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A Study of Anatomical Variations of the Pancreaticobiliary System in Magnetic Resonance Cholangiopancreatography

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ABSTRACT

Background: Magnetic Resonance Cholangiopancreatography (MRCP) is a non-invasive imaging technique widely used to evaluate biliary and pancreatic duct abnormalities, aiding in the diagnosis and management of various conditions such as choledocholithiasis, acute pancreatitis, and obstructive jaundice. This study examines the clinical and anatomical characteristics of MRCP patients, focusing on the prevalence of anatomical variations and their association with surgical complications.

Methods: A retrospective analysis of MRCP data was conducted, including demographic information, clinical indications, and anatomical variants of the biliary and pancreatic ducts. Surgical complications were also recorded and analyzed for any significant associations with anatomical variations.

Results: A total of 141 patients were included. The most common indications for MRCP were cholelithiasis (32%), acute cholecystitis (19%), and choledocholithiasis (14%). Anatomical variations in the biliary and pancreatic ducts were prevalent, with Type 1 right hepatic bile duct (HBD) variants observed in 67% of cases and Type A left HBD variants in 69%. Cystic duct variations showed that Type C was the most common (41%). In terms of treatment, 79% of patients received medical management, while 21% underwent surgery. Surgical complications were reported in 28.6% of patients, but no significant association between anatomical variants and surgical complications was found (p-values ranged from 0.5614 to 0.9826).

Discussion: The findings highlight MRCP's critical role in diagnosing and managing biliary and pancreatic diseases, offering high-resolution images that guide therapeutic decisions. Despite the prevalence of anatomical variations, no significant correlations were found between these variants and surgical complications. These results are consistent with previous studies, suggesting that while anatomical variations are important for surgical planning, they do not necessarily predict postoperative complications.

Conclusion: MRCP remains a valuable tool in the assessment of biliary and pancreatic duct anatomy, providing essential information for clinical management. Although anatomical variants are common, they do not appear to be directly associated with increased surgical complications, emphasizing the need for individualized surgical approaches.

1. INTRODUCTION

The anatomy of the pancreatic duct and biliary tree exhibits significant variability among individuals, making it essential for hepatobiliary surgeons to have a comprehensive understanding of these differences. The biliary system, responsible for bile production, storage, and transport, plays a central role in digestion and is composed of the hepatic ducts, common hepatic duct, cystic duct, and the pancreatic duct. Variations in this complex system, though often asymptomatic, can pose serious risks during surgeries such as cholecystectomy, liver resection, or bile duct exploration. Unrecognized anatomical anomalies can result in iatrogenic injuries, leading to complications like bile duct injury, bile leaks, sepsis, and prolonged recovery, underscoring the need for careful preoperative planning. (1)

One of the most effective ways to identify such variations is through advanced imaging techniques. Magnetic Resonance Cholangiopancreatography (MRCP) is a non-invasive modality with high diagnostic accuracy (90-95%) that allows for detailed visualization of the pancreaticobiliary system. Unlike other invasive methods, MRCP does not require contrast injections, anesthesia, or the risks associated with procedures like Endoscopic Retrograde Cholangiopancreatography (ERCP). As a result, MRCP has become a preferred imaging technique for assessing anatomical variants, aiding in both diagnosis and surgical planning. (2)

Anatomical variations within the biliary tree are common and have been classified in various ways. For example, Couinaud's classification divides the liver into two main lobes, with the right hepatic duct draining segments 5-8 and the left hepatic duct draining segments 1-4. These ducts join to form the common hepatic duct, which eventually leads to the common bile duct. However, variants like the "right posterior duct" draining into the left hepatic duct, or the "triple confluence" where three ducts converge, can complicate surgeries such as liver resections or bile duct explorations. The identification of these variants is critical, as they may not be apparent during routine procedures, increasing the risk of surgical complications. (3)

In addition to surgery, knowledge of biliary anatomy is essential in liver transplantation, where the complexity of biliary anatomy can influence the choice of donor and the technical approach to bile duct anastomosis. Abnormalities in ductal anatomy may require alterations in surgical techniques or even disqualify certain donors. Therefore, accurate preoperative assessment using MRCP is essential in both the surgical and transplant settings. (4)

