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A Study of Variations in Origin of Cystic Artery and Relation of Cystic Artery to Biliary Ducts

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Abstract

Background and aims: The gallbladder and extra-hepatic biliary system are more often called for operative treatment as compared to any other intra-abdominal viscera, being second only to vermiform appendix. With the advent of laparoscopic cholecystectomy, sound knowledge of cystic artery and its variations has gained paramount importance. The very limited field of vision during laparoscopic surgeries can lead to intra- and post-operative complications, the most serious being haemorrhage and bile leakage. *Materials and Methods:* In the present study 40 adult cadavers were studied for site of origin of cystic artery and relations of cystic artery (origin) to Calot's triangle and to the biliary ducts. *Results:* In 23 cases, cystic artery originated from right hepatic artery, from proper hepatic artery in 8 cases, from superior mesenteric artery in 6 cases, from segmental branch of left hepatic artery in 2 cases and in 1 case from common hepatic artery. In 35 specimens cystic artery originated outside the Calot's triangle. In 28 specimens cystic artery was lying medial to cystic duct. In 27 specimens cystic artery was lateral to common hepatic duct and it passed anterior to common hepatic duct in 13 specimens. These variations are seen due to the alterations of the pattern of absorption of vessels during intrauterine life. *Conclusion:* The present study not only adds knowledge to the existing literature, but also, helps both the interventional radiologists and the surgeons in reducing the chances of injury to cystic artery and biliary ducts which usually lead to complications, morbidity and mortality.

Keywords: Cystic Artery; Calot's Triangle; Gallbladder; Cholecystectomy.

Introduction

The blood supply to the gallbladder, cystic duct, hepatic ducts and upper portion of the common bile duct is done by the cystic artery. The cystic artery normally arises from the right hepatic artery in the Calot's triangle. The cystohepatic triangle of Calot is an anatomical space bounded superiorly by the inferior surface of segment V of the liver, inferiorly by the cystic duct and medially by the common hepatic duct [1]. In 1891, Calot described this famous triangle as bounded by cystic duct, common hepatic duct/bile duct and cystic artery in its original description [2]. Later in 1981, Rocko and Di Gioia inferred that the triangle is bounded by cystic duct, common hepatic duct/bile duct and inferior surface of liver [3]. Hugh et al suggested that this triangle should be called the hepatobiliary triangle, with the small cystic artery branches supplying the cystic duct being called Calot's arteries [4]. The contents of this triangle are right hepatic artery, cystic artery, cystic lymph node of Lund and lymphatics.

Variations in the origin and course of the cystic artery are very common. The cystic artery most commonly arises from the right hepatic artery, but can also arise from left hepatic artery, proper hepatic artery, common hepatic artery, gastroduodenal artery, superior pancreaticoduodenal artery or superior mesenteric artery. The cystic artery may arise outside the Calot's triangle and then it passes anterior to the common hepatic duct [5].

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The course and length of the cystic artery in the Calot's triangle is variable, and it usually enters the gallbladder in the neck or body area. The cystic artery traverses through the centre of the triangle, but may at times be very close or even slightly inferior to the cystic duct. It further passes behind the common hepatic duct to reach the superior aspect of the neck of gallbladder, and then descends to the body [6]. On the body, the cystic artery divides into superficial branch that runs along the peritoneal surface (subserously) of the gallbladder, and a deep branch, which runs between the gallbladder and gallbladder fossa. These 2 branches anastomose and yield small branches that enter the gallbladder parenchyma [2]. In 25% of cases, the superficial and deep branches arise separately, deep branch usually from right hepatic and superficial from superior mesenteric artery [7].

Since the advent of laparoscopic cholecystectomy, a good knowledge of Calot's triangle is important as this triangle forms an imaginary reference area for all biliary surgeries. The variations in origin and course of the cystic artery can cause serious problems resulting from severe arterial bleeding during surgical procedures [6]. Cystic artery bleeding along with other intra-operative complications like injury to extra-hepatic bile duct leading to bile leakage are the most common cause for conversion of laparoscopic to open cholecystectomy. Poor identification of anatomical structures in the operation field along with the presence of anatomical variations contributes to the occurrence of major intra- and post-operative complications. Hence a thorough knowledge of Calot's triangle and its contents, both normal and its variations, is a must for surgeons operating in this area. The aim of this study was to evaluate the variations in the origin of cystic artery and the relation of cystic artery to the biliary ducts so as to help surgeons in avoiding injury to the cystic artery which usually leads to complications, morbidity and mortality.

