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Frequency of Cystic Duct Anatomical Variations on ERCP- A Retrospective Cross-Sectional Study

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ABSTRACT

Cystic duct (CD) anatomical variations are common, but they frequently go unrecognized. Their prevalence differs among different studies. A proper understanding of these variations is important before performing any percutaneous, surgical, or endoscopic interventions to avoid complications. **Objectives:** To evaluate the frequency of anatomical variations of cystic duct insertion observed on endoscopic retrograde cholangiograms. **Methods:** A total of 500 cholangiograms (2020-2022) fulfilling the inclusion criteria were analyzed retrospectively for various CD insertion patterns from the Endoscopy suite of Lahore General Hospital, Lahore, after approval from the IRB. Patient information, including age, gender, and indication of ERCP were also recorded. Data were processed on SPSS v.25. Results of continuous measurements were expressed as mean ± SD (min, max), and results of categorical measurements were presented as number (%). **Results:** Among 500, there were 45% male and 55% female. Normal cystic duct mid-lateral insertion was seen in 62.2% of patients, while 37.8% showed anatomical variations. Among these variations, the most frequent one was low medial (15.4%), followed by middle medial (8.6%) and high lateral (7%). **Conclusions:** The study identified a high frequency of CD variations, thus highlighting the importance of imaging for the identification of these variations before performing any surgical or endoscopic procedures.

INTRODUCTION

The cystic duct is a long tubular structure connecting the gall bladder with the extrahepatic bile duct. Its normal width is 1-5 mm and length 2-4 cm. It normally inserts to the right side of the common hepatic duct and then forms the common bile duct [1]. However, there are various anatomical variations of cystic duct insertion, such as low medial or high lateral. Similarly, other variations like long parallel course of CD or a short CD are also common. If these variations go unrecognized while performing endoscopic or surgical procedures, complications may arise [2]. The most common complication encountered during surgery due to these variations is bile duct injury leading to biliary leakage, especially in a long parallel course or a short CD due to difficulty in dissection and ligation, respectively [3]. Similarly, while performing ERCP, the low medial insertion variant poses difficulty in

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cannulation or instrumentation. In some studies, this variant is also linked with high recurrence of gallstones and CBD stones [4]. Imaging modalities like MRCP (accuracy 90%) and ERCP are critical for detecting CD variations [5]. ERCP is not only the best diagnostic but also a minimally invasive therapeutic tool to treat biliary and pancreatic pathologies by offering high- resolution visualization during endoscopic interventions [6]. Many studies have been published so far describing the prevalence of these variations, but results vary among studies (22.8% to 48.5%). Similarly, the most prevalent anatomical variation also differs among studies, some showing it to be a high insertion [7] while others favor mid-posterior [8]. The likely reasons for such differences might be the different study populations and their ethnicities, imaging techniques, and use of nomenclature for describing these variations. Some studies included anomalous variations like short, long, or bifurcated CD, and others also included aberrant insertion like into the right or left hepatic duct, among anatomical insertion variations as well. Data from Pakistan is sparse; one study reported 8.33% variation rate during cholecystectomy, potentially underestimating true prevalence due to limited imaging, and also only anomalous variations, e.g., short, long, double, or absent cystic duct, were included in the study [9].

Although there are several international reports regarding the cystic duct anatomical variations, the results are inconsistent, and the Pakistani data are also quite limited and probably under-estimated because of the lack of imaging testing of the results. The presence of unidentified variation may augment the threat of bile duct injury, leakage, and the complexity of the procedure in the course of surgery or ERCP. This study aimed to determine the prevalence of CD anatomical variations using ERCP cholangiograms to characterize local patterns and enhance the safety of surgical and endoscopic procedures.