While MRCP has been widely recognized for its ability to assess biliary anatomy, local studies on the prevalence of biliary tree anatomical variants remain limited. This study aims to address this gap by using MRCP to evaluate the prevalence of biliary tree variations in a tertiary care hospital. (5) By documenting the frequency and types of these variations, this research seeks to contribute valuable data to improve clinical practices, guide surgical decisions, and minimize complications in hepatobiliary surgeries. Understanding these anatomical differences and incorporating them into surgical planning will ultimately improve patient safety and outcomes in hepatobiliary procedures.

2. MATERIALS AND METHODS

Study Design: This was a cross-sectional study designed to examine the anatomical variants of the biliary and pancreatic ducts using Magnetic Resonance Cholangiopancreatography (MRCP).

Study Area: The study was conducted in the Department of Radiodiagnosis at Sree Balaji Medical College and Hospital, Chennai – 600044.

Study Population: The study included patients referred to the Radiodiagnosis Department for MRCP due to suspected pancreaticobiliary disease or for preoperative liver transplantation evaluation.

Study Period: The study was conducted from March 2021 to June 2024.

Inclusion Criteria:

- All consecutive patients undergoing MRCP during the study period.
- All patients referred for MRCP due to suspected pancreaticobiliary disease or for liver transplantation evaluation.
- Patients who provided informed consent to participate in the study.

Exclusion Criteria:

- Patients for whom MRI is contraindicated (e.g., patients with pacemakers, metallic implants, or claustrophobia).
- Patients who refused to participate in the study.

Sample Size: The sample size was calculated using the formula:

n=Z2×P×Qd2n = \frac{Z^2 \times P \times Q}{d^2}n=d2Z2×P×Q

Where:

- P = 56.65% (estimated prevalence of biliary duct and pancreatic duct variants)

- Q = 43.35% (1 - P)
- Z = 1.96 (z-value for 95% confidence)
- d = 5% (desired margin of error)

Using this formula, the calculated sample size was approximately 94.34, rounded to 100 participants. Therefore, 100 patients who underwent MRCP during the study period were included in the study.

Data for this study were collected from participants referred to the Department of Radiodiagnosis with clinical symptoms such as abdominal pain and deranged liver function tests (LFTs). After a detailed explanation of the study's purpose and procedures, participants were informed of their right to decline participation, and written informed consent was obtained. Clinical presentation and demographic details were recorded using a structured proforma. MRCP was performed on all participants using a 3.0 Tesla G.E MRI scanner, a non-invasive imaging technique that utilizes T2-weighted magnetic resonance imaging to assess the anatomy of the pancreaticobiliary system, including intra- and extrahepatic biliary channels, without the need for contrast material. Following MRCP, any anatomical variants in the biliary and pancreatic ducts were documented. The data were entered into an Excel sheet and analyzed using SPSS version 19, with descriptive statistics (mean, standard deviation, and proportions) computed for quantitative and categorical variables. The Chi-square test was used to test hypotheses, and a p-value of less than 0.05 was considered statistically significant. Findings were summarized in tables and graphs to present the prevalence and types of anatomical variations observed.

3. RESULT

Table 1: Demographic and Clinical Characteristics of MRCP Patients

Category	Subcategory	Percentage (%)
Age Groups	18-30 years	8
	31-40 years	14
	41-50 years	33
	51-60 years	27
	>60 years	18
Gender	Male	59
	Female	41
Body Mass Index (BMI)	Normal	41
	Overweight	35
	Obese	2

Table 2: Distribution of Clinical and Anatomical Characteristics of MRCP Patients

Indications for MRCP	Cholelithiasis	32
	Obstructive jaundice	12
	Choledocholithiasis	14
	Acute cholecystitis	19
	Acute pancreatitis	13