Materials and Methods

The present study was carried out on 40 adult human preserved cadavers in the Department of Anatomy from January 2015 to February 2016. The abdomen was opened as per Cunningham's Manual, and after exploring the peritoneal cavity, the anterior layer of peritoneum was removed from the lesser curvature of the stomach. The cystic duct, right and left hepatic duct, common hepatic duct, common bile duct were traced, identified and dissected out. Boundaries of Calot's triangle were defined. Cystic artery, right hepatic artery, common hepatic artery and proper hepatic artery were identified [8]. The site of origin of the cystic artery and relation of its origin to the triangle were studied. The course of the cystic artery and the relation of the cystic artery to the common hepatic duct and bile duct were studied and noted. Variations found were recorded and photographed.

Results

In the present study of 40 specimens, the cystic artery originated from right hepatic artery in 23 specimens (57.5%), from proper hepatic artery in 8 specimens (20%), from superior mesenteric artery in 6 specimens (15%), from segmental branch of left hepatic artery in 2 specimens (5%) and from the common hepatic artery in 1 specimen (2.5%) (Table 1). Thus the site of origin of cystic artery varied. In 35 specimens (87.5%), the cystic artery originated outside the Calot's triangle, whereas in only 5 specimens (12.5%) it took origin within the triangle. Irrespective of the site of origin, in all the cases the cystic artery traversed through the triangle before reaching the gallbladder. Depending on the site of origin, the course and relation of the cystic artery to common hepatic or bile duct and to the cystic duct was different.

Out of the 23 specimens wherein the cystic artery originated from right hepatic artery (Figure 1), in 18 cases the site of origin was outside the Calot's triangle and in 5 specimens it was within the triangle. Where the site of origin was outside the triangle, in 15 specimens the cystic artery was crossing the common hepatic duct from the posterior aspect and in 3 specimens it crossed anteriorly. In the 5 specimens wherein the site of origin was within the triangle, the right hepatic artery crossed the common hepatic duct from posterior aspect in 3 specimens and from the anterior aspect in 2 specimens.

In 2 specimens the cystic artery originated from segmental branch of left hepatic artery outside the Calot's triangle and the segmental branch of left hepatic artery passed posterior to the common hepatic duct.

In 2 specimens the common hepatic artery trifurcated to give right hepatic, left hepatic and gastroduodenal arteries. In 1 case the cystic artery arose from right hepatic artery (Figure 1) and in the other case it was a branch of the segmental branch of left hepatic artery.

In 1 specimen, 2 cystic arteries were seen, 1 originating from the right hepatic artery and the other from segmental branch of left hepatic artery. They passed through the triangle parallel to each other up to the neck of the gallbladder (Figure 2).

In 8 specimens the cystic artery took origin from proper hepatic artery outside the triangle (Figure 3). In 6 cases the cystic artery was crossing the common hepatic duct from its posterior aspect and in 2 specimens from its anterior aspect.

In 1 specimen the cystic artery arose from the common hepatic artery outside the triangle and passed posterior to the common hepatic duct. In 6 specimens the cystic artery took origin from the superior mesenteric artery outside the triangle (Figure 4). In all these specimens the cystic artery was passing anterior to the bile duct (Table 2).

In 70% cases the cystic artery was medial to the cystic duct. In 67.5% of cases the cystic artery was lying lateral to the common hepatic duct and it passed anterior to the common hepatic duct in 32.5% of the

Table 1: Variation in the site of origin of cystic artery

Site of origin of Cystic Artery	Number of Cases (out of 40 cadavers)	Percentage (%)
Right Hepatic Artery	**23**	**57.5**
Proper Hepatic Artery	**8**	**20**
Superior Mesenteric Artery	**6**	**15**
Segmental branch of Left Hepatic Artery	**2**	**5**
Common Hepatic Artery	**1**	**2.5**

Table 2: Relation of site of origin of cystic artery to Calot's triangle and relation of cystic artery to common hepatic duct/bile duct

