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Original Article

Surgery Section

Anatomical Variations in Cystic Artery Observed during Laparoscopic Cholecystectomy: A Cross-sectional Study from West Bengal, India

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ABSTRACT

Introduction: Laparoscopic cholecystectomy, while considered the gold standard for managing symptomatic gallstone disease, can lead to complications such as iatrogenic injuries to the cystic artery and bile duct. Therefore, surgeons must possess a comprehensive understanding of the anatomical variations of the cystic artery to identify a safe dissection area.

Aim: To determine the association between the anatomical variations of the cystic artery, the clinical profiles of patients, and the final surgical approach adopted during cholecystectomy.

Materials and Methods: The present cross-sectional study was conducted in the Department of Surgery, Deben Mahata Government Medical College and Hospital, Purulia, West Bengal, India, from April 2023 to March 2024. Study was conducted among 196 patients undergoing laparoscopic cholecystectomy. Data were collected using a predesigned structured schedule and hospital records to assess the clinical profiles of patients, anatomical variations in the cystic artery and the surgical approaches adopted. Bivariate analyses were performed using the Fisher's-exact test to determine the associations between anatomical and clinical variables, and conversion to open cholecystectomy, using Jamovi (Solid version 2.3.28).

Results: The mean age of the participants was 41.75±12.68 years, with 45 males and 151 females. The most common position of the cystic artery was superomedial, 176 (89.8%), while the anterior position was the least common, 5 (2.5%), in relation to the cystic duct. The right hepatic artery was the origin of the cystic artery in 189 (96.4%) patients. The operative procedure was converted to open cholecystectomy in 11 patients. The proportion of patients undergoing open cholecystectomy was higher in males, (6/45, 13.3%) compared to females, (5/151, 3.3%) (p-value=0.0196), more prevalent among acute-on-chronic patients, (6/27, 22.2%) compared to those without, (5/169, 3.0%) (p-value=0.0011), and among patients with mucocele, empyema, or both (7/29, 24.1%) vs those without (4/167, 2.4%) (p-value=0.0001).

Conclusion: The anterior position of the cystic artery in relation to the cystic duct was the least common finding in Calot's triangle. To reduce the risk of iatrogenic injury to the cystic artery, blind dissection in Calot's triangle should begin from the anterior aspect of the cystic duct.

Keywords: Calot's triangle, Cystic duct, Gallbladder, Iatrogenic injury

INTRODUCTION

Gallstone disease, or cholelithiasis, is one of the most prevalent surgical pathologies worldwide, and laparoscopic cholecystectomy is the gold standard for managing symptomatic gallstone disease [1]. Although this operation is performed very frequently, it is not free from complications, with significant risks including injury to the cystic artery, hepatic artery and bile duct [2]. Worldwide, it has been reported that 5-10% of laparoscopic cholecystectomies undergo conversion to open cholecystectomy [3]. Such conversions may lead to more adverse outcomes, as the laparoscopic technique offers many advantages over the open approach, including reduced postoperative pain, decreased complications, shorter hospital stays with early mobility, quicker returns to normal activities and better cosmetic results [4].

The cystic artery is often discussed in relation to Calot's triangle, which is bounded by the cystic duct, common hepatic duct and the lower edge of the liver [5]. Jean-François Calot first described this anatomical landmark in 1891 [6]. The cystic artery typically arises from the right hepatic artery within Calot's triangle. Upon reaching the neck of the gallbladder, it divides into superficial and deep branches to supply the free peritoneal surface and the attached non peritoneal surface of the gallbladder, respectively. In about 25% of individuals, the superficial and deep branches of the cystic artery have separate origins, a condition referred to as double cystic arteries according to Michels [5]. Variations in the position of the cystic arteries in relation to the cystic ducts, such as superomedial, posterolateral and anterior placements, are also common [7].

