CLINICAL RELEVANCE OF MORPHOMETRIC ANALYSIS OF THE BILIARY SYSTEM IN THE SOUTH INDIAN POPULATION USING MRCP

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Abstract

Introduction: This study investigates into the importance of understanding anatomical variations in the extrahepatic biliary system, crucial for comprehending associated pathological conditions and surgical interventions. Despite being overlooked in medical education and practice, recent advancements in imaging technologies and anatomy studies have enhanced our knowledge of these variations. **Aim and Objectives:** The principal aim is to assess the anatomical variations of the extrahepatic biliary system. The objectives are to evaluate the morphological characteristics, variations and determine the extrahepatic biliary system using Magnetic Resonance Cholangiopancreatography (MRCP). **Methods:** A retrospective investigation was conducted at Saveetha Medical College and Hospital, focusing on individuals with biliary tree variations causing obstruction. MRCP images of 115 patients were reviewed, with specific inclusion and exclusion criteria established. **Results:** Among 100 patients meeting the criteria, 38 exhibited anatomical variants in the extrahepatic bile tract, predominantly a looped entry of the cystic duct. The study highlights the value of MRCP in visualizing biliary anomalies and the most frequent variations observed. **Conclusions:** Anatomical anomalies within the extrahepatic biliary system, often underrepresented, were prevalent in this study. The research emphasizes the significance of understanding these variations for improved diagnostic accuracy and emphasizes MRCP's role in identifying biliary system anomalies. Overall, this study contributes to a more comprehensive understanding of extrahepatic biliary system anomalies and their diagnosis using MRCP.

Keywords: Anatomical Variations, Extrahepatic Biliary System, Magnetic Resonance Cholangiopancreatography and Medical Imaging.

INTRODUCTION

Understanding the typical variations in the anatomical structure of the extrahepatic biliary system is crucial for gaining insights into its pathological conditions and the associated surgical interventions. Paradoxically, despite their critical relevance for accurate diagnosis and effective treatment, these anatomical variations are often neglected in the educational framework of medical schools and clinical practice. However, recent advances in imaging technologies and a renewed interest in the study of anatomical variations through hands-on dissection in gross anatomy laboratories have led to a more comprehensive understanding of the diversity within the extrahepatic biliary system [1].

Anomalies in the extrahepatic biliary system include deviations such as unusual or supplementary biliary ducts or cystic ducts, as well as changes in the biliary tract, with or without situs inversus [2]. Understanding the developmental processes involved is invaluable for detecting these anomalies. The biliary tree originates from the hepatic diverticulum located at the midpoint of the second segment of the duodenum.

This structure eventually gives rise to the gallbladder and the extrahepatic ductal system, including the hepatic parenchyma [3].

Recent enhancements in Magnetic Resonance Cholangiopancreatography (MRCP) technology have significantly improved image quality, thereby increasing the detection of anomalies in the extrahepatic biliary system. Approximately 15% of individuals with cholelithiasis also suffer from choledocholithiasis [4]. In such cases, variations in the biliary system structure may be the underlying cause. Therefore, a comprehensive understanding of these anomalies is essential for enhancing diagnostic accuracy.

The principal aim of this research is to assess the morphological characteristics of the biliary system, determine the prevalence of anatomical deviations, and identify congenital abnormalities within the extrahepatic biliary system as observed through MRCP imaging.

MATERIALS AND METHODS

This retrospective investigation examines the diagnostic efficacy of Magnetic Resonance Cholangiopancreatography (MRCP) in individuals presenting with biliary tree variations leading to biliary obstruction. The study was conducted at the Department of Radiology and Medical Imaging within the esteemed Saveetha Medical College and Hospital, a recognized center for advanced medical care and research located in Chennai. Ethical clearance was obtained from the Institutional Review Board (IRB) before the commencement of this research endeavor. The study scrutinized the medical records of patients experiencing biliary tree variations resulting in biliary obstruction over a one-year period spanning from October 2022 to September 2023. A total of 115 MRCPs were acquired from the medical information system of our institution. However, the medical records of 15 patients were excluded due to inadequate image quality. Subsequently, two radiologists conducted a retrospective review of the remaining images. The inclusion criteria encompassed individuals aged 18 years and older, as well as patients exhibiting indications suggestive of biliary obstruction with documented biliary tree variations. Additionally, eligible participants included those who had undergone MRCP imaging as part of their diagnostic evaluation and who possessed accessible medical records and imaging data within the study period.

