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Anatomical variations and clinical relevance of cystic artery: a brief review

Abebe Ayalew Bekel

Department of Human Anatomy, College of Medicine and Health Sciences, Bahir Dar University, Ethiopia

SUMMARY

Although the cystic artery commonly originates from a right hepatic artery, variations in the origin and course of the cystic artery occur in 24.5% of people. The explanation for the variations of the cystic artery is found in the developmental pattern of the biliary system. Thus, the various origins of the cystic artery and its course concerning the Calot's triangle require the attention of surgeons in order to avoid iatrogenic injury of the bile ducts and vessels. Hence, the course of the cystic artery regarding hepatobiliary ducts has also to be noted by surgeons during cholecystectomy.

Key words: Cystic artery – Calot's triangle – Hepatobiliary ducts – Cholecystectomy

INTRODUCTION

As the cystic artery is the main blood supply of the cystic duct and gallbladder (Moore et al., 2013; Kankhare et al., 2016; Prasoon et al., 2018; Singombe et al., 2019; Patil et al., 2015), the surgical importance of the cystic artery goes hand in hand with the history of cholecystectomy (Dandekar and Dandekar, 2016). Although the first cholecystostomy was done on a 45-year-old woman with obstructive jaundice in 1878, the patient died on the eighth postoperative day due to massive internal hemorrhage (De, 2004). By 1890, the early modern surgeons were having doubts over the utility of cholecystectomy, but gradually cholecystectomy was accepted. But even after acceptance and wide application, the aura of apprehension remained with cholecystectomy because of recurring complications. The cystic artery always remained the center of attraction, as complications were centered on the key step of ligating and dividing the cystic artery (Dandekar and Dandekar, 2016). Open cholecystectomy remained the gold standard for symptomatic cholelithiasis for over a century. However, these days, the introduction of laparoscopic techniques to perform cholecystectomy has revolutionized this procedure (Prasoon et al., 2018; Dandekar and Dandekar, 2016; Almutairi and Hussain, 2009; De Silva and Fernando, 2014; Ding et al., 2007; Torres et al., 2009; Rashid et al., 2015; Duca et al., 2003; Kaushik, 2010). Although laparoscopic cholecystectomy has many advantages over open cholecystectomy, it stimulated a renewed interest in the anatomy of Calot's triangle (Zubair et al., 2012), because laparoscopic cholecystectomy has led to an increase in the injury of hepatobiliary structures (Almutairi and Hussain, 2009; Ding et al., 2007; Kaushik, 2010; Nagral, 2005; Radunovic et al., 2016). Blood vessel injuries during laparoscopic cholecystectomy, including cystic artery bleeding, result in conversion to open surgery in up to 1.9 % of cases, causing mortality of about 0.02 % (Polguj et al., 2014).

This is because the cystic artery varies in origin, course and number (Patil et al., 2015; Radunovic

Corresponding author: Abebe Ayalew Bekel (MSc.) Department of Human Anatomy, College of Medicine and Health Sciences, Bahir Dar University, Ethiopia. Phone: +251918169513; Fax: 251 /0582202025
E-mail: abebeayaleww@gmail.com

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et al., 2016). These variations have always attracted both the anatomists and surgeons (Bakheit, 2009). Therefore, it is important to recognize these variations during the operative procedure. Accordingly, accurate knowledge of variability in the anatomy of the cystic artery is important to prevent iatrogenic injuries and to manage complications once they occur. Hence, identifying the anatomical variability of the cystic artery is an important task for surgeons in all hepatobiliary surgical procedures.

BASIC ANATOMY OF CYSTIC ARTERY AND CALOT'S TRIANGLE

Misinterpretation of normal anatomy and anatomical variations contribute to the occurrence of major postoperative complications like biliary injuries following a cholecystectomy, the incidence being higher with laparoscopic cholecystectomy. This includes normal anatomy and variations of the biliary apparatus, as well as the arterial supply to the gallbladder (Flisinski et al., 2004). As standard anatomy textbooks and most studies have depicted, the cystic artery commonly arises from the right hepatic artery in the triangle of Calot (Fig. 1). On approaching the gallbladder, the cystic artery

