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Anatomical Variability of Cystic Artery Position During Laparoscopic Cholecystectomy: An Observational Study in North-East India

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ABSTRACT

Background: Anatomical variability of the cystic artery within Calot's triangle poses a significant risk during laparoscopic cholecystectomy (LC), potentially leading to vascular injury, uncontrolled haemorrhage, and conversion to open surgery.
Objective: To document the anatomical positions of the cystic artery among patients undergoing LC in North-East India and assess their clinical relevance.
Methods: A prospective observational study was conducted from June 2024 to November 2025. Intraoperative findings of 141 patients undergoing LC were systematically recorded, focusing on cystic artery position, associated variations, and radiological features.
Results: The cystic artery was most commonly superomedial to the cystic duct (82.3%). Variations included superolateral (9.9%), posterolateral (3.5%), anterior (2.1%), and double cystic artery (1.4%). Radiological findings revealed increased gallbladder wall thickness in 17.7% and pericholecystic fluid in 14.2%, both indicative of acute inflammatory changes. Most patients were female (76.6%) and aged 21–40 years (51.8%). Comorbidities were uncommon, with hypertension (12.8%) and diabetes (7.1%) being the most frequent.
Conclusion: While the superomedial course of the cystic artery predominates, nearly one-fifth of patients exhibit variations that increase operative difficulty. Awareness of these patterns is essential for safe dissection, prevention of vascular injury, and reduction of conversion rates.

Keywords: Cystic artery, anatomical variation, laparoscopic cholecystectomy, Calot's triangle, vascular injury, gallstone disease

INTRODUCTION

Cholelithiasis remains one of the most prevalent gastrointestinal disorders worldwide, with gallstone disease affecting between 10–20% of adults in many populations and showing increasing incidence in India.[1,2] Laparoscopic cholecystectomy (LC) has become the gold standard for symptomatic gallstone disease, offering reduced postoperative pain, shorter hospital stay, and faster recovery compared to open cholecystectomy.[3,4] Despite these advantages, LC carries a higher risk of vasculobiliary injury, particularly due to anatomical variability within Calot's triangle.[5,6]

The cystic artery, which typically arises from the right hepatic artery, demonstrates considerable variation in origin, course, and relation to the cystic duct and common bile duct.[7] These variations are clinically significant because inadvertent injury to the cystic artery can lead to uncontrolled haemorrhage, poor visualisation, and increased conversion rates to open surgery.[8] Studies have reported conversion rates ranging from 1.2% to 6.6% due to vascular injury, with bleeding in Calot's triangle contributing to conversion in up to 17% of cases.[9,10]

Recent literature emphasises the importance of achieving the "critical view of safety" during LC, which requires meticulous clearance of fibrofatty tissue in Calot's triangle and identification of only two structures entering the gallbladder: the cystic duct and cystic artery.[11] Anatomical variations, however, may obscure this view. For example, double cystic arteries have been reported in 2–25% of cases, while aberrant origins from the middle hepatic, gastroduodenal, or left hepatic arteries, though rare, pose significant intraoperative challenges.[7]

An earlier report highlighted a rare variation where the cystic artery originated from the middle hepatic artery, underscoring the potential for misidentification and inadvertent ligation if surgeons are not vigilant.[12] Similarly, classification studies have demonstrated that while 85.5% of cystic arteries lie within Calot's triangle, up to 13% may course outside, increasing the risk of injury during dissection.[13] These findings reinforce the need for region-specific data, as anatomical variability may differ across populations.

In India, despite the high burden of gallstone disease, few studies have systematically documented variations in the cystic artery during LC. Given the rising prevalence of cholelithiasis in North-East India, understanding local anatomical patterns is crucial for surgical safety. This study was therefore undertaken to determine the proportions of common and uncommon positions of the cystic artery relative to the cystic duct among patients undergoing LC at a tertiary care hospital in Tripura. By documenting these variations, the research aims to provide practical insights for surgeons, reduce intraoperative complications, and contribute to safer surgical practice in the region.

