60/60)
95% CI	94.0-100%	88.5-99.6%	94.0-100%	94.0-100%
Kappa Value	1.0	0.81	1.0	1.0

The performance characteristics are shown in Table 7. In gallstone detection, both imaging modalities had 100% sensitivity, specificity, and accuracy (Kappa = 1.0). In CBD pathology, ultrasound (USG) had a sensitivity of 71.4%, while MRCP had 100%. USG had an accuracy of 96.7%, whereas MRCP had 100%. It is important to note that USG missed the detection of hepatic and cystic duct anatomical variations by 0%, whereas MRCP correctly identified all 12 cases by 100%, thereby emphasizing the importance of MRCP in biliary assessment.

Table 8: Comprehensive Stone Location Distribution by MRCP (N=50 patients with stones)

Stone Location (MRCP)	Frequency (n)	Percentage (%)	95% CI
GB Stones Only	33	66	51.2-78.8
GB + Distal CBD	6	12	4.5-24.3
GB + Mid CBD	4	8	2.2-19.2
GB + Proximal CBD	4	8	2.2-19.2
GB + CHD	2	4	0.5-13.7
GB + Cystic Duct	1	2	0.05-10.7
GB + Ampullary	2	4	0.5-13.7
GB + Intrahepatic Duct	2	4	0.5-13.7
GB + Hepatic Duct Confluence	2	4	0.5-13.7
Total with Extra-GB Stones	17	34	21.2-48.8

Table 8. shows the distribution of MRCP-determined stone location. In the cohort of patients examined, 33 (66%) of the patients had stones located only within the gallbladder, while 17 (34%) of the patients were found to have stones located within the biliary ducts, as determined by MRCP. Other locations include the distal common bile duct (CBD) at 12%, the mid-CBD at 8%, and the proximal CBD at 8%. These findings emphasize the advantage of MRCP in providing detailed visualization of the entire anatomy of the biliary system and the locations of ductal stones, as well as the hepatic and cystic duct anatomy, which is critical to surgical planning and the avoidance of iatrogenic injury to the biliary system.

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Table 9: Comparative Performance- USG VS MRCP for Bile Duct Stones

Parameter	Distal CBD	Mid CBD	Proximal CBD	CHD/Hepatic Confluence	Ampullary/ Cystic	Intrahepatic	Overall Extra-GB
USG Sensitivity (%)	16.7	25	0	0	0	0	11.8
USG Specificity (%)	100	100	100	100	100	100	100
USG PPV (%)	100	100	-	-	-	-	100
USG NPV (%)	91.7	93	93.1	96.6	98.3	96.6	78.6
USG Accuracy (%)	91.7	93.3	93.3	96.7	98.3	96.7	88.3

Table 9. compares the sensitivity and specificity of ultrasonography (USG) and magnetic resonance cholangiopancreatography (MRCP) in all locations of the biliary ducts. The sensitivity of USG was found to be very low in all locations. It was 16.7% in the distal common bile duct (CBD), 25% in the mid CBD, and 0% in proximal CBD, CHD (choledochus), ampullary/cystic, and intrahepatic locations. The sensitivity of MRCP was found to be 100% in all locations. The sensitivity for detecting extra-gallbladder stones was 11.8% for USG and 100% for MRCP ($p < 0.001$). These results prove that MRCP plays an important role in detecting stones in the biliary ducts, particularly in proximal and intrahepatic locations.

Table 10: Hepatic and Cystic Duct Anatomical Variants Detected by MRCP (N=60)

Variant Type	MRCP (n)	USG Detected (n)	USG Missed (n)	USG Sensitivity	MRCP Sensitivity
Aberrant Right Hepatic Duct	3	2	1	66.7%	100%
Low Cystic Duct Insertion	2	0	2	0%	100%
Medial Cystic Duct Insertion	1	0	1	0%	100%
High Cystic Duct Insertion	1	0	1	0%	100%
Parallel Cystic Duct Course	1	0	1	0%	100%
Trifurcation of Hepatic Confluence	1	1	1	100%	100%
Cystic Duct to Right Hepatic Duct	1	0	1	0%	100%
Double/Accessory Cystic Duct	1	0	1	0%	100%
Aberrant RHD to Cystic Duct	1	0	1	0%	100%

Table 10. shows the incidence of anatomical variations in the hepatic and cystic ducts, which were identified solely by MRCP in 12 out of 60 patients (20.0%). The sensitivity of USG in the detection of these variations was 25%, while MRCP was 100%. This is a statistically significant difference (McNemar's $\chi^2 = 9.0$, $p < 0.001$). The common variations were low insertion of the cystic duct (3.3%), aberrant right hepatic duct (5.0%), and trifurcation variant (1.7%).