Site of Origin of cystic artery	Relation of origin to Calot's triangle	Relation to Common Hepatic Duct/Bile Duct	No. of cases with percentage
Right Hepatic Artery **(23)** **57.5%**	Outside the triangle: **18**	Cystic Artery to Common Hepatic Duct	Posterior: **15 (37.5%)** Anterior: **3 (7.5%)**
	Within the triangle: **5**	Right Hepatic Artery to Common Hepatic Duct	Posterior: **3 (7.5%)** Anterior: **2 (5%)**
Segmental branch of Left Hepatic Artery **(2)** **5%**	Outside the triangle: **2**	Segmental branch of Left Hepatic Artery to Common Hepatic Duct	Posterior: **2 (5%)** Anterior: **0**
Proper Hepatic Artery **(8)** **20%**	Outside the triangle: **8**	Cystic Artery to Common Hepatic Duct	Posterior: **6 (15%)** Anterior: **2 (5%)**
Common Hepatic Artery **(1)** **2.5%**	Outside the triangle: **1**	Cystic Artery to Common Hepatic Duct	Posterior: **1 (2.5%)** Anterior: **0**
Superior Mesenteric Artery **(6) 15%**	Outside the triangle: **6**	Cystic Artery to Bile Duct	Posterior: **0** Anterior: **6 (15%)**

Table 3: Comparison of site of origin of cystic artery with previous studies (RHA- Right Hepatic Artery, PHA- Proper Hepatic Artery, LHA- Left Hepatic Artery, CHA- Common Hepatic Artery, GDA- Gastroduodenal Artery, CT- Coeliac Trunk, SMA- Superior Mesenteric Artery, SPDA- Superior Pancreaticoduodenal Artery, ABRHA- Aberrant Right Hepatic Artery)

Sr. No.	Author	Year of Study	No. of cases	Site of origin of cystic artery (% of cases)									
				RHA	PHA	LHA	CHA	GDA	CT	SMA	SPDA	ABRHA	Others
1	Anson[13]	-	676	61.3	3.4	5.9	-	2.5	0.9	0.9	0.9	10.2	14
2	Flint[14]	1923	200	98	-	1.5	-	0.5	-	-	-	-	-
3	Daseler[15]	1947	580	71.5	-	6.2	2.7	2.6	0.35	0.1	-	16.4	-
4	Michels[16]	1956	200	77.5	-	5	1.5	4	-	-	-	12	-
5	DeSilva[17]	2001	50	96	-	4	-	-	-	-	-	-	-
6	Futura[18]	2001	110	75.5	-	4.5	-	7.3	-	-	-	-	12.7
7	Flisinski[19]	2004	34	82.3	8.8	5.8	-	2.9	-	-	-	-	-
8	Khalil[20]	2008	60	90	2	3	2	2	-	-	1	-	-
9	Bakheit[5]	2009	106	78	-	2	17	3	-	-	-	-	-
10	Pushpalata[21]	2010	50	54	22	-	12	8	-	2	-	2	-
11	Present study	2016	40	57.5	20	-	2.5	-	-	15	-	-	5

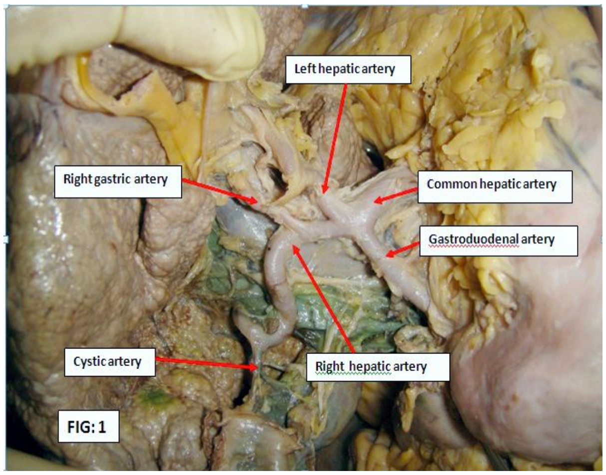

Fig. 1: Cystic artery arising from right hepatic artery; common hepatic artery trifurcating into right hepatic, left hepatic and gastroduodenal arteries