MATERIALS AND METHODS

Study Design

This was a prospective observational study designed to evaluate anatomical variations of Calot's triangle and their impact on intra-operative and post-operative outcomes during laparoscopic cholecystectomy.

Study Setting

The study was conducted in the Department of General Surgery, Agartala Government Medical College & Govind Ballabh Pant (GBP) Hospital, the only government medical college serving the population of Tripura.

Study Period

The study was carried out over 18 months, from June 2024 to November 2025.

Study Population

The study population comprised all patients who underwent laparoscopic cholecystectomy in the Department of General Surgery during the study period.

Eligibility Criteria

- Inclusion criteria: Patients undergoing laparoscopic cholecystectomy.
- Exclusion criteria: Patients who did not provide informed consent.

Sample Size and Sampling

During the study period, 145 patients underwent laparoscopic cholecystectomy. Based on the selection criteria, 141 patients were included in the final analysis. A non-probability sampling technique was employed.

Recruitment and Study Procedure

Written informed consent was obtained from all eligible patients prior to surgery. Each consenting patient underwent routine clinical, radiological, and pathological evaluation. A standard four-port laparoscopic cholecystectomy was performed in the reverse Trendelenburg position.

Intra-operative findings regarding the anatomy of Calot's triangle, the presence of anatomical variations, and any complications were documented in detail. Post-operative outcomes were assessed during hospital stay and follow-up visits. Data were recorded in a semi-structured proforma prepared for the study.

Data Processing and Analysis

Collected data were entered into Microsoft Excel and analysed using SPSS version 26.0. Quantitative variables were summarized using mean and standard deviation, while qualitative variables were expressed as proportions and percentages.

Ethical Considerations

Ethical clearance was obtained from the Institutional Ethics Committee of Agartala Government Medical College, Agartala, Tripura, prior to commencement of the study (Ref. No. F.4(6-13)/AGMC/Medical Education/IEC Approval/2022/6079). The study objectives were explained to all participants, and both verbal and written informed consent were obtained. Privacy and confidentiality were strictly maintained. All surgical procedures and patient management adhered to standard clinical guidelines.

RESULTS

The study included 141 patients undergoing laparoscopic cholecystectomy. The largest proportion of participants was in the 21–40 years age group (51.8%), indicating that gallstone disease is most prevalent among young to middle-aged adults. The 41–60-year-old group also contributed significantly (36.2%), reflecting the continued risk among older adults. Only 9.2% were under 20 years, and a small fraction (2.8%) were over 60 years, indicating that gallstone disease is relatively uncommon at the extremes of age (Figure 1).

