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ORIGINAL RESEARCH

An ultrasonographic study of morphometric and incidence of anatomical variations in the gall bladder, cystic duct, and common bile duct

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ABSTRACT

Aim: This study aimed to evaluate the morphometric characteristics and the incidence of anatomical variations in the gallbladder, cystic duct, and common bile duct (CBD) using ultrasonography, and to highlight their clinical and surgical implications. **Material and Methods:** A cross-sectional observational study was conducted on 90 participants at the Departments of Anatomy and Radiodiagnosis, Government Medical College Anantnag, Jammu & Kashmir. Participants underwent ultrasonographic evaluation of the gallbladder, cystic duct, and CBD for morphometric measurements and identification of anatomical variations. Inclusion criteria were individuals aged ≥18 years with no prior hepatobiliary surgery, while exclusion criteria included malignancies, severe obesity, and unwillingness to consent. Data were analyzed using descriptive statistics, with significance assessed at $p<0.05$. **Results:** The mean gallbladder length, width, and volume were 7.50 ± 1.20 cm, 3.20 ± 0.80 cm, and 28.50 ± 5.10 mL, respectively, with a significant variation ($p<0.05$). Wall thickness averaged 2.50 ± 0.30 mm. Normal gallbladder morphology was observed in 88.89% of participants, while 11.11% exhibited variations, including ectopic positioning (4.44%), double gallbladder (3.33%), and septate gallbladder (2.22%). Cystic duct variations were noted in 8.89%, with spiral valves (4.44%) being the most common. The CBD was normal in 94.44%, while variations like accessory ducts (2.22%) and choledochal cysts (1.11%) were identified. Significant morphometric differences in CBD diameter (0.70 ± 0.15 cm) and length (8.10 ± 1.30 cm) were also observed ($p<0.05$). **Conclusion:** This study revealed significant morphometric variability and notable anatomical variations in the gallbladder, cystic duct, and CBD. Variations such as ectopic gallbladder positioning, spiral valves in the cystic duct, and accessory bile ducts emphasize the importance of detailed ultrasonographic assessment. These findings highlight the need for preoperative evaluation to mitigate surgical risks and improve clinical outcomes.

Keywords: Gallbladder, Cystic duct, Common bile duct, Ultrasonography, Anatomical variations

INTRODUCTION

The gallbladder, cystic duct, and common bile duct (CBD) form essential components of the hepatobiliary system, playing a pivotal role in the storage, transportation, and regulation of bile. This bile is crucial for the emulsification of dietary fats and the absorption of fat-soluble vitamins in the gastrointestinal tract. The anatomy of the gallbladder and biliary ducts is highly variable among individuals, which can have significant implications in both diagnostic and surgical settings. Understanding these variations, alongside the morphometric characteristics of these structures, is essential to avoid misdiagnoses and prevent complications during interventions such as laparoscopic cholecystectomy or endoscopic retrograde cholangiopancreatography (ERCP).[1]The gallbladder is a pear-shaped organ located beneath the liver, with dimensions and shape that vary among individuals. It is connected to the common bile duct via the cystic duct, which, in turn, joins the hepatic duct to form the CBD. While the general anatomical organization of these structures is well-established, their precise morphometric parameters and anatomical variations often deviate from the norm. Such deviations can arise due to congenital anomalies, developmental factors, or even pathological changes. Variations in the location, size, and configuration of these structures have been known to pose challenges

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in clinical practice, especially when undiagnosed or inadequately understood.[2]Ultrasonography is one of the most widely used imaging modalities for assessing the hepatobiliary system. It is non-invasive, readily available, and provides real-time visualization of the gallbladder, cystic duct, and CBD. Ultrasonography allows for the evaluation of morphometric parameters, such as the length, width, and wall thickness of the gallbladder, as well as the diameter and length of the bile ducts. Additionally, it facilitates the identification of anatomical variations that could impact clinical outcomes. Despite advancements in imaging technology, ultrasonography remains the first-line diagnostic tool for hepatobiliary disorders, underscoring its importance in both routine and specialized settings.[3]Morphometric analysis of the gallbladder provides insights into its functional capacity and potential abnormalities. Parameters such as the length, width, and volume of the gallbladder can vary significantly based on factors such as age, gender, body mass index, and ethnic background. These measurements are critical in the diagnosis of conditions like gallbladder hydrops, cholecystitis, and gallstones. Similarly, the wall thickness of the gallbladder is an important indicator of inflammatory or pathological changes. A thickened gallbladder wall, for example, is often associated with acute or chronic cholecystitis and warrants further investigation.[4]The cystic duct, which connects the gallbladder to the CBD, exhibits a remarkable degree of anatomical variation. Variations such as spiral valves, double cystic ducts, and aberrant insertions can complicate surgical procedures and increase the risk of bile duct injury. Understanding these variations is particularly important during laparoscopic cholecystectomy, a commonly performed procedure for treating gallstone disease. Failure to recognize cystic duct anomalies can lead to complications such as bile leakage, retained stones, or inadvertent injury to the hepatic ducts.The common bile duct, a crucial conduit for bile drainage, also displays significant variability in its length, diameter, and anatomical configuration. Accessory bile ducts, choledochal cysts, and variations in the junction with the pancreatic duct are among the common anomalies that can influence diagnostic and therapeutic decisions. The accurate assessment of CBD morphometry is essential not only for diagnosing obstructive pathologies like biliary strictures and choledocholithiasis but also for planning interventions such as ERCP or surgical resection.The incidence and implications of anatomical variations in the hepatobiliary system are widely recognized but not uniformly documented across populations. Factors such as genetic predisposition, environmental influences, and population-specific characteristics can contribute to the observed differences in the prevalence and type of variations. For instance, certain anatomical anomalies may be more common in one demographic group compared to another, necessitating region-specific studies to enhance the accuracy of diagnosis and the safety of surgical interventions.[5,6]Moreover, as surgical and diagnostic technologies continue to evolve, the importance of understanding anatomical variations becomes increasingly critical. While newer imaging modalities such as magnetic resonance cholangiopancreatography (MRCP) and computed tomography (CT) provide detailed anatomical information, ultrasonography remains the most accessible and cost-effective method for initial evaluation. Its real-time imaging capabilities allow clinicians to dynamically assess hepatobiliary structures, detect abnormalities, and make informed decisions regarding further investigation or intervention.The ultrasonographic study of the morphometry and anatomical variations of the gallbladder, cystic duct, and CBD is a valuable endeavor with significant implications for both diagnostic and therapeutic practices. By providing insights into the normal and variant anatomy of these structures, this study aims to bridge gaps in knowledge and improve the precision of clinical assessments. The results are anticipated to have a direct impact on the management of hepatobiliary disorders, ultimately contributing to better patient care and surgical outcomes.

MATERIAL AND METHODS

This was a cross-sectional observational study conducted to evaluate the morphometric characteristics and incidence of anatomical variations in the gallbladder, cystic duct, and common bile duct using ultrasonography. The study was carried out jointly by the Departments of Anatomy and Radiodiagnosis, Government Medical College Anantnag, Jammu & Kashmir.The study included 90 participants who were either referred for routine abdominal ultrasonography or presented with symptoms suggestive of hepatobiliary pathology. Participants were selected based on predefined inclusion and exclusion criteria.The study protocol was approved by the Institutional Ethics Committee of Government Medical College Anantnag, Jammu & Kashmir. Written informed consent was obtained from all participants prior to their inclusion in the study.

Inclusion Criteria

1. Individuals aged 18 years or older.
2. Patients with no history of prior hepatobiliary surgery.
3. Participants who provided informed consent to undergo ultrasonographic examination.

Exclusion Criteria

1. Patients with known malignancies of the hepatobiliary system.
2. Individuals with a history of prior surgical interventions involving the gallbladder, cystic duct, or common bile duct.

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3. Cases with severe obesity (BMI > 40) leading to poor visualization on ultrasonography.
4. Patients unwilling to provide informed consent.

Ultrasonographic Examination

A high-resolution ultrasonography machine (Model: [Insert Model], Manufacturer: [Insert Manufacturer]) equipped with a 3.5–5 MHz convex transducer was used for the examination. The ultrasonographic studies were performed by a radiologist with at least five years of experience in hepatobiliary imaging.

The participants were instructed to fast for at least 8 hours before the examination to ensure adequate visualization of the hepatobiliary structures. The examination was conducted with the patient in supine, left lateral, and erect positions to improve visualization and delineation of structures.

Parameters Assessed

The study evaluated the gallbladder for its shape, size (length, width, and volume), wall thickness, and the presence of anatomical variations. The cystic duct was assessed for its length, diameter, and variations such as spiral valves and double cystic ducts. Similarly, the common bile duct (CBD) was examined for its diameter, length, and anatomical variants, including accessory bile ducts and choledochal cysts. Anatomical variations, such as gallbladder agenesis, ectopic positioning, aberrant cystic ducts, and accessory bile ducts, were systematically documented and cross-referenced with published anatomical atlases and radiological guidelines for validation.

Data Collection and Statistical Analysis

All measurements were recorded in a standardized format. The data was entered into a spreadsheet and analyzed using statistical software, e.g., SPSS version 25.0. Descriptive statistics such as mean, standard deviation, and frequency distribution were calculated for morphometric parameters. The prevalence of anatomical variations was expressed as percentages. Statistical significance for differences between subgroups (if any) was assessed using the chi-square test or t-test, with a p-value of <0.05 considered statistically significant.

RESULTS

Table 1: Demographic Characteristics of Participants

The study included 90 participants, with a slightly higher proportion of females (55.56%) compared to males (44.44%), and this difference was statistically significant (p=0.045). The age distribution was relatively balanced across the three categories: 18–30 years (27.78%), 31–50 years (44.44%), and 51+ years (27.78%). A significant difference was observed among the age groups (p=0.032), suggesting that the sample distribution was not uniform and may reflect varying prevalence of gallbladder and biliary variations across age groups.

Table 2: Morphometric Characteristics of the Gallbladder

The mean gallbladder length was 7.50 ± 1.20 cm, with a range of 5.00–9.80 cm, and this value was significantly variable among participants (p=0.001). The mean width was 3.20 ± 0.80 cm, ranging from 2.00 to 4.90 cm, showing a statistically significant variation (p=0.012). The gallbladder volume had a mean of 28.50 ± 5.10 mL, ranging from 20.00 to 40.00 mL, and was also significantly variable (p=0.018). The wall thickness had a mean of 2.50 ± 0.30 mm, with a range of 1.80–3.20 mm, and this variation was highly significant (p=0.005). These results indicate considerable individual differences in gallbladder morphometry within the study population, highlighting the need for individualized assessment in clinical practice.

Table 3: Anatomical Variations of the Gallbladder

Most participants (88.89%) had a normal gallbladder morphology, while 11.11% exhibited anatomical variations, which were statistically significant ($p<0.001$). Among the variations, ectopic positioning was the most common (4.44%), followed by double gallbladder (3.33%) and septate gallbladder (2.22%). Gallbladder agenesis was observed in only 1.11% of cases. These findings demonstrate that while most gallbladders are morphologically normal, a notable percentage exhibit variations that may impact clinical management and surgical planning.

Table 4: Anatomical Variations of the Cystic Duct

A normal cystic duct was observed in 91.11% of participants, while 8.89% showed anatomical variations, which was highly significant ($p<0.001$). The most common variation was the presence of spiral valves (4.44%), followed by double cystic ducts (2.22%) and aberrant ducts (2.22%). These results emphasize the importance of identifying cystic duct variations during diagnostic imaging or surgical procedures to minimize the risk of complications.

Table 5: Morphometric and Anatomical Variations of the Common Bile Duct (CBD)

The majority of participants (94.44%) had a normal common bile duct, while 5.56% exhibited anatomical variations, which was statistically significant ($p<0.001$). The most common variation was the presence of accessory ducts (2.22%), followed by choledochal cysts (1.11%). The mean CBD diameter was 0.70 ± 0.15 cm, ranging from 0.40 to 1.20 cm, with significant variability (p=0.008). The mean CBD length was 8.10 ± 1.30 cm, ranging from 6.50 to 10.50 cm, with a significant difference (p=0.014). These findings underscore the necessity of careful evaluation of the CBD for variations and abnormal dimensions, as these factors can have clinical and surgical implications.

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Table 1: Demographic Characteristics of Participants

Parameter	Frequency (n)	Percentage (%)	p-value
Gender			0.045*
Male	40	44.44	
Female	50	55.56	
Age Group (Years)			0.032*
18–30	25	27.78	
31–50	40	44.44	
51+	25	27.78	

Table 2: Morphometric Characteristics of the Gallbladder

Parameter	Mean ± SD	Range	p-value
Gallbladder Length (cm)	7.50 ± 1.20	5.00–9.80	0.001**
Gallbladder Width (cm)	3.20 ± 0.80	2.00–4.90	0.012*
Gallbladder Volume (mL)	28.50 ± 5.10	20.00–40.00	0.018*
Wall Thickness (mm)	2.50 ± 0.30	1.80–3.20	0.005**

Table 3: Anatomical Variations of the Gallbladder

Anatomical Variation	Frequency (n)	Percentage (%)	p-value
Normal	80	88.89	<0.001**
Agenesis	1	1.11	
Ectopic Position	4	4.44	
Septate Gallbladder	2	2.22	
Double Gallbladder	3	3.33	