Conversely, the exclusion criteria entailed excluding patients with contraindications to MRCP imaging, such as severe claustrophobia, the presence of metal implants incompatible with MRI, or known allergic reactions to contrast agents. Additionally, patients with biliary obstruction arising from causes other than biliary tree variations, such as neoplastic lesions, gallstones, or infectious origins, were not considered eligible. Furthermore, individuals with a history of prior surgical interventions that significantly altered the anatomy of the biliary system were also excluded from the study. Magnetic Resonance Pancreatography (MRCP) has emerged as the preeminent imaging technique for evaluating the biliary tree. It excels at providing precise visualization of ductal enlargements, constrictions, and abnormalities within the ductal passages. The assessment of both the extrahepatic and intrahepatic bile ducts was carried out using a 1.5 Tesla Philips Multiva System during MRCP. The MRCP images were scrutinized to identify any variations in the bile ducts and anomalies in the gallbladder. The data were analyzed using descriptive analysis in Microsoft Excel, 2023.

RESULTS

Out of 100 patients undergoing MRCP, 58 were females and 42 were males. The measurements were as follows: for the right hepatic duct, we found the caliber ranged between 1.6-7.4 mm in males and 1.7-12 mm in females, with an overall range of 1.6-12 mm. The length of the right hepatic duct was between 6.9-30.4 mm in males and 4.0-24.2 mm in females, with an overall range of 4.0-30.4 mm.

For the left hepatic duct, the caliber ranged from 2.1-10.3 mm in males and 1.3-12 mm in females, with an overall range of 1.3-12 mm. The length of the left hepatic duct was 8.1-26.3 mm in males and 4.3-28 mm in females, with an overall range of 4.3-28 mm. At the confluence of the two hepatic ducts to form the common hepatic duct, the angle in males was found to be between 48.0-139.0 degrees, while in females, it was between 31.0-110.0 degrees, with an overall range of 31.0-139.0 degrees (Figure 1).