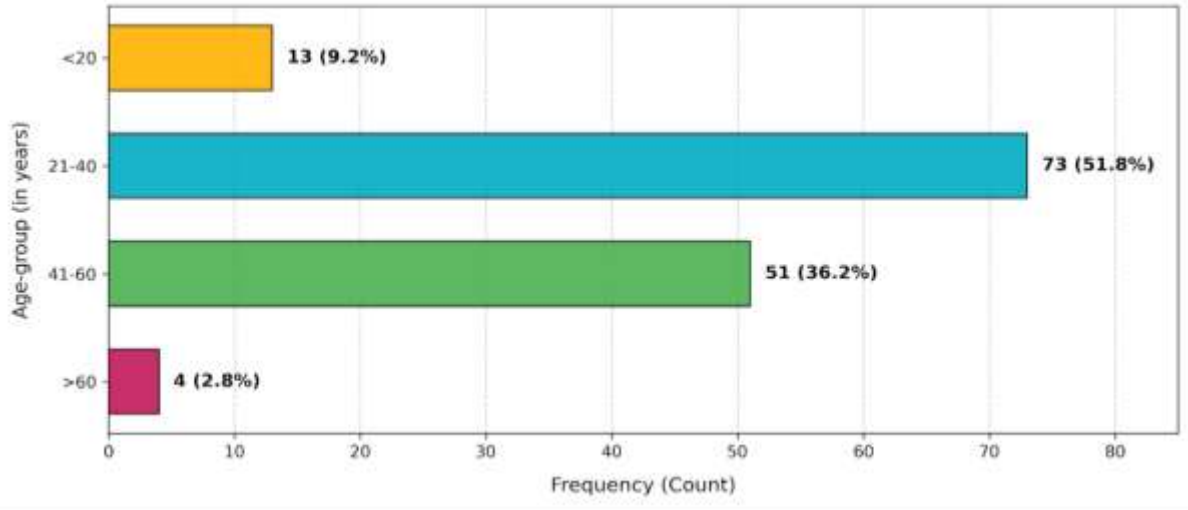

Figure 1: Age distribution of participants

Figure 2 illustrates that the majority were female (76.6%, n=108), while males accounted for 23.4% (n=33).

Figure 2: Gender distribution of participants

The majority (79.4%, n=112) had no comorbidities, indicating that most individuals undergoing laparoscopic cholecystectomy were otherwise healthy. Hypertension was the most common comorbidity, present in 12.8% (n=18), followed by diabetes mellitus in 7.1% (n=10). Only one patient (0.7%) had both diabetes and hypertension (Figure 3).

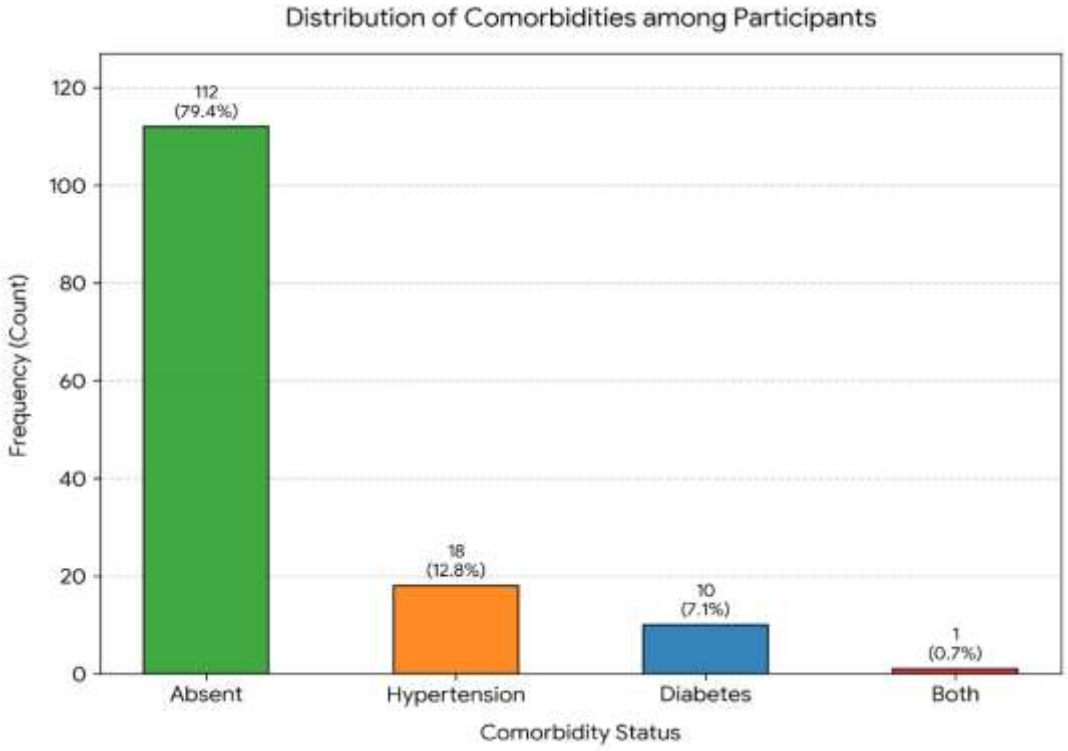

Figure 3: Distribution of comorbidities among participants

The majority (78.0%, n=110) presented with symptomatic gallstone disease, confirming that most individuals undergoing laparoscopic cholecystectomy had clear clinical manifestations such as biliary colic or dyspeptic symptoms. Cholecystitis was observed in 18.4% (n=26), reflecting the subset of patients with acute or chronic inflammatory changes of the gallbladder. Only 5 patients (3.5%) were asymptomatic, where gallstones were detected incidentally during evaluation for other conditions (Figure 4).