Intraoperative haemorrhages are defined as any unusual bleeding from an injured vessel during dissection of Calot's triangle or while separating the gallbladder from its fossa [8]. Bleeding from the cystic artery during laparoscopic cholecystectomy decreases overall visibility in the abdomen and is therefore a serious complication. The gallbladder is mobilised during laparoscopic cholecystectomy to achieve the critical view of safety; however, this manoeuvre pulls the structures associated with the gallbladder and alters the anatomy [7]. The anatomical variations of the cystic artery in terms of origin and course further complicate the surgery, potentially leading to conversion to open cholecystectomy. Blood vessel injuries contribute to 1.2-6.6% of conversions to open cholecystectomy [7]. Therefore, a thorough and comprehensive understanding of the anatomical variations of the cystic artery is crucial for the surgeon [3].

Nevertheless, studies regarding the identification of variations in the origin and course of the cystic artery to provide a safe zone for dissection are scarce in Eastern India, particularly in the state of West Bengal. With this background in mind, a cross-sectional study was conducted to determine the association between the anatomical variations of the cystic artery and the final surgical approach adopted during cholecystectomy, as well as, the association between the clinical profiles of the patients and the final surgical approach taken.

MATERIALS AND METHODS

A cross-sectional study was conducted in the Department of Surgery, Deben Mahata Government Medical College and Hospital (DMGMCH), Purulia, West Bengal, India, from April 2023 to March 2024. The present study Institution serves the populations of mainly two districts in West Bengal: Purulia and Bankura. Ethical approval was obtained from the Institutional Ethics Committee (IEC) of DMGMCH before the commencement of the study (vide Memo no. DMGMCH/PUR/IEC/2023, dated 17.03.2023).

Sample size calculation: In a prospective study conducted by Fateh O et al., the prevalence of the cystic artery positioned superomedial to the cystic duct was found to be 90.59% [7]. The estimated sample size, calculated using the formula for proportions (i.e., $Z\alpha\ pq/d^2$), was 167 (with $Z\alpha$ set at a 95% confidence level, p representing the proportion of patients with the cystic artery superomedial to the cystic duct, q representing the proportion of patients without this positioning, and d denoting the relative precision taken as 5%). Considering a 15% non response rate, the final sample size was adjusted to 192.

In the present study, a systematic random sampling method was adopted, where every second patient undergoing laparoscopic cholecystectomy was included to meet the required sample size.

Inclusion criteria: All selected patients scheduled to undergo laparoscopic cholecystectomy and willing to participate were included in the study.

Exclusion criteria: Patients with gallstone disease who had concomitant common bile duct stones, suspected gallbladder masses, were pregnant, or had co-morbidities that would limit laparoscopic cholecystectomy were excluded from the study.

Study Procedure

All eligible patients underwent preoperative ultrasonography of the entire abdomen, followed by a preoperative anaesthesia fitness check-up. Those deemed fit for surgery were treated with a standard four-port laparoscopic cholecystectomy under general anaesthesia.

Data were collected using a predesigned structured schedule and with the help of hospital records from the Outpatient Department (OPD), Inpatient Department (IPD) and Surgical Operation Theatre. The collected data included the clinical profile of the patients, anatomical variations in the cystic artery, and the surgical approach adopted. The variables included gender, the number of stones in the gallbladder, the chronicity of the disease (i.e., whether it was acute-on-chronic or chronic), and the condition of the gallbladder (i.e., presence of mucocele, empyema, or both). Additionally, information was gathered regarding the place of origin of the cystic artery, its position in relation to the cystic duct, the number of cystic arteries when originating from the right hepatic artery, and the final surgical approach adopted (i.e., laparoscopic or open).

The outcomes assessed included the proportion of patients exhibiting the aforementioned demographic and clinical variables, the proportion of patients in whom the laparoscopic approach had to be converted to open cholecystectomy, the association between clinical profiles and the final surgical approach, and the association between anatomical variations of the cystic artery and the final surgical approach. Recurrent attacks of biliary colic, with temporary occlusion of the cystic duct causing inflammation and scarring of the neck of the gallbladder and cystic duct, were considered chronic cholecystitis, whereas acute exacerbations of biliary colic or its progression to a more severe form of cholecystitis requiring urgent intervention were considered acute-on-chronic cholecystitis.