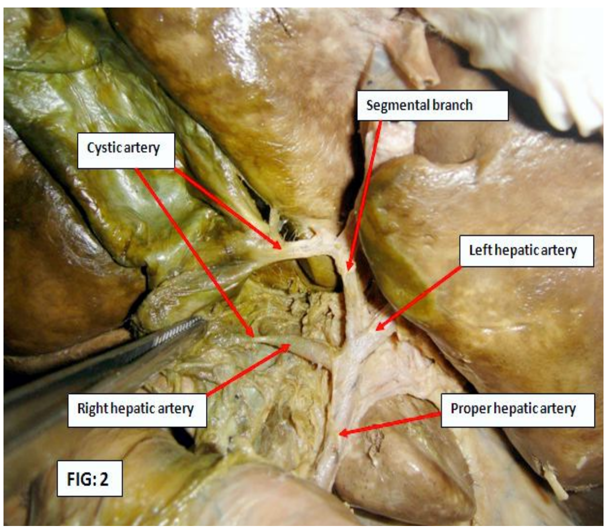

Fig. 2: Two Cystic arteries: one arising from right hepatic artery and one from segmental branch of left hepatic artery

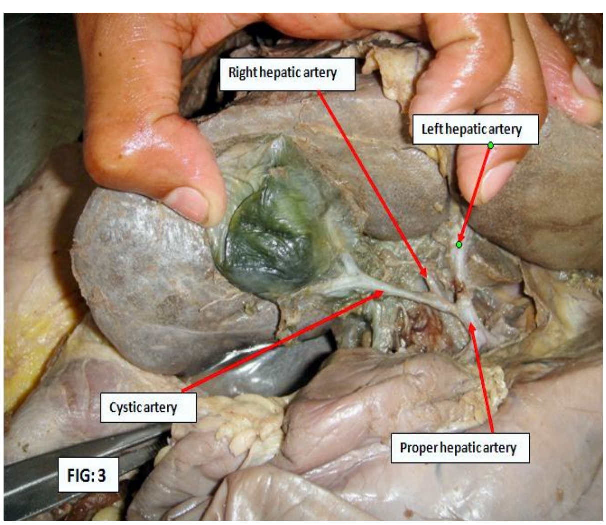

Fig. 3: Cystic artery direct branch from proper hepatic artery; right hepatic artery is branch of cystic artery

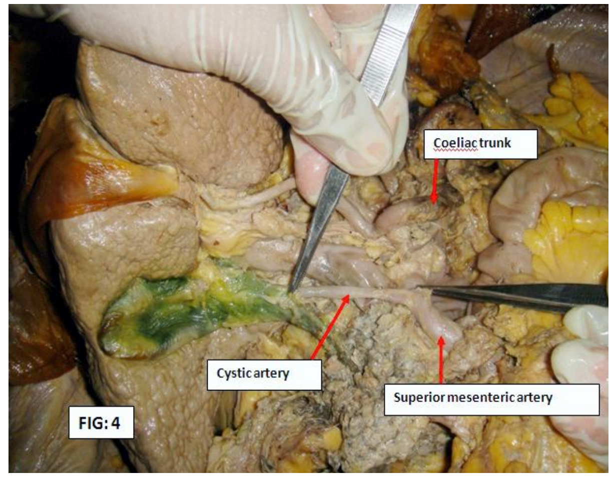

Fig. 4: Cystic artery arising from superior mesenteric artery

cases.

Discussion

The cystic artery is normally a branch of right hepatic artery and along with gallbladder it also supplies blood to common hepatic duct, hepatic ducts and upper portion of common bile duct through numerous small branches [9].

Embryologically, the liver and gallbladder develop from the hepatic diverticulum of foregut in the 4th week of intra-uterine life. This diverticulum has a rich blood supply from abdominal aorta and its branches. Most of these branches degenerate during its development leaving only the mature vascular system [10]. The simple branching pattern of the gastroduodenal and hepatobiliary vasculature is majorly altered by the growth of the liver and pancreas and also by the assumption of a curved form in the stomach and duodenum [11]. As the degeneration pattern is highly variable, hence there are variations in the blood supply of the liver and gallbladder. This explains the variations in origin of cystic artery from: right hepatic (63.9%), hepatic trunk (26.9%), left hepatic (5.5%), gastroduodenal (2.6%), superior pancreaticoduodenal (0.3%), right gastric (0.1%), coeliac trunk (0.3%), and superior mesenteric artery (0.8%) as are reported by Patil et al [12].