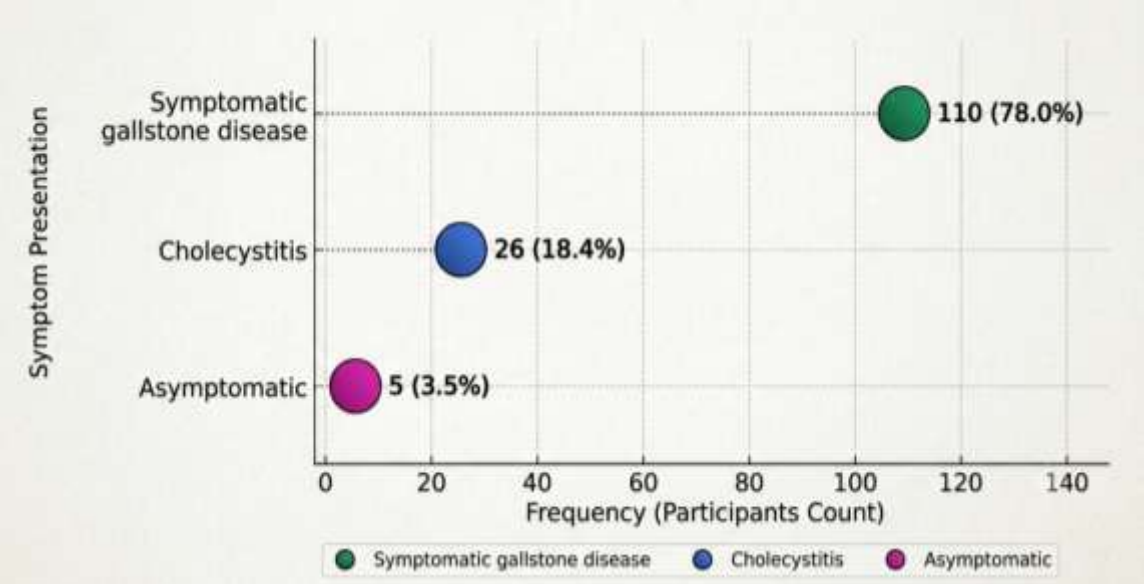

Figure 4: Distribution of symptom frequencies in the study cohort

The majority of patients demonstrated normal baseline investigations, reflecting that gallstone disease often occurs in otherwise healthy individuals. A normal complete blood count (58.2%) and normal liver function tests (91.5%) were observed in most cases, while 41.8% had haematological abnormalities, likely related to inflammatory or nutritional status.

Radiological findings showed that 82.3% had normal gallbladder wall thickness, whereas 17.7% had thickened walls, consistent with cholecystitis. Gallstones were single in 53.2% and multiple in 46.8%, indicating nearly equal distribution. Pericholecystic fluid collection was present in 14.2%, signifying acute inflammatory changes. Regarding liver status, 93.6% were normal, while 6.4% had cirrhosis, highlighting a small but clinically relevant subgroup with coexisting chronic liver disease (Table 1).