Peroperative visualisation of Calot's triangle and variations in the position of the cystic artery were performed and duly noted in the aforementioned schedule. All routine operative notes were preserved and reviewed.

STATISTICAL ANALYSIS

Statistical analyses were performed using Jamovi (The Jamovi Project, 2024) (Computer Software) solid version 2.3.28. Retrieved from https://www.jamovi.org, Sydney, Australia. Continuous data were presented as mean±standard deviation, while categorical data were presented as frequency and percentages. Appropriate bivariate analyses were conducted using the Fisher's-exact test to determine the association between clinical and anatomical variables and the surgical approach adopted during cholecystectomy. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The mean age was 41.75±12.68 years. There were 151 (77%) female patients and 45 (23%) male patients [Table/Fig-1].

Variables	n (%)
Gender	
Female	151 (77)
Male	45 (23)
Number of stones in gallbladder	
Multiple	158 (80.6)
Single	38 (19.4)
Chronicity of the cases	
Chronic	169 (86.2)
Acute-on-chronic	27 (13.8)
Condition of gallbladder	
Mucocele	17 (8.7)
Empyema	8 (4.1)
Mucocele+Empyema	4 (2)
No mucocele or empyema	167 (85.2)

[Table/Fig-1]: Clinical profile of the patients undergone cholecystectomy (N=196).

The cystic artery was identified in all the patients. Among them, 189 (96.4%) patients had the cystic artery arising from the right hepatic artery. Of the 189 patients, a double cystic artery was found in 22 (11.2%) cases, in which the cystic artery, after originating from the right hepatic artery, soon divided into anterior and posterior branches [Table/Fig-2].

Variables	n (%)
Place of origin	
Right hepatic artery	189 (96.4)
Left hepatic artery	5 (2.6)
Common hepatic artery	2 (1.0)
Position in relation to the cystic duct	
Superomedial	176 (89.8)
Posterolateral	15 (7.7)
Anterior	5 (2.5)

[Table/Fig-2]: Distribution of patients according to the origin and position of cystic artery (N=196).

In the present study, 185 (94.39%) patients were managed laparoscopically without any significant perioperative complications. Nevertheless, the operative procedure had to be converted to open cholecystectomy in 11 (5.6%) patients. The major reason for converting to open cholecystectomy was dense adhesion at Calot's triangle, which resulted in poor visibility of structures in 5 (45.4%) patients. Among the others, uncontrolled haemorrhage from the cystic artery was the reason in 4 (36.4%) patients, and suspected injury to the bile duct was the reason in 2 (18.2%) patients.

During the analysis of the clinical and demographic profile, it was observed that the proportion of patients undergoing open cholecystectomy was higher in male patients than in female patients {Fisher's-exact test statistic=0.0196, p-value <0.05, degree of

freedom (df)=1}. It was found that the proportion of patients with pathological conditions such as mucocele, empyema, or both had a higher incidence of open cholecystectomy (24.1%) compared to those without such pathological conditions (2.4%), which was statistically significant (Fisher's-exact test statistic=0.0001, p-value <0.05, df=1) [Table/Fig-3].

Variables	Type of cholecystectomy		Total, n (%)	p-value, df
	Laparoscopic n (%)	Open n (%)		
Gender				
Male	39 (86.7)	6 (13.3)	45 (100.0)	0.0196*, df=1 (Fisher-exact test statistic)
Female	146 (96.7)	5 (3.3)	151 (100.0)	
Number of stones in gallbladder				
Multiple	150 (95.0)	8 (5.0)	158 (100.0)	0.4488, df=1 (Fisher-exact test statistic)
Single	35 (92.1)	3 (7.9)	38 (100.0)	
Chronicity of the cases				
Chronic	164 (97.0)	5 (3.0)	169 (100.0)	0011*, df=1 (Fisher-exact test statistic)
Acute-on-chronic	21 (77.8)	6 (22.2)	27 (100.0)	
Condition of gallbladder				
Mucocele	17 (100.0)	0	17 (100.0)	0.0002*, df=1 (Fisher-exact test statistic)
Empyema	5 (62.5)	3 (37.5)	8 (100.0)	
Mucocele+Empyema	0	4 (100.0)	4 (100.0)	
Others#	163 (97.6)	4 (2.4)	167 (100.0)	