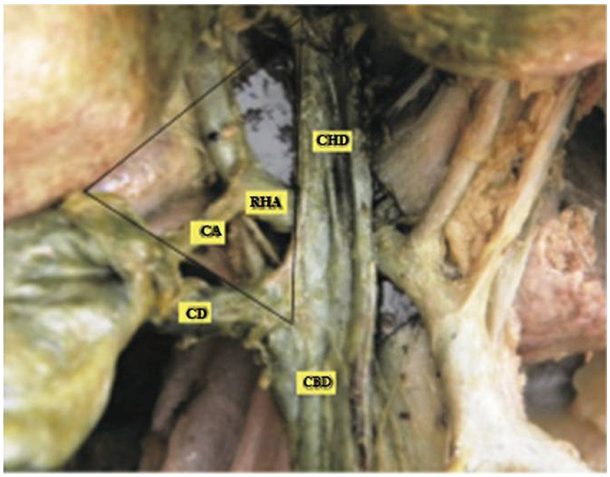

Fig 1. The cystic artery arises from the right hepatic artery in Calot's triangle: common bile duct (CBD), cystic duct (CD), cystic artery (CA), right hepatic artery (RHA), common hepatic duct (CHD).

divides into superficial and deep branches that run on the anterior and the posterior surface of the gallbladder (Fig. 2) (Eyni et al., 2015).

The Calot's triangle is a very important landmark for intraoperative localization of the cystic artery. Thus, a good knowledge of Calot's triangle is important for conventional and laparoscopic cholecystectomy (Dandekar and Dandekar, 2016; Ding et al., 2007). This triangle was described by Calot in 1891 (Zubair et al. 2012). The boundaries of Calot's triangle are the inferior surface of the right lobe of the liver superiorly, the cystic duct inferiorly and the common hepatic duct medially (Fig. 1) (Ding et al., 2007; Torres et al., 2009; Abeysuriya

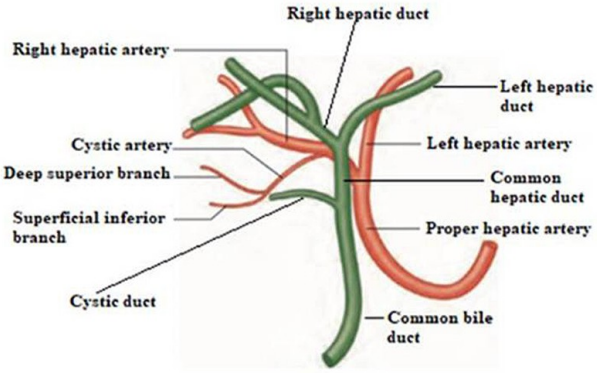

Fig 2. A picture showing the superficial and deep branch cystic artery.

et al., 2016). The most important content of the triangle is the cystic artery, the cystic lymph node, connective tissue, and lymphatics (Kankhare et al., 2016; Flisinski et al., 2004). This triangle also usually contains the right hepatic artery, and occasionally a bile duct (Abeysuriya et al., 2016). Occasionally, it may contain accessory hepatic ducts (Flisinski et al., 2004). Therefore, it is critical to perform an attentive dissection in this anatomical triangular area, before the ligation and division of the cystic duct and artery during cholecystectomy and common bile duct surgery (Dandekar and Dandekar, 2016; Torres et al., 2009).

VARIANT ANATOMY OF CYSTIC ARTERY

Although the cystic artery commonly (75.5%) originates from the right hepatic artery (RHA), variations in the origin and course of the cystic artery occur in 24.5% of people (Fig. 3) (Moore et al., 2013). The cystic artery may also arise from the left hepatic artery (LHA) (Kankhare et al., 2016; Singombe et al., 2019; Dandekar and Dandekar, 2016; Futara et al., 2001), gastroduodenal artery (GDA) (Kankhare et al., 2016; Bakheit, 2009; Futara et al., 2001; Sarkar and Roy, 2000), proper hepatic artery (PHA) (Kankhare et al., 2016; Singombe et al., 2019; Dandekar and Dandekar,

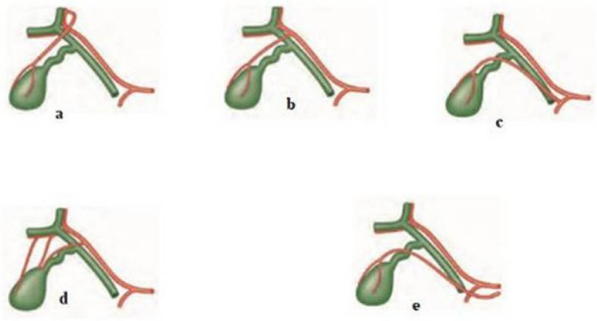

Fig 3. Shows variant anatomy of the cystic artery; **a)** the cystic artery arises from a left hepatic artery; **b)** the cystic artery arises from the proper hepatic artery; **c)** the cystic artery arises from the gastroduodenal artery; **d)** multiple cystic arteries; **e)** the cystic artery arises from celiac or right gastric arteries.