Table 1: Distribution of different laboratory and radiological findings (n=141)

Parameter	Findings	Frequency	Percentage
Complete Blood Count	Normal	82	58.2 %
	Abnormal	59	41.8 %
Liver Function Test	Normal	129	91.5 %
	Deranged	12	8.5 %
GB wall thickness	Normal	116	82.3 %
	Increased	25	17.7 %
Stones	Single	75	53.2 %
	Multiple	66	46.8 %
Pericholecystic fluid collection	Absent	121	85.8 %
	Present	20	14.2 %
Liver status	Normal	132	93.6 %
	Cirrhotic	9	6.4 %

The cystic artery was identified in nearly all cases, with only one patient (0.7%) showing absence. The superomedial position was by far the most common, observed in 82.3% (n=116), confirming it as the typical anatomical course. Variations were also documented: superolateral (9.9%), posterolateral (3.5%), anterior (2.1%), and double cystic artery (1.4%). These uncommon positions together accounted for 17.0% of cases, underscoring the importance of anticipating variability during laparoscopic dissection (Figure 5).

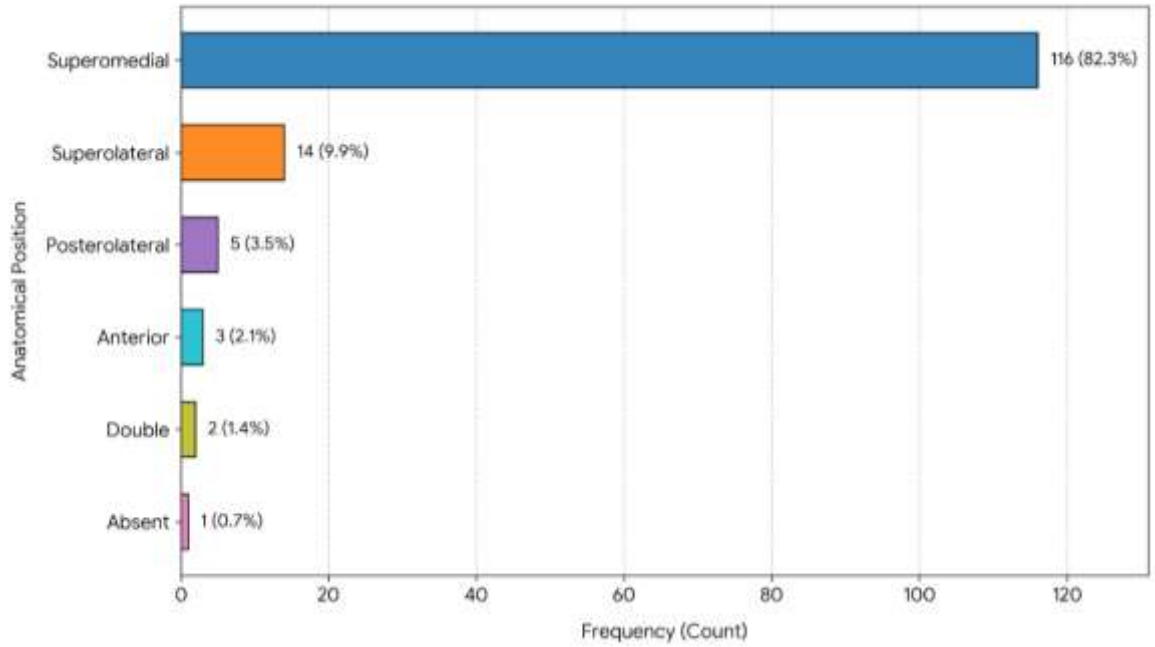

Figure 5: Anatomical position of the cystic artery

DISCUSSION

The present study highlights the anatomical variability of the cystic artery encountered during laparoscopic cholecystectomy in a North-East Indian population. Among 141 patients, the cystic artery was most commonly found in the superomedial position (82.3%), consistent with classical anatomical descriptions and previous reports identifying this course as the typical pattern.[14] However, nearly one-fifth of patients demonstrated variations, including superolateral, posterolateral, anterior, and double cystic arteries. Recognition of these variations is crucial, as they may complicate dissection within Calot's triangle and increase the risk of vascular injury.