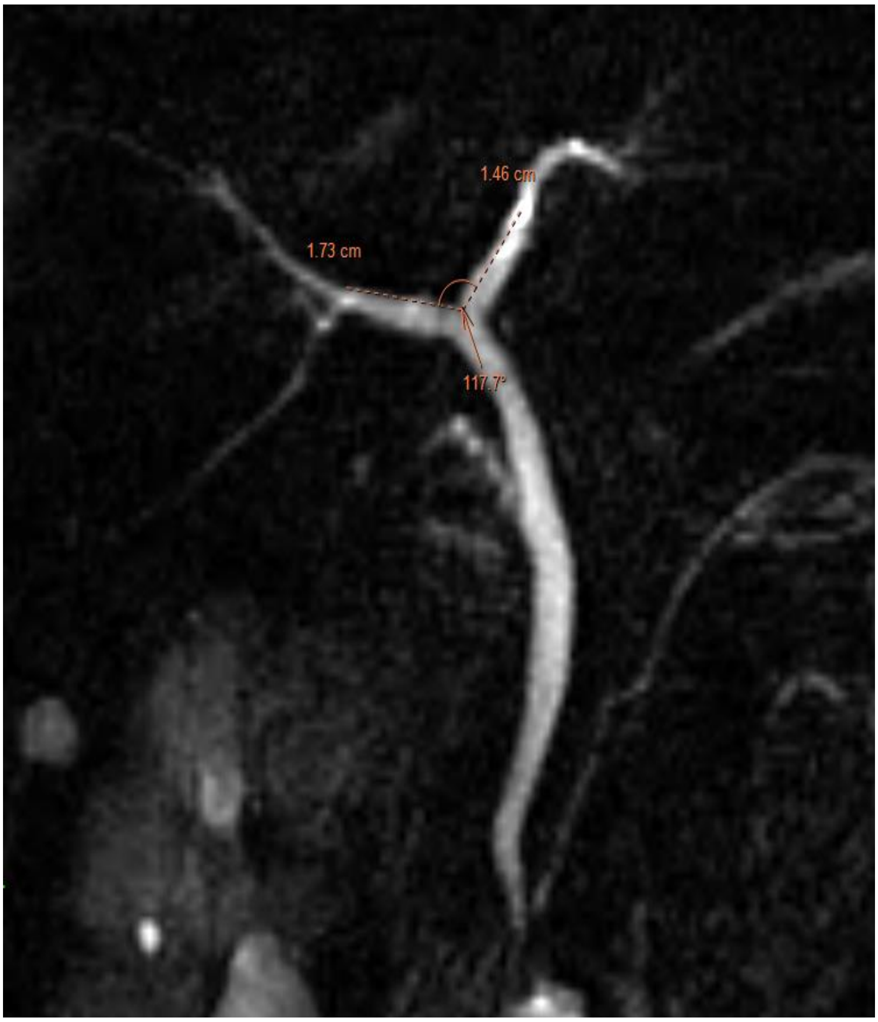

Figure 1: Maximum Intensity Projection (MIP) Image – MRCP of a 37 Year old Male, Demostrating an Inter Hepatic Angle of 117.7 Degrees

For the common hepatic duct, we found a caliber of 2.8-17 mm, with males having a caliber of 2.8-13 mm and females 3.1-17 mm. The length of the common hepatic duct ranged from 6.8-42.0 mm, with males at 6.8-38.4 mm and females at 9.6-42.0 mm. Detailed morphometric values are presented in Table 1 and illustrated in Figure 2.

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Table 1: Measurements of Biliary Tree

		Mean(mm)	SD	Range (mm)
Right hepatic duct (caliber)	Male	4.2	1.68	1.6-7.4
	Female	4.14	2.54	1.7-12
Right hepatic duct (length)	Male	14.52	6.68	6.9-30.4
	Female	12.94	5.51	4-24.2
Left hepatic duct (caliber)	Male	4.78	2.15	2.1-10.3
	Female	4.33	2.68	1.3-12
Left hepatic duct (length)	Male	15.7	4.81	8.1- 26.3
	Female	13.56	5.2	4.3-28
Common hepatic duct (caliber)	Male	6.71	3.06	2.8- 13
	Female	6.41	3.74	3.1-17
Common hepatic duct (length)	Male	21.96	7.87	6.8-38.4
	Female	19.49	8.06	9.6-42
Cystic duct diameter	Male	4.11	2.5	1.7-9.7
	Female	5.51	4.05	2-19
Common bile duct (calibre)	Male	6.52	4.8	3.1-20.7
	Female	8.25	5.15	2.5-23

This table presents the mean, standard deviation (SD), and range (in mm) of the caliber and length of the right hepatic duct, left hepatic duct, and common hepatic duct for both male and female patients. It also includes the measurements for the cystic duct diameter and common bile duct caliber.

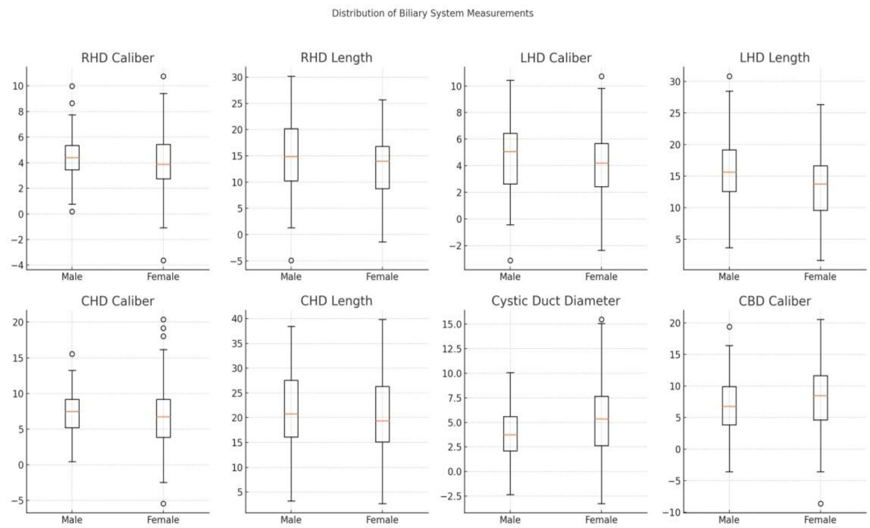

Figure 2: Box Plots Comparing the Distribution of Biliary System Measurements between Male and Female Patients