2016; Saidi et al., 2007), common hepatic artery (CHA) (Patil et al., 2015; De Silva and Fernando, 2014; Bakheit, 2009) or middle hepatic artery (MHA) (Dandekar and Dandekar, 2016; Futara et al., 2001). Rarely, it also arises from a superior mesenteric artery (SMA), right gastric artery (RGA) (Kankhare et al., 2016 ;), celiac trunk (CT) (Flisinski et al., 2004), or aberrant right hepatic artery (ARHA) (Dandekar and Dandekar, 2016). When cystic artery arises from GDA, CT, RGA or SMA, it may not traverse Calot's triangle (Standring, 2015).

The explanation for the variations in the cystic artery is found in the developmental pattern of the biliary system. Embryologically, the simple branching pattern of the gastroduodenal and hepatobiliary vasculature is profoundly altered by the growth of the liver and pancreas and by the assumption of a curved form in the stomach and duodenum. These factors operate to complicate the branching of the celiac axis and the proximal segment of the superior mesenteric artery. Considering that the liver is derived from a portion of the primitive duct supplied primordially by the celiac and mesenteric arteries, it may receive rami from both of these sources. The same is true from the gallbladder. The liver and gallbladder develop from a foregut endodermal hepatic diverticulum, which usually carries a rich supply of vessels from the abdominal aorta and its initial branches. Most of the vessels picked up from the abdominal aorta during development degenerate, leaving in place the mature vascular system. Because the pattern of degeneration is highly variable, the origin and branching pattern of the vessels to these organs also vary considerably. Considering the complexity of this developmental scheme, it is easy to understand the large degree of arterial variations within this vascular system. Knowledge of the different anatomical variations of the arterial supply of the gallbladder, liver and stomach is of great importance in hepatobiliary and gastric surgical procedures (Daseler, 1947; Flint, 1923; Moore et al., 2015; Sadler, 2011; Schoenwolf et al., 2014; Moore et al., 2018).

ORIGIN OF THE CYSTIC ARTERY

As explained earlier, the chief source of blood supply to the gallbladder and the cystic duct is the cystic artery. But it has a variation in origin. Knowledge and awareness of these variations are very essential for surgeons to avoid intraoperative and postoperative complications (Dandekar and Dandekar, 2016). The source of origin of the cystic artery is variable, as reported by different authors and shown in the table below (Table 1).

RELATIONS OF THE CYSTIC ARTERY TO CALOT'S TRIANGLE

The various origins of the cystic artery and its course with respect to Calot's triangle require the attention of surgeons in order to avoid iatrogenic injury of the bile ducts and vessels (Flisinski et al., 2004). The cystic artery usually arises from the right hepatic artery to the right of the common hepatic duct in Calot's triangle (Dandekar and Dandekar, 2016). When the cystic artery originates outside Calot's triangle, it crosses anterior to the common hepatic duct. This condition may create complications during surgery (Kankhare et al., 2016). The relation of cystic artery to Calot's triangle is described by different authors, as shown in

Table 1. Comparison of different studies with reference to the source of cystic artery

Authors	Number of samples studied	Source of cystic artery									
		RHA %	LHA %	GDA %	PHA %	CHA %	SMA %	RGA %	CT %	MHA %	ARHA %
Abeysuriya et al., 2016	200	100	0	0	0	0	0	0	0	0	0
Bakheit, 2009	160	78	2	3	0	17	0	0	0	0	0
Flisinski et al., 2004	34	82.34	5.88	2.94	0	0	0	0	8.82	0	0
Dandekar and Dandekar, 2016	82	79.3	1.2	0	3.7	2.5	0	0	0	1.2	12.1
Kankhare et al., 2016	40	70	5	10	7.5	0	5	2.5	0	0	0
De Silva and Fernando, 2014	50	96	0	0	0	4	0	0	0	0	0
Singombe et al., 2019	32	87.5	3.1	0	9.4	0	0	0	0	0	0
Futara et al., 2001	110	75.5	4.5	7.3	0	0	0	0	0	12.7	0
Saidi et al., 2007	102	92.2	0	0	7.8	0	0	0	0	0	0
Aristotle, 2014	40	92.5	0	0	5	2.5	0	0	0	0	0

Table 2. Comparison of different studies regarding the course of cystic artery in relation to Calot's triangle

Authors	Number of samples studied	Relation of cystic artery with the Calot's triangle	
		Inside (%)	Outside (%)
Abeysuriya et al., 2016	200	89	21
Bakheit, 2009	160	32	68
Flisinski et al., 2004	34	97.06	2.94
Dandekar and Dandekar, 2016	82	96.4	3.6
Kankhare et al., 2016	40	95	5
Singombe et al., 2019	32	84.3	9.4
De Silva and Fernando, 2014	50	100	0
Rashid et al., 2015	176	76.4	23.86
Futara et al., 2001	110	89	11

the table below (Table 2).