Case 1: Dilatation of Common Bile Duct

Figure 3: USG Image

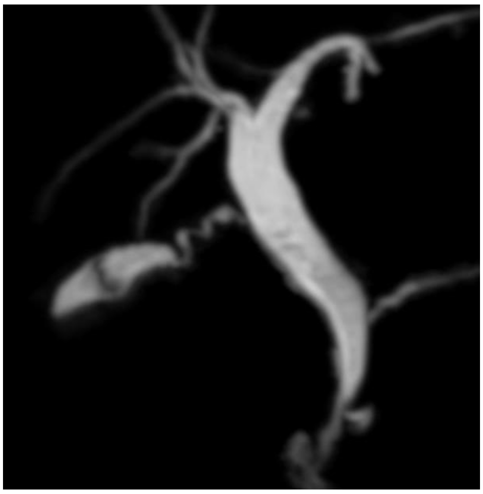

Figure 4: Coronal MIP MRCP image

Case 2: Microcholelithiasis

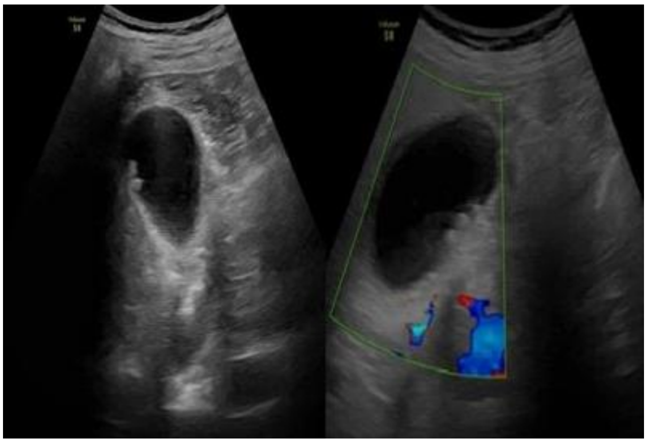

Figure 5: USG B Mode Image shows multiple echogenic calculi with posterior acoustic shadowing noted in lumen of Gall Bladder

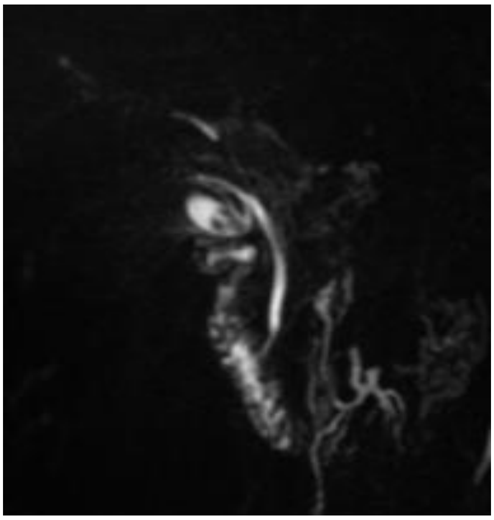

Figure 6: Coronal MIP MRCP image MRCP

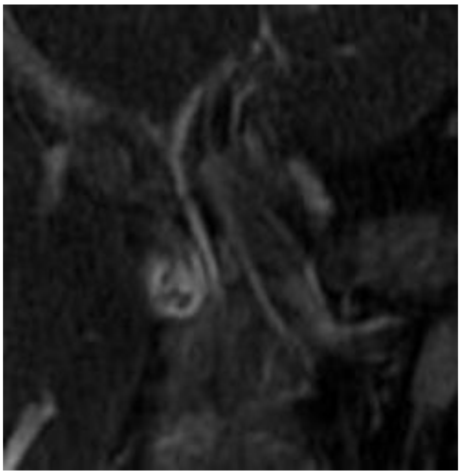

Figure 7: COR T2 FS

4. Discussion

The current study was designed to assess and compare the diagnostic capabilities of Ultrasonography (USG) and Magnetic Resonance Cholangiopancreatography (MRCP) in the evaluation of gallstone disease and biliary pathologies in 60 symptomatic patients.

The study population demonstrated a female predominance (70%) with a female-to-male ratio of 2.3:1 and a mean age of 47.8 ± 7.6 years. Most patients belonged to the 41–50 year's age group. These findings are consistent with the established epidemiology of gallstone disease. Stinton and Shaffer [7] reported that female sex is a major risk factor for cholelithiasis due to hormonal influences on cholesterol metabolism and gallbladder motility. Similarly, Shaffer [8] observed a female-to-male ratio ranging from 2:1 to 3:1 across different populations. The age distribution in the present study is comparable to the findings of Kratzer et al. [9], who reported a peak prevalence of gallstone disease between 40 and 60 years of age.

MRCP detected gallstones in 50 of 60 patients (83.3%), including multiple calculi in 63.3% and single calculi in 20.0% of cases. The predominance of multiple calculi is consistent with the observations of Tazuma [10], who reported that cholesterol stones commonly occur as multiple calculi due to cholesterol supersaturation and impaired gallbladder emptying. The high detection rate demonstrates the effectiveness of MRCP in identifying gallstone disease while simultaneously providing comprehensive evaluation of the biliary tree.

