



## Original

# Clinicoanatomical Study of Blood Supply of Extrahepatic Biliary Ductal System

Sachin Patil<sup>1</sup>, Kumkum Rana<sup>2</sup>, Smita Kakar<sup>3</sup> and A K Mittal<sup>4</sup>

<sup>1</sup>Senior Resident, Dept of Anatomy, MAMC

<sup>2</sup>Professor, Dept of Anatomy, North DMC Medical College

<sup>3</sup>Director/Professor, Dept of Anatomy, MAMC

<sup>4</sup>HOD, Dept of Forensic medicine, VMMC & Safdarjung Hospital, New Delhi

## ARTICLE INFO

Received 14 June 2014

Received in revised form 22 June 2014

Accepted 27 June 2014

### Keywords:

Cystic artery,  
Extra hepatic,  
Bile ducts,  
Variations,  
Laparoscopic cholecystectomy.

**Corresponding author:** Department of Anatomy Maulana Azad Medical College, Bahadur shah zafar marg, New Delhi-110002, India

**E-mail address:** [drsachin6880@gmail.com](mailto:drsachin6880@gmail.com)

## ABSTRACT

The major blood supply of extrahepatic biliary ductal system is by cystic artery, which supplies to cystic duct, common hepatic duct and the upper part of the common bile duct. The lower part of bile duct is supplied by gastroduodenal artery. The present study is aimed at determining the anatomical variations of blood supply of extrahepatic biliary ductal system and its clinical implications. The present study of the blood supply of extrahepatic biliary ductal system has been conducted on 30 cadavers. After exposing the abdominal cavity and removing peritoneal fat, extrahepatic biliary system and its blood supply was carefully dissected and relevant photographs were taken. Special attention was given to the relationship of the cystic artery to the Calot's triangle. Along with the arteries, the variations in the venous drainage were also noted. Major importance of knowledge of blood supply of extrahepatic biliary ductal system may well lie in the understanding of the etiology of postoperative bile duct strictures and in their prevention. A clear understanding of the major arterial supply to the extrahepatic bile ducts should be of assistance in biliary reconstruction and treating hemobilia.

© 2