RELATIONS OF THE CYSTIC ARTERY TO HEPATOBILIARY DUCTS

Available literature revealed that the cystic artery commonly (75.5%) passes posterior to the common bile duct (Fig. 4a). It may also pass over the common hepatic duct (Fig. 4b), and most rarely on the left side of the cystic duct (Kankhare et al., 2016). The knowledge of these variations in the origin and cause of cystic artery is important for the surgeons, as uncontrolled bleeding from the cystic artery and its branches can be fatal during cholecystectomy. The relation of the course of the cystic artery to the hepatobiliary ducts is illustrated by different studies, as shown in the table given below (Table 3).

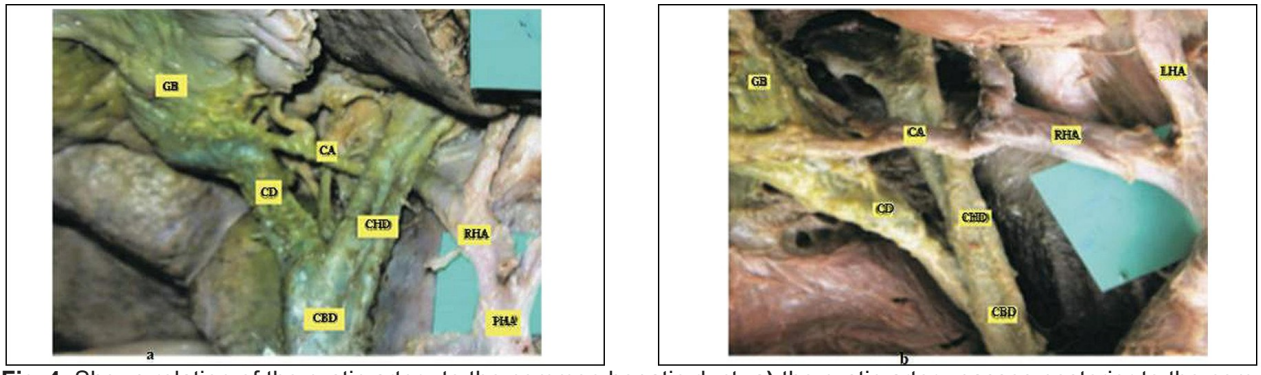

Fig 4. Shows relation of the cystic artery to the common hepatic duct; **a)** the cystic artery passes posterior to the common hepatic duct; **b)** the cystic artery passes anterior to the common hepatic duct: common bile duct (CBD), cystic duct (CD), cystic artery (CA), right hepatic artery (RHA), left hepatic artery (LHA), common hepatic duct (CHD), Gallbladder (GB).

Table 3. Comparison of different studies concerning the course of cystic artery with regard to hepatobiliary ducts

Authors	Number of samples studied	Relation of cystic artery with hepatobiliary ducts			
			Anterior (%)	Posterior (%)	Remark
Abeysuriya et al., 2016	200	Common hepatic duct	5	89	5% of cystic artery were given off in a Calot's triangle
		Cystic duct	1	-	
Bakheit, 2009	160	Common hepatic duct	7	25%	
		Cystic duct	53	13	
		Bile duct	2	-	
Dandekar and Dandekar, 2016	82	Common hepatic duct	26.8	6.1	62.2% of cystic artery were given off in a Calot's triangle
		Bile duct	1.2	3.7	
Kankhare et al., 2016	40	Common hepatic duct	10	90	
Saidi et al., 2007	102	Common hepatic duct	45.1	46.1	2% of cystic artery were given off in a Calot's triangle
		Bile duct	2.9	3.9	
Flisinski et al., 2004	34	Common hepatic duct	29.4	67.66	2.94% pass on the left side of cystic duct

CONCLUSION

The cystic artery is the chief blood supply of the gallbladder. It is a key anatomical structure to be identified and ligated during cholecystectomy. Since it has significant anatomical variations, possible complications are known to occur during the search, dissection, or ligation of the cystic artery. It is crucial for the surgeon to give careful attention, identify, and confirm the cystic artery before ligation. The explanation of the anatomical variations of the cystic artery is associated with the developmental pattern of the biliary system. Hence, detailed knowledge of the normal as well as the variant anatomy of the cystic artery is crucial to minimize iatrogenic injuries that occur during the operative procedure of the hepatobiliary structures.

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