	Liver mass	9
	Klatskin tumor	1
Right HBD Anatomical Variants	Type 1	67
	Type 2	10
	Type 3	15
	Type 4	7
	Type 5	1
Left HBD Anatomical Variants	Type A	69
	Type B	6
	Type C	22
	Type D	3
Cystic Duct Anatomical Variants	Type A	19
	Type B	35
	Type C	41
	Type D	4
	Type E	1
Pancreatic Duct Anatomical Variants	Type 1	43
	Type 2	13
	Type 3	44
Treatment Modalities	Surgical	21
	Medical	79
Surgical Complications	Present	28.6
	Absent	71.4

Table 3: Association with Surgical Complications and Anatomical Variants

Anatomical Variation	**Surgical Complications (Present)**	**p-value**
Right HBD Anatomical Variants		
Type 1	3	0.9093
Type 2	1	

Anatomical Variation	Surgical Complications (Present)	p-value
Type 3	1	
Type 4	1	
Left HBD Anatomical Variants		
Type A	4	0.5614
Type B	0	
Type C	2	
Type D	0	
Cystic Duct Anatomical Variants		
Type A	1	0.9826
Type B	2	
Type C	3	
Pancreatic Duct Anatomical Variants		
Type 1	3	0.9162
Type 2	1	
Type 3	2	

4. DISCUSSION

Magnetic Resonance Cholangiopancreatography (MRCP) has become an essential non-invasive imaging modality for evaluating the biliary and pancreatic ducts, particularly in diagnosing conditions such as choledocholithiasis, pancreatic disorders, and biliary strictures. Studies like Beyer et al. (2023) [6] have highlighted age-dependent variations in the diameters of the common bile duct (CBD) and pancreatic duct (PD), noting that both ducts tend to increase in size with age, which is crucial for clinicians to differentiate between normal anatomical changes and pathological conditions like choledocholithiasis or cholangiocarcinoma.

Additionally, Anand et al. (2016) [7] have emphasized MRCP's role in risk stratification for patients with high suspicion of choledocholithiasis, enabling more targeted management and reducing unnecessary invasive procedures like Endoscopic Retrograde Cholangiopancreatography (ERCP). These findings underscore MRCP's significance in diagnosing, planning treatment, and monitoring patients with biliary and pancreatic diseases, providing high-resolution images without the need for invasive contrast agents

The distribution of clinical and anatomical characteristics of patients undergoing Magnetic Resonance Cholangiopancreatography (MRCP) reveals important insights into the role of MRCP in diagnosing and managing biliary and pancreatic disorders, in line with findings from several key studies. The most common indications for MRCP in this cohort were cholelithiasis (32%), acute cholecystitis (19%), and choledocholithiasis (14%), which align with findings from Fernandez et al. (1999), [8] who noted the significant role of MRCP in the diagnosis of biliary tract diseases such as cholelithiasis and choledocholithiasis, emphasizing its non-invasive capabilities.

Similarly, Bobek-Billewicz et al. (2002) [9] highlighted the utility of MRCP in evaluating obstructive jaundice, a condition also prevalent in this study (12%), showing MRCP's importance in detecting bile duct obstructions and abnormalities. Acute pancreatitis (13%) and liver masses (9%) were also noted as indications for MRCP, consistent with Bülow et al. (2014), [10] who pointed out MRCP's role in identifying pancreatic duct abnormalities and masses, including those associated with pancreatic pathologies.

The study also explored anatomical variations in the biliary and pancreatic ducts, which were notably diverse. The right hepatic bile duct (HBD) exhibited Type 1 anatomical variants in 67% of cases, with Type A left HBD variants being the most common (69%), reflecting Uysal et al. (2014) [11] and Nayman et al. (2016) [12] , who described similar findings regarding the anatomical variations of the bile ducts. Uysal et al. (2014) specifically noted the prevalence of Type 1 variants in the right HBD, while Nayman et al. (2016) [12] updated classifications of intrahepatic bile duct variations that have clinical significance, supporting the findings of this study.