MRCP demonstrated significantly higher gallbladder volume measurements than USG (34.1 ± 8.4 ml vs. 31.2 ± 7.8 ml; $p < 0.001$), although the correlation between modalities was excellent ($r = 0.985$). Similar findings have been reported by Katariya et al. [11] and Pauletzki et al. [12], who noted that cross-sectional imaging techniques provide more accurate volumetric assessment due to superior spatial resolution and multiplanar capability. Despite the statistically significant difference, the strong correlation indicates that USG remains a reliable modality for routine gallbladder volume assessment.

MRCP measured slightly larger CBD diameters compared with USG (6.8 ± 1.9 mm vs. 6.5 ± 1.8 mm; $p < 0.001$), with near-perfect correlation ($r = 0.993$). These findings are in agreement with Park et al. [13], who demonstrated the superior accuracy of MRCP in evaluating the biliary tree, particularly in distal ductal segments where ultrasound assessment may be limited by bowel gas and acoustic shadowing.

A perfect concordance was observed between USG and MRCP for gallstone detection, with identical categorization of single calculi, multiple calculi, and stone-free cases (Kappa = 1.0). Both modalities also demonstrated complete agreement in sludge detection. These findings support previous reports indicating that transabdominal ultrasonography has excellent sensitivity for gallstones larger than 5 mm and remains the preferred first-line imaging modality for symptomatic cholelithiasis [14].

Biliary tract anomalies were identified in 15.0% of patients, with CBD dilatation being the most common abnormality. MRCP detected additional cases of CBD pathology and choledocholithiasis that were not identified on USG. Similar observations were reported by Yu et al. [15], who emphasized the importance of identifying biliary tract variants before surgery to reduce the risk of iatrogenic bile duct injury. These findings highlight the added diagnostic value of MRCP beyond simple gallstone detection.

Both USG and MRCP demonstrated 100% sensitivity, specificity, positive predictive value, negative predictive value, and accuracy for gallstone detection. However, MRCP showed superior performance for CBD pathology, achieving 100% sensitivity compared with 71.4% for USG. These findings are consistent with the meta-analysis by Chen et al. [16], which reported high sensitivity and specificity of MRCP for choledocholithiasis. The results confirm that while USG is highly reliable for gallbladder stones, MRCP is more effective for evaluating bile duct pathology.

MRCP demonstrated superior capability in mapping stone location throughout the biliary system. While 66% of patients had stones confined to the gallbladder, 34% had associated extra-gallbladder ductal stones involving the distal CBD, mid CBD, proximal CBD, common hepatic duct, ampullary region, intrahepatic ducts, or hepatic duct confluence. Similar findings have been reported by Calvo et al. [17], who showed that MRCP accurately identifies choledocholithiasis and can reliably exclude bile duct stones when negative. These findings underscore the importance of MRCP in preoperative biliary assessment.

USG demonstrated limited sensitivity for bile duct stone detection, ranging from 0% to 25% depending on stone location, with an overall sensitivity of 11.8% for extra-gallbladder stones. In contrast, MRCP achieved 100% sensitivity across all biliary duct locations. These findings are consistent with reports by Afzalpurkar et al. [18], who demonstrated the superior diagnostic accuracy of MRCP for choledocholithiasis. The results emphasize the limitations of USG for ductal stone evaluation and support the routine use of MRCP when bile duct involvement is suspected.

MRCP identified hepatic and cystic duct anatomical variants in 20.0% of patients, whereas USG detected only a minority of these abnormalities. The most common variant was an aberrant right hepatic duct. Similar prevalence rates have been reported by Uysal et al. [19] and Sarawagi et al. [20], who documented biliary anatomical variations in approximately one-quarter of patients undergoing MRCP. The superior performance of MRCP in delineating biliary anatomy supports its role in preoperative planning and prevention of bile duct injury during laparoscopic cholecystectomy.

The current study has a number of strengths, including its prospective and comparative nature in which both modalities were used in all 60 patients, comprehensive analysis of gallstone detection, use of measurements, stone localization mapping, and biliary anatomical variant detection, and the use of robust statistical analysis (McNemar's test, Cohen's Kappa, Pearson's correlation, and paired t-tests). The limitations include the small sample size (n = 60), single-center study, lack of intraoperative cholangiography or surgical and histopathological validation as the gold standard, and the pre-selection of patients with symptoms, which may limit generalizability to the general population.

5. Conclusion

Based on the above findings, it can be concluded that USG should remain the primary screening investigation for gallstone disease due to its excellent diagnostic accuracy, non-invasive nature, real-time capability, low cost, and wide availability. The MRCP should be employed as a critical complementary tool in patients with suspected choledocholithiasis, biliary duct dilatation, elevated hepatobiliary enzymes, or as a prelude to laparoscopic cholecystectomy in complex cases for complete biliary imaging and characterization of anatomical variants. This complementary, tiered approach to imaging improves diagnostic performance, enhances surgical safety by enabling preoperative characterization of biliary anatomical variants, prevents iatrogenic bile duct injury, and ultimately improves patient outcomes. Future multicenter studies with larger patient populations and intraoperative/histopathological validation are proposed to confirm these observations and establish definitive, evidence-based imaging practices for the treatment of gallstone disease.

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