The origin of cystic artery in our study was from: right hepatic (57.5%), proper hepatic (20%), superior mesenteric (15%), segmental branch of left hepatic (5%) and common hepatic (2.5%). Table 3 shows the comparison of site of origin of cystic artery with previous studies. Our findings on the site of origin of cystic artery are similar to those of Pushpalata and Shamsundar and this could be due to regional similarity as both these studies were done in the region of Karnataka.

Ding et al in 2007 presented a new laparoscopic classification of anatomic variations of the cystic artery, which can be divided into 3 groups: Calot's triangle type, which includes single cystic artery and double cystic arteries; outside Calot's triangle type, which includes 4 variants: cystic artery originating from gastroduodenal artery; cystic artery originating from the variant right hepatic artery; cystic artery directly arising from the liver parenchyma; and, cystic artery originating from the left hepatic artery; and, compound type, wherein the cystic artery is situated within and outside the Calot's triangle [22]. Balija et al have classified cystic artery variations into 2 groups. Group I comprises 5 variations of the cystic artery within the hepatobiliary triangle: normal position; frontal cystic artery; backside; multiple; and, short. Group II consists of variations of the cystic artery that approaches the gallbladder beyond the hepatobiliary triangle and includes low-lying, transhepatic and recurrent cystic artery [23]. Ignjatovic et al have divided cystic artery into 3 types in minimally invasive surgical procedures as: type 1 showing normal anatomy; type 2 showing more than one artery in Calot's triangle; and, type 3 showing no artery in Calot's triangle [24]. These classifications are of great help to the surgeons and radiologists in proper identification of the contents of the Calot's triangle.

In the present study, the cystic artery was a content of the Calot's triangle in 34 specimens (85%). The study done by Tejaswi et al [25] in 2013 showed this to be 65% whereas Aristotle [26] in 2014 reported it to be 92.5%. Rahman and Anwar [27] in 2012 found the incidence of the same to be 96.65%.

We found the cystic artery lying medial to the cystic duct in 28 cases (70%). Tejawsi et al [25] have reported the same as 65%. In 27 cases (67.5%) we noted the cystic artery lying lateral to the common hepatic duct and it was passing anterior to the common hepatic duct in 13 cases (32.5%). These are comparable to the findings of Tejaswi et al [25] at 67% and 30% respectively.

The gallbladder and its duct are more often called for operative treatment as compared to any other intra-abdominal viscera, being second only to vermiform appendix. Currently laparoscopic cholecystectomy is a gold standard treatment for cholelithiasis as it has many advantages over open cholecystectomy. All the more so, on laparoscopic visualization, the anatomical structures and their relations are seen differently as compared to the conventional surgeries. Hence misinterpretation of anatomy as well as the presence of anatomical variations can contribute to major intra- and post-operative complications [2].

The most frequent complications are: haemorrhage or bile leakage [28], lost gall stones [29], and iatrogenic bile duct injuries [30]. Haemorrhage and bile leakage usually occurs due to variations in structures present in the Calot's triangle and are the most common cause for conversion to open cholecystectomy. Lost gall stones often lead to stones in the port site or the abdominal abscesses. Iatrogenic bile duct injuries are the most serious and important causes of morbidity after cholecystectomy [31]. Hence every surgeon should be familiar with the anatomical conditions in the Calot's triangle in order to achieve proper recognition, ligation and cutting of the cystic duct and cystic artery with its branches during gallbladder removal surgeries.

Conclusion

Variations in origin and course of the cystic artery are very common. Thorough knowledge of these variations and also of the relations of the cystic artery with the biliary ducts is essential in performing cholecystectomy, both, open and laparoscopic. This not only helps the interventional radiologists but also the surgeons, and also goes a long way in preventing intra- and postoperative complications like haemorrhage and bile leakage.

Our study adds to the existing knowledge and helps the surgeons to minimize the chances of complications during cholecystectomy.

Conflicts of Interest

The authors do not have any conflicts of interest.

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