Cystic duct variations were also prevalent, with Type C being the most common (41%), followed by Types B (35%) and A (19%), which corroborates findings from Sarawagi et al. (2016) [13], who explored the anatomical diversity of the cystic duct and its implications in clinical practice. Pancreatic duct variations were also reported, with Types 1 (43%) and 3 (44%) being the most common, consistent with Bülow et al. (2014) [10], who explored variations in pancreatic duct anatomy and their clinical relevance, further supporting MRCP's role in accurate diagnosis and treatment planning for such conditions.

In terms of treatment modalities, most patients (79%) were managed medically, while 21% required surgical interventions. This distribution is like findings by Bobek-Billewicz et al. (2002) [9], who also observed a high rate of medical management in patients with biliary disorders. However, surgical complications were present in 28.6% of cases in the current study, underscoring the complexity of surgical interventions in patients with anatomical variants or complex biliary/pancreatic conditions, an observation consistent with the studies of Fernandez et al. (1999) [8] and Sarawagi et al. (2016), [13] who also noted the potential for complications when managing complex biliary duct conditions surgically.

Our study on anatomical variations in the biliary and pancreatic ducts provides valuable insights into the prevalence of these variants and their association with surgical complications. For instance, your findings on the right hepatic bile duct (HBD) variants showed that Type 1 was the most common (67%), followed by Types 2, 3, and 4, with a surgical complication rate of 0.9093. However, no significant association between these variants and surgical complications was observed. This aligns with findings from Adatepe et al. (2016), [14] who explored various right HBD variants using MRCP and noted their prevalence but did not specifically report complication rates correlated with the variants. Similarly, Sherifi et al. (2018) [15] discussed the potential influence of right HBD anatomical variations on surgical outcomes but did not provide detailed complication statistics. They focused on the importance of recognizing these variants for surgical planning.

Regarding the left hepatic bile duct (HBD) variants, Type A was the most common (69%) in your study, and the p-value for surgical complications was 0.5614, suggesting no significant association. Sherifi et al. (2018) [15] similarly identified several left HBD variants and discussed their clinical relevance in pre-surgical evaluations, although they did not directly link these variants to surgical complications. Adibelli et al. (2017) [16] also examined left HBD variations, especially in liver resections, but their study was more focused on categorizing the variants rather than correlating them with complications.

In terms of cystic duct anatomical variants, Type C was the most common (41%) in your study, followed by Types B (35%) and A (19%), with a p-value of 0.9826, indicating no significant link to surgical complications. These findings are consistent with Sarawagi et al. (2016), [13] who found Type C to be the most prevalent cystic duct variant and noted its relevance in bile duct exploration surgeries, although, like your study, they did not establish a direct correlation with surgical complications. Sherifi et al. (2018) [15] also recognized the importance of understanding cystic duct variations for accurate surgical planning and reported a high prevalence of Type C variants, supporting your observations.

Our study also found that Types 1 and 3 were the most common pancreatic duct variants (43% and 44%, respectively), but with no significant correlation to surgical complications (p-value 0.9162). This is in line with Ishaque et al. (2020), [18] who highlighted the role of pancreatic duct variations, particularly Type 3, in pancreatitis and surgical complications, although they found that these variants did not always correlate directly with complications. Prasad et al. (2019) [19] also identified a high prevalence of Types 1 and 3 pancreatic duct variants, yet they did not establish a direct link to surgical complications, reflecting a similar conclusion to your study.

In general, the findings from your study align with those from Adibelli et al. (2016) [20] and Prasad et al. (2019) [19] , who emphasized the clinical significance of identifying anatomical variations in the biliary and pancreatic duct systems. Both studies noted the importance of these variants for surgical procedures but did not specifically correlate them with higher complication rates.

5. CONCLUSION

This study emphasizes the importance of MRCP in evaluating anatomical variations of the biliary and pancreatic ducts. With its high diagnostic accuracy and non-invasive nature, MRCP is a valuable tool in diagnosing and managing patients with biliary and pancreatic diseases. The findings of this study support the existing literature on the prevalence and clinical significance of anatomical variations, further validating the role of MRCP in surgical planning and patient management. Further research is warranted to explore the long-term outcomes of MRCP-guided surgical interventions and to determine the impact of these anatomical variants on surgical success rates.

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