The predominance of gallstone disease in the 21–40 year age group (51.8%) and the marked female predominance (76.6%) observed in this study align with global epidemiological trends. Gallstone disease is known to be more common in women, attributed to hormonal influences such as estrogen and progesterone, which alter bile composition and gallbladder motility.[15] Similar demographic patterns have been reported in Indian and Western populations, reinforcing the consistency of these findings across diverse regions.[2,16]

Comorbidities were relatively uncommon in this cohort, with 79.4% of patients having no systemic illness. Hypertension (12.8%) and diabetes mellitus (7.1%) were the most frequent comorbidities, reflecting their high prevalence in the general population. Although metabolic syndrome has been linked to gallstone formation, the relatively low proportion of comorbidities in this study suggests that gallstone disease often occurs independently of systemic illness.[17]

Symptomatic gallstone disease was the predominant clinical presentation (78.0%), followed by cholecystitis (18.4%). Only a

small fraction (3.5%) was asymptomatic, where gallstones were detected incidentally. This distribution is consistent with earlier studies, which report that most patients undergoing cholecystectomy are symptomatic, with biliary colic being the most common complaint.[7] The presence of cholecystitis in nearly one-fifth of patients underscores the importance of timely surgical intervention to prevent complications such as empyema or perforation.

Radiological findings revealed that 17.7% of patients had increased gallbladder wall thickness and 14.2% had pericholecystic fluid collection, both indicative of acute inflammatory changes. These features are known to increase operative difficulty and risk of complications during laparoscopic cholecystectomy.[18] The presence of cirrhosis in 6.4% of patients also has surgical implications, as portal hypertension and altered anatomy may complicate dissection and increase bleeding risk.

The anatomical variability of the cystic artery observed in this study is comparable to that reported in the global literature. Ding et al. classified cystic artery variations and reported that, although most arteries lie within Calot's triangle, up to 13% course outside it, thereby increasing the risk of injury during dissection.[13] Double cystic arteries, identified in 1.4% of patients in this study, have been reported in 2–25% of cases worldwide.[19] Failure to recognise this anomaly may result in persistent bleeding if only one branch is ligated. Similarly, anterior and posterolateral courses, though less frequent, pose significant intraoperative challenges due to their proximity to the common bile duct and hepatic artery.[20,21]

The clinical relevance of these findings lies in the potential for intraoperative bleeding and conversion to open surgery. Although this study primarily focused on anatomical variability rather than outcomes, the literature suggests that vascular injury contributes to conversion rates ranging from 1.2% to 6.6%.[10] Bleeding in Calot's triangle has been associated with conversion in up to 1-24% of cases.[22] Therefore, awareness of anatomical variations is essential for safe dissection and the prevention of complications.

The results reinforce the importance of achieving the critical view of safety (CVS) during laparoscopic cholecystectomy. Strasberg and Brunt emphasised that CVS requires identification of only two structures entering the gallbladder—the cystic duct and cystic artery—after complete clearance of fibrofatty tissue.[5] Anatomical variations, however, may obscure this view, necessitating meticulous dissection and, in difficult cases, consideration of subtotal cholecystectomy or conversion to open surgery.

Limitations

- The study was conducted at a single tertiary care centre in Tripura, which may limit generalizability to other populations.
- The sample size, though adequate for descriptive analysis, may not capture rarer anatomical variations.
- The study focused primarily on anatomical variability rather than long-term surgical outcomes such as postoperative complications or recurrence.
- Radiological findings were limited to routine preoperative imaging; advanced modalities (CT, MRCP) were not systematically employed.

CONCLUSION

This study demonstrates that although the superomedial position of the cystic artery is the most common, significant variations—including superolateral, anterior, posterolateral, and double cystic arteries—were observed in nearly one-fifth of patients. These variations are clinically relevant, as they increase the risk of uncontrolled haemorrhage, poor visualisation, and conversion to open surgery. Radiological findings of gallbladder wall thickening and pericholecystic fluid further highlight the potential for operative difficulty.

Region-specific data such as these are vital to guide surgeons in anticipating anatomical variability, adhering to the principles of the critical view of safety, and ensuring safer outcomes in laparoscopic cholecystectomy.

Declaration by Authors

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