The plots show the right hepatic duct (RHD) caliber and length, left hepatic duct (LHD) caliber and length, common hepatic duct (CHD) caliber and length, cystic duct diameter, and common bile duct (CBD) caliber. Each box represents the interquartile range, the central line indicates the median, and whiskers extend to 1.5 times the interquartile range. Outliers are shown as circles.

The cystic duct caliber ranged from 1.7-19.0 mm, with males at 1.7-9.7 mm and females at 2.0-19 mm. We could not assess the length of the cystic duct due to variations in its insertion.

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The angle formed at the end of the cystic duct in the common hepatic duct (Hepato-cystic angle) ranged from 20-141 degrees. In males, the angle was between 20-104 degrees, and in females, it was between 20-141 degrees. Between the cystic duct and the common bile duct (cystic choledochal angle), we found an angle between 76-160 degrees. In males, the value was 76-160 degrees, and in females, it was 86-156 degrees.

Regarding the insertion of the cystic duct, the majority were right lateral insertions (Figure 3).

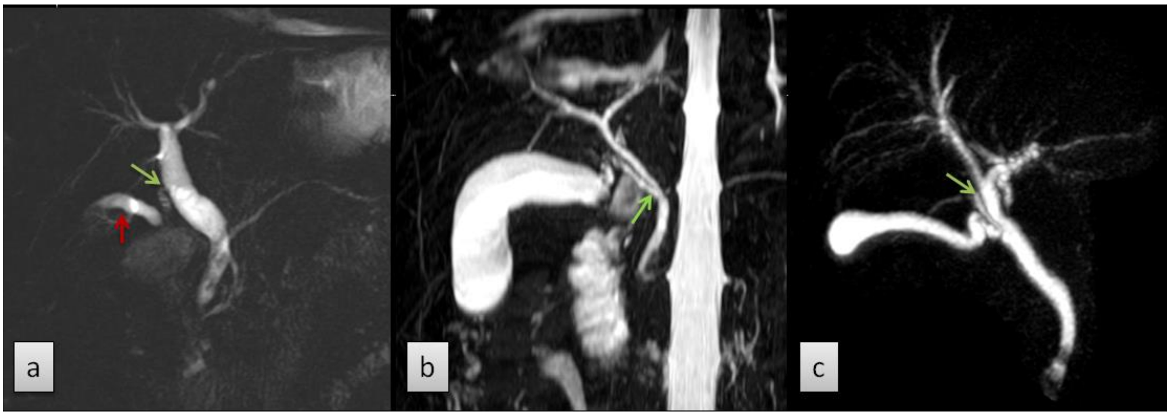

Figure 3: Maximum Intensity Projection (MIP) MRCP Images of 3 Different Patients Depicting the Various Lateral Insertions of the Cystic Duct

(a) a 32 year old male showcasing multiple calculi in the gall bladder (red arrows) and mid lateral insertion of the cystic duct (green arrows), (b) a 38 year old female showing low lateral insertion and (c) a 41 year old male, showing chronic contracted gall bladder with high lateral insertion of the cystic duct (green arrows)

The variations recorded in our study included posterior insertion and spiral insertion (Figure 4,5). For the common bile duct, we found a caliber of 2.5-23 mm. In males, the caliber was between 3.1-20.7 mm, and in females, it was between 2.5-23 mm.