[Table/Fig-3]: Association between clinical profile and type of cholecystectomy (N=196).
#Others mean no mucocele or empyema; *The p-value <0.05 was considered statistically significant; #in superscript

Among patients undergoing open surgery, no statistically significant difference was found between the proportions of patients with the origin of the cystic artery from the left hepatic artery (20%) and those with other origins of the cystic artery (5.3%). The proportion of patients undergoing open cholecystectomy was slightly higher among those with a single cystic artery compared to those with a double cystic artery (5.4% vs. 4.5%), but this difference was not found to be statistically significant [Table/Fig-4].

Variables	Type of cholecystectomy		Total, n (%)	p-value, df
	Laparoscopic, n (%)	Open, n (%)		
Place of origin (N=196)				
Right hepatic artery	179 (94.7)	10 (5.3)	189 (100.0)	0.3369, df=1 (Fisher-exact test statistic)
Left hepatic artery	4 (80.0)	1 (20.0)	5 (100.0)	
Common hepatic artery	2 (100.0)	0	2 (100.0)	
Position in relation to the cystic duct (N=196)				
Superomedial	165 (93.8)	11 (6.2)	176 (100.0)	NA
Posterolateral	15 (100.0)	0	15 (100.0)	
Anterior	5 (100.0)	0	5 (100.0)	
Number of cystic artery (n=189)*				
Single	158 (94.6)	9 (5.4)	167 (100.0)	1.0, df=1
Double	21 (95.5)	1 (4.5)	22 (100.0)	

[Table/Fig-4]: Association between anatomical profile of cystic artery and type of cholecystectomy.
*For patients in which the cystic artery had its origin from the right hepatic artery

DISCUSSION

In the recent era, laparoscopic cholecystectomy has been accepted as the gold standard technique, which has limited the acceptance of open cholecystectomy. However, vascular and biliary variations in Calot's triangle contribute to the majority of intraoperative complications during laparoscopic cholecystectomy. Knowledge of these possible variations will help prevent intraoperative and postoperative complications, ultimately decreasing mortality and morbidity [8].

The mean±SD age in the present study was 41.75±12.68 years. A study conducted by Farooq S et al., reported a mean±SD age of patients as 38.98±7.68 years, with a range of 27-65 years [3]. In the study conducted by Badshah M et al., the mean age of patients was 42.5 years, with a range of 20-65 years [9]. The mean±SD age of patients in the study conducted by Taimur M et al., was 48±13 years, with an age range of 19 to 88 years [10]. Another study by Talpur KA et al., found that the mean±SD age of patients was 39.85±18.82 years [11]. The slight variations in mean age may be attributed to differences in the effects of ethnic and demographic characteristics on the age of onset of chronic cholecystitis among different study settings.

There was a female preponderance in the present study, where 77% of the patients were females. Farooq S et al., reported that 84.5% of their study population was female [3]. However, Badshah M et al., reported a male preponderance (56%), which can be explained by differences in health-seeking behaviour and dietary habits of female patients in different socio-cultural contexts [9]. Taimur M et al., and Talpur KA et al., reported female predominance of 98% and 85%, respectively, similar to the findings of the present study [10,11].

The present study found single stones in 19.4% of cases. Farooq S et al., found a higher proportion of single stones (49.5%), probably due to differences in dietary patterns and other lifestyle factors among the study populations [3]. A similar finding was reported by Talpur KA et al., (20.3%) [11].

The present study reported acute on chronic cholecystitis and chronic cholecystitis in 13.8% and 86.2% of the cases, respectively. Farooq S et al., reported 14% of cases as acute on chronic cholecystitis and 52.75% as chronic cholecystitis [3], whereas Taimur M et al., reported acute on chronic cholecystitis in 7% of patients [10]. This difference can be explained by variations in health-seeking behaviour and dietary habits of patients in different socio-cultural contexts.