Table 4: Anatomical Variations of the Cystic Duct

Anatomical Variation	Frequency (n)	Percentage (%)	p-value
Normal	82	91.11	<0.001**
Spiral Valves	4	4.44	
Double Cystic Duct	2	2.22	
Aberrant Duct	2	2.22	

Table 5: Morphometric and Anatomical Variations of the Common Bile Duct (CBD)

Parameter or Variation	Frequency (n)	Percentage (%)	p-value
Normal	85	94.44	<0.001**
Accessory Duct	2	2.22	
Choledochal Cyst	1	1.11	
CBD Diameter (cm, Mean ± SD)	0.70 ± 0.15	0.40–1.20	0.008**
CBD Length (cm, Mean ± SD)	8.10 ± 1.30	6.50–10.50	0.014*

DISCUSSION

In this study, the majority of participants were female (55.56%), and a statistically significant difference was observed between genders (p=0.045). This aligns with the findings of Gupta et al. (2018), who reported a higher prevalence of gallbladder anomalies and pathologies in females (56%) compared to males (44%), attributed to hormonal influences such as estrogen and progesterone on bile composition.7 The age distribution showed the highest prevalence in the 31–50 years age group (44.44%), consistent with Singh et al. (2020), who noted peak gallbladder variation prevalence in middle-aged adults, potentially due to cumulative physiological changes with aging.[8]The mean gallbladder length in this study was 7.50 ± 1.20 cm, with a mean width of 3.20 ± 0.80 cm, and volume of 28.50 ± 5.10 mL. These findings are consistent with those reported by Ahmed et al. (2019), who observed a mean gallbladder length of 7.45 ± 1.30 cm and width of 3.10 ± 0.75 cm in a similar population.[9] The wall thickness in this study was 2.50 ± 0.30 mm, slightly higher than the 2.30 ± 0.25 mm reported by Pandey et al. (2021). Variability in gallbladder measurements may be influenced by factors such as dietary habits, ethnicity, and imaging techniques. Statistically significant variations ($p<0.05$) in all morphometric parameters underscore the importance of considering individual differences during diagnostic evaluation.[10]Normal gallbladder morphology was observed in 88.89% of participants, while 11.11% exhibited variations, including ectopic positioning (4.44%), double gallbladder (3.33%), septate gallbladder (2.22%), and agenesis (1.11%). These findings are consistent with the study by Rajkumar et al. (2017), which reported anatomical variations in 10.5% of cases, with ectopic positioning being the most frequent variation (5%).[11] Gallbladder agenesis, though rare, was comparable to the

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prevalence (1.0%) reported by Patil et al. (2020). Variations in gallbladder morphology have significant clinical implications, especially in laparoscopic cholecystectomy, where unrecognized variations can increase the risk of complications.[12]Anatomical variations in the cystic duct were noted in 8.89% of participants, with the most common being spiral valves (4.44%), followed by double cystic ducts (2.22%) and aberrant ducts (2.22%). A similar prevalence was observed by Sharma et al. (2018), who reported cystic duct variations in 9.1% of cases, with spiral valves accounting for 4.8%. Variations in the cystic duct are critical during biliary surgery, as they increase the risk of inadvertent injury or incomplete ductal clearance. The highly significant p-value (<0.001) in this study highlights the importance of preoperative imaging to identify such anomalies.[13]The majority of participants (94.44%) had a normal CBD, while 5.56% exhibited anatomical variations, including accessory ducts (2.22%) and choledochal cysts (1.11%). The mean CBD diameter in this study was 0.70 ± 0.15 cm, similar to the findings of Das et al. (2019), who reported a mean diameter of 0.72 ± 0.14 cm in a healthy population.[14] The mean length of the CBD was 8.10 ± 1.30 cm, comparable to the 8.25 ± 1.25 cm reported by Ali et al. (2020). Anatomical variations in the CBD have critical implications in endoscopic retrograde cholangiopancreatography (ERCP) and biliary surgery. Identifying accessory ducts is crucial, as their inadvertent injury can lead to bile leakage or stricture formation.[15]

CONCLUSION

This study highlights the significant morphometric variability and incidence of anatomical variations in the gallbladder, cystic duct, and common bile duct as observed through ultrasonography. Normal morphology was predominant, but variations such as ectopic gallbladder positioning (4.44%), spiral valves in the cystic duct (4.44%), and accessory bile ducts (2.22%) were notable. Statistically significant differences in parameters such as gallbladder length (7.50 ± 1.20 cm) and CBD diameter (0.70 ± 0.15 cm) underscore the importance of individualized assessment. These findings emphasize the need for careful preoperative evaluation to minimize complications and enhance the safety of hepatobiliary interventions.

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