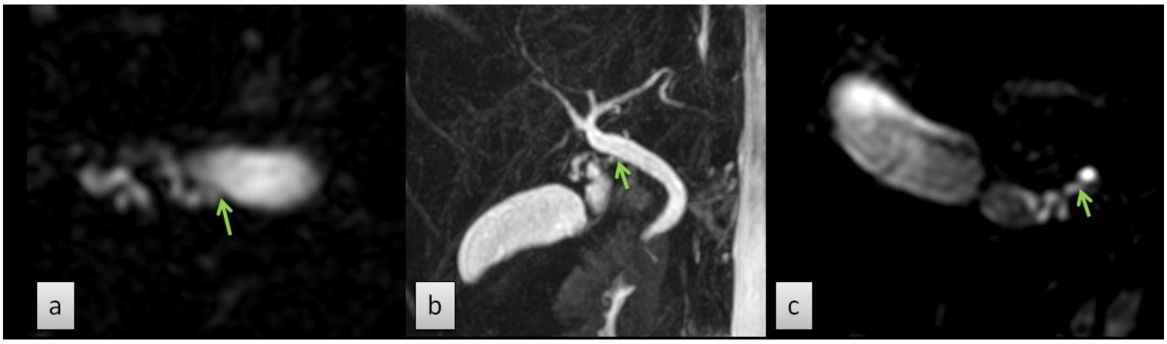

Figure 4: Heavily Weighted T2 MRCP Images Detail the Cystic Duct's Anatomy

Images (a) and (b) from a 41-year-old male show an axial section with posterior spiral insertion and a coronal MIP revealing the spiral course and mid-posterior insertion. Image (c) from a 33-year-old female shows a posterior insertion. These images are crucial for accurate diagnosis and surgical planning, providing insights into anatomical variations of the cystic duct.

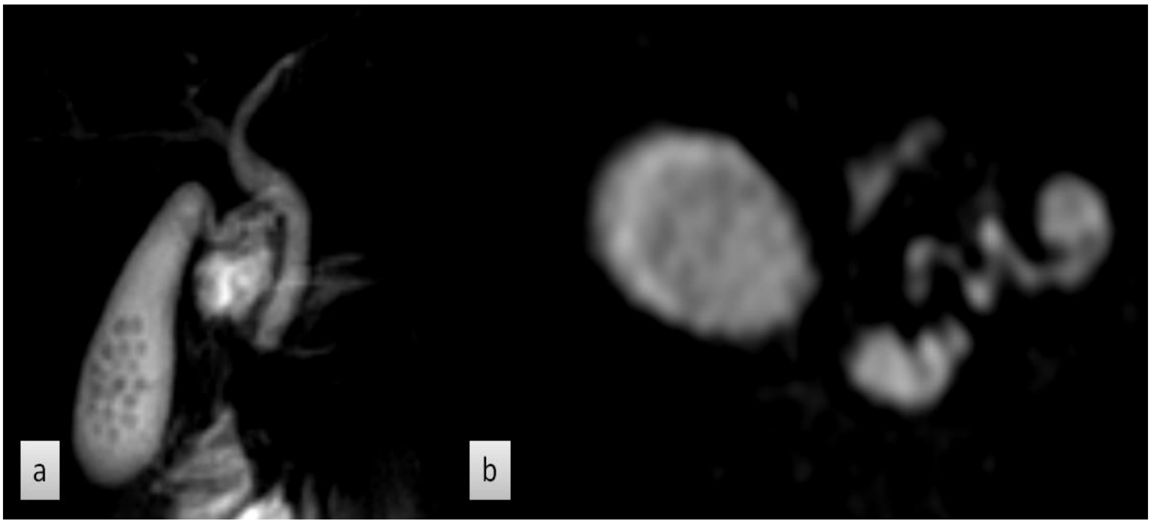

Figure 5: MRCP Images of a 37 Year Old Male

Maximum Intensity Projection (MIP) image (a) showing multiple calculi within the gallbladder and on close scrutiny, axial section (b) revealed a posterior insertion of cystic duct

DISCUSSION

The prevalence of gallstone disease within the general population ranges from approximately 6% to 15%, with a higher occurrence among females [5, 6]. Merely 2% to 4% of individuals diagnosed with gallstones experience symptoms like biliary colic (pain), acute cholecystitis (inflammation), obstructive jaundice, or gallstone pancreatitis within a year [7,8]. Notably, the recommended course of action for individuals with symptomatic gallstones involves the removal of the gallbladder [9]. In patients undergoing laparoscopic cholecystectomy for symptomatic gallstones, between 3% and 22% simultaneously exhibit common bile duct stones [10 – 11].

Limited studies address the disparities in the prevalence and types of biliary abnormalities across different regions, ethnicities, or demographic features. Renard noted that the modal disposition of extrahepatic ducts is present in only 35% of cases [13]. Anatomical variations within the branching of the biliary tree most commonly involve the branching of the cystic duct, the upper biliary confluence, and the right posterior duct merging with the right anterior or left hepatic duct [14]. In our investigation, out of 100 patients, 38 exhibited anatomical variants within the extra-hepatic bile tract. The most frequent observed variation was a looped entry of the cystic duct.

Variations in the cystic duct are notably common and hold considerable importance in the context of cholecystectomy. The conventional depiction found in textbooks, describing an angular lateral junction with the common bile duct (CBD), is evident in only 17% of cases. The trajectory and manner in which the cystic duct enters the common hepatic duct (CHD) exhibit remarkable variability.

The point of junction is determined by the separation process between the pars hepatica and pars cystica. Malrotations of the cystic duct occur due to erroneous relocation of the choledocho-duodenal junction during the duodenum's rotation. During its formation, the duct may twist either clockwise or anticlockwise, resulting in the cystic duct adopting a spiral course, positioned either in front of or behind the CHD

[15, 16]. Variations result from anomalies in embryological development. The liver, gallbladder, and biliary tree originate as a ventral bud (hepatic diverticulum) from the caudal part of the foregut in the early fourth week of gestation.

This outgrowth extends into the septum transversum, dividing into two components within the ventral mesentery's layers: the larger cranial part (pars hepatica), forming the liver, and the smaller caudal part (pars cystica), which develops into the gallbladder, with its stalk transforming into the cystic duct.

The pars cystica elongates, establishing the gallbladder, cystic duct, and common bile duct (ductus choledochus). During the initial 8 weeks of gestation, the extra-hepatic biliary tree further develops through the extension of the caudal part of the hepatic diverticulum. Initially, the pars cystica of the hepatic diverticulum emerges from the anterior aspect of the future duodenum. By the fifth week, the duodenum undergoes a rotation to the right, relocating the attachment of the developing common bile duct to its definitive position on the dorsal aspect of the duodenum. The hepatic duct (ductus hepaticus) derives from the cranial part (pars hepatica) of the hepatic diverticulum [17].

In a 34-day embryo, the common hepatic duct presents as a wide, funnel-shaped structure directly connected to the evolving liver, without distinct left or right hepatic ducts. The distal segments of the right and left hepatic ducts form from the extrahepatic ducts and exhibit well-defined tubular structures by the 12th week of gestation.

The initial portions of the primary hilar ducts arise from the first intra-hepatic ductal plates. The term "ductal plate" refers to the layer of cells encircling the portal vein branches resembling a cylindrical sleeve [18]. From the very inception of organogenesis and throughout further development, there is a continuous lumen in the extra-hepatic bile ducts and the maturing intra-hepatic biliary tree.

The strengths of this study are that MRCP is a non-invasive and highly effective imaging modality for studying biliary structures, thus contributing to the credibility of the findings. The study emphasizes the clinical implications of morphometric analysis and biliary system variations. This indicates the potential direct applicability of the findings to medical practice and patient care. The limitations of this study are that the sample size is small and not representative of diverse demographics, and the generalizability of the results could be limited. This is an initial study, further confirmation through replication or expansion of the research may be necessary to solidify the findings and confirm their consistency.

CONCLUSION

Understanding the complexities of anatomical variations within the extrahepatic biliary system is pivotal for diagnosing pathologies and guiding surgical interventions. Despite being historically overlooked in medical education, recent advancements in imaging technologies, specifically Magnetic Resonance Cholangiopancreatography (MRCP), have significantly improved the detection of biliary anomalies.

The findings underscore MRCP's efficacy in visualizing intricate biliary structures and reveal the prevalence of anatomical variations, particularly noting the common occurrence of cystic duct anomalies. This research reinforces the importance of understanding biliary system anomalies for accurate diagnostics and emphasizes MRCP's role in identifying and characterizing these variations.

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