In the present study, the cystic artery was detected in 100% of cases. Farooq S et al., also identified the cystic artery in 100% of cases [3]. However, Taimur M et al., reported the absence of the cystic artery in 3% of the cases [10,12]. The present study found that the cystic artery originated from the right hepatic artery in 96.4% of cases and from the left hepatic artery in 2.6% of cases. Farooq S et al., reported that the most common source of the cystic artery was the right hepatic artery (90.25%), while the other sources included the left hepatic artery (6.75%) and the common hepatic artery (3%) [3]. Badshah M et al., reported that the cystic artery originated from the right hepatic artery in 92.4% of cases [9]. Hasan MA reported that the cystic artery originated from the right hepatic artery in 95.5% of cases, with its origin not being visualised in 1.5% of cases [12]. Taimur M et al., reported that the right hepatic artery was the source of the cystic artery in 96% of cases [10]. The findings from these other studies regarding the major origins of the cystic artery were consistent with the findings of the current study.

In the present study, a classical single cystic artery arising from the right hepatic artery was found in 85.2% of cases, while a double cystic artery was found in 11.2% of cases. Similarly, Farooq S et al., reported a single cystic artery in 92.25% of cases and a double cystic artery in 7.75% of cases [3]. Reported incidences of a single cystic artery were 91% and 95.5%, according to Taimur M et al., and Hasan MA, respectively [10,12]. Anatomical variations could be attributed to racial and ethnic differences among various study populations.

In the present study, the most common position of the cystic artery was superomedial to the cystic duct (89.8%), followed by posterolateral to the cystic duct (7.7%), while the least common position was anterior to the cystic duct (2.5%). Farooq S et al., reported that the cystic artery was superomedial to the cystic duct

(72.75%) as the most common position, followed by posterolateral (12%), and anterior was the least common position (3.75%) [3]. Fateh O et al., also reported superomedial (90.6%) and anterior (2.6%) as the extremes of the positions [7]. Similarly, Taimur M et al., reported superomedial as the most common position (88%) and anterior as the least common position (3%) [10]. All of these studies found the most common position of the cystic artery to be superomedial to the cystic duct and the least common position to be anterior to the duct. Such findings regarding the anatomical locations of the cystic artery in relation to the cystic duct are vital for the uneventful dissection of Calot's triangle to ensure safe cholecystectomy.

The authors would recommend conducting more studies, preferably longitudinal in design and with larger sample sizes, in other medical colleges across different geographic locations. This will help to better understand the ethnic and racial differences in anatomical variations of the cystic artery and their association with the type of cholecystectomy in a more comprehensive manner.

Limitation(s)

The biggest limitation of the present study is that it was conducted in only one medical college in the state, which limits its generalisability to the broader population.

CONCLUSION(S)

In conclusion, the most common position of the cystic artery was superomedial to the cystic duct, and the most frequent site of origin for the cystic artery was the right hepatic artery. Laparoscopic procedures were converted to open cholecystectomy in eleven patients, with the most common cause being dense adhesions at Calot's triangle. Significant associations were found between the conversion to open cholecystectomy and male gender, as well as, patients presenting with acute-on-chronic cholecystitis and pathological conditions of the gallbladder, such as empyema, mucocele, or both. Thus, the results of the present study have helped us identify the safe plane of dissection in Calot's triangle during laparoscopic cholecystectomy.

Authors' contribution: RS: Concept, design, data acquisition, data analysis, drafting of article, editing the article critically and approval to the final version. SD: Concept, design, data acquisition, data analysis, drafting of article, editing the article critically and approval to the final version. DD: Concept, design, data analysis and interpretation, drafting of article, editing the article critically and approval to the final version. SG: Concept, design, data analysis and interpretation, drafting of article, editing the article critically and approval to the final version. CS: Concept, design, data analysis and interpretation, drafting article, editing the article critically and approval to the final version.

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