METHODS

This retrospective cross-sectional study was carried out at the Department of Gastroenterology, Lahore General Hospital, after approval from the institutional ethical committee (Reference No. AMC/PGMI/LGH/Article/Research No/2025/ERC/37; dated 1st April 2025). After taking written departmental permission for data access, a total of 1474 ERCP cholangiogram images from March 2020 to October 2022 were collected and reviewed from the Picture Archiving Communication System (PACS) of the endoscopy suite. Two endoscopists with 8 years and 5 years of experience in advanced endoscopy reviewed the ERCP images. Both were blinded to clinical data and reviewed images on separate occasions for interobserver agreement analysis. Cholangiograms of patients aged >18 years that clearly demonstrated the cystic duct anatomy were included. However, images of patients who had a history of biliary surgery, distorted anatomy, or incomplete images were excluded. A total of 500 cholangiograms that met the inclusion criteria were selected for the study using a non-probability purposive sampling technique. These images were reviewed for anatomical variations of the cystic duct based on insertion type (medial and lateral) and level (high, mid, and low). Patient information, including age, gender, and pathological diagnosis for which ERCP was done, was also recorded from the database. All participants provided verbal informed consent telephonically for the use of their data in the study. The sample size was calculated using the primary outcome variable, i.e., the prevalence of cystic duct anatomical variations on ERCP. Based on previously reported prevalence of CD variations of 39.5%, a 95% confidence interval (CI), and a 5% margin of error, the initial sample size was calculated to be 368 cholangiograms [10]. To enhance the statistical power and robustness of current findings, the sample size was subsequently increased to 500 images. The classification of Cystic Duct (CD) insertion patterns was systematically determined based on the cranio-caudal (vertical) and transverse (horizontal) union with the extrahepatic duct (EHD), a system chosen because ERCP provides 2D cholangiograms with excellent visualization of these major biliary channels and their junctions. The EHD itself was defined as the segment beginning at the confluence of the right and left hepatic ducts and terminating at the point where the Common Bile Duct (CBD) opens into the Ampulla of Vater. To classify the vertical level of insertion, the EHD was divided subjectively into three equal thirds, classifying the union as high, middle, or low (Figure 1).

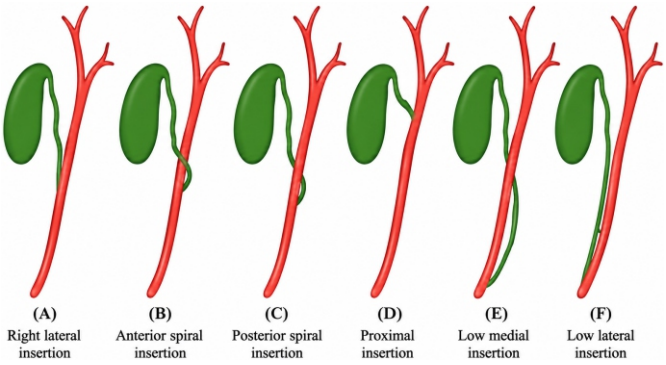

Figure 1: Various Cystic Duct Insertions into the Common Bile Duct [11]

The transverse union was classified based on the perceived side of insertion relative to the EHD in the 2D image, categorizing it as Lateral (insertion from the right side) or Medial (insertion from the left side). CD insertion was considered Normal only when it joined the EHD through the middle one-third of its lateral border, while all other

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insertion patterns were consequently recorded as anatomical variants (Figure 2).

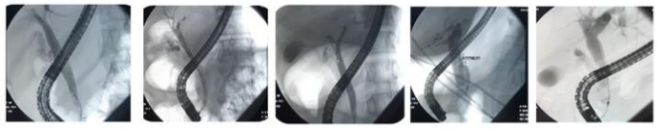

Figure 2: Various Insertion Patterns of Cystic Duct Seen on ERCP images

Statistical analysis was carried out with SPSS version 25.0. In current study, descriptive and inferential analyses were carried out. Continuous measurements are calculated as mean ± SD (min, max), while results of categorical measurements are presented as frequencies and percentages. The chi-square test was used to assess the association between craniocaudal and transverse cystic duct insertion patterns. A p-value of <0.05 was considered statistically significant. Interobserver agreement was analyzed by using Cohen's Kappa statistic.

RESULTS

The cohort consisted primarily of females 275 (55%), with males accounting for 225 (45%) of the sample. The mean age was 45.6±12.52 years (range: 25–74 years). The predominant indication for ERCP in this study was choledocholithiasis (79.6%) (Table 1).

Table 1: Demographics of Patients

Demographic Features	Frequency (%)
Gender	
Male	225 (45%)
Female	275 (55%)
Age (Years)	
Mean ± SD	45.6 ± 12.52
25-49	304 (60.8%)
50-74	196 (39.2%)
Diagnosis	
Choledocholithiasis	398 (79.6%)
Distal Stricture	43 (8.6%)
Hilar Stricture	25 (5.0%)
Biliary Leak	08 (1.6%)
Mirizzi Syndrome	17 (3.4%)
IGg4 Cholangiopathy	08 (1.6%)
Post LT	01 (0.2%)

311(62.2%) cholangiograms showed normal insertion (Middle Lateral) pattern, while anatomical variations were seen in 189(37.8%) images. Low Medial insertion (15.4%) was the most common variation type, while the least common was high medial (1.2%). To ensure reliability, interobserver agreement was assessed using Cohen's Kappa (κ) statistic and was found to be substantial (κ=0.693) (Table 2).

Table 2: Distribution of All Cystic Duct Insertion Patterns in Whole Cohort

Craniocaudal Insertion, n (%)	Transverse Insertion, n (%)		
	Lateral	Medial	Total
High	38 (7.6%)	6 (1.2%)	44 (8.2%)
Middle	311 (62.2%)	43 (8.6%)	354 (70.8%)
Low	25 (5%)	77 (15.4%)	102 (20.4%)
Total	374 (74.8%)	126 (25.2%)	500 (100%)

Chi-Square Test: p-value = <0.001

The study summarizes previously published literature regarding cystic duct anatomical variations using different imaging and assessment modalities rather than findings from the present study (Table 3).

Table 3: Comparative Distribution of Cystic Duct Insertion Patterns and Anatomical Variants of Different Studies

Sr. No.	Study/ Country	Imaging/ Assessment Modality	Reported CD variation (%)	Most Common Variants	Classification system
1-	Present study (Pakistan)	ERCP	37.8	Low Medial (15.4%) Middle Medial (8.6%)	ERCP 2D image-based Insertion classification
2-	Turkish Study (10)	ERCP	39.5	Middle Medial (9.8%), Low Medial (6.8%)	Insertion variations
3-	Turkish Study (14)	MRCP	60	Lateral Insertion: 40%. Medial Insertion: 24.3%, High Insertion (14.7%)	Anomalous & Insertion variations
4-	Nepal Study (15)	MRCP	52.38%	Posterior Insertion (14.3%)	Variable classification
5-	Cadaveric Study (17)	Liver specimen in Anatomy Department	10.3	High union 7.2%	Insertion variations according to level and mode of insertion
6-	Odisha Study (18)	MRCP	––	Posterior Insertion 42.8%	Insertion Classification

DISCUSSION

Gall bladder and biliary tree pathologies are usually managed by a surgical and endoscopic approach. Both are invasive means of management and linked with complications. One important reason for complications like injury or ligation of the bile duct is the failure to recognize the ductal anatomy variations [12]. As a whole, total biliary tree variations are seen in 42% of the population and are the frequent cause of iatrogenic bile duct injury [13]. The incidence of CD anatomical variation in present study was 37.8%, with other studies showing a range from 39% to 60% depending upon imaging modality and classification criteria (Table 3). Current results align

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with the Turkish study reporting 39.5% variations, with middle medial being the most frequent one (9.8%) [10]. Some studies reported quite high percentages of CD variations up to 60% [14, 15]. The higher percentages might be because of the use of different imaging modalities (MRCP) and the use of anomalous union in addition to insertion variations in nomenclature. These studies also included various courses of the cystic duct, like short, parallel, or spiral courses, which essentially are not the insertion variations. A local study from Pakistan reported the incidence of CD variants of only 4.4% [16]. It's likely due to a smaller sample size and reliance on Laparoscopic observation. Also, the nomenclature for various insertion variations was not mentioned. A significant observation of present study was a higher prevalence of low medial insertion (15.4%) in contrast with studies reporting lower rates. Among these, one study conducted on 100 cadaveric specimens showed 3.1% incidence [17]. Another larger study on the Odisha population of 1038 patients showed low medial insertion was present in 3.8% patients [18]. It's possibly due to population-specific embryological differences or ERCP's enhanced visualization compared to MRCP or surgical findings. Clinically, low medial insertions pose challenges for ERCP cannulation or instrumentation and increase the risk of CBD stone recurrence [19]. Pre-procedural MRCP, being noninvasive, can guide endoscopists and surgeons, reducing risks like pancreatitis, bile duct injury, or leakage. In current study, the second most common variant was middle medial with an incidence of 8.6%. Sherifi *et al.* reported the incidence of 6.3%, which was nearly comparable to present study [20]

Limitations of current study include single center retrospective design, subjective classifications of insertion levels, and a lack of MRCP or surgical correlations. Overall, present study results revealed a higher frequency of CD variations. However, larger multicenter studies are required to compare the results of ERCP images with MRCP and intraoperative surgical anatomy. Such validation will help refine the classification system and ultimately enhance procedural safety across diverse populations.

CONCLUSIONS

The anatomical variations observed in current population are quite high (37.8%), with low medial insertion being the most common. Given the clinical challenges these variants pose, we strongly recommend mandatory pre-procedural imaging, preferably MRCP, to reduce the risk of iatrogenic injury and complications during both surgical and endoscopic biliary procedures. Furthermore, these findings underscore the importance of enhanced education and training for endoscopists and surgeons regarding biliary anatomy and its variants to ensure optimal procedural safety.

Authors' Contribution

Conceptualization: SR, MAF, KM, HR, HIM, GUNT
Methodology: SR, MAF, KM, HR, HIM, GUNT
Formal analysis: SR, MAF, KM, HR, HIM, GUNT
Writing and Drafting: SR, MAF, KM, HR, HIM, GUNT
Review and Editing: SR, MAF, KM, HR, HIM, GUNT

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflicts of Interest

All the authors declare no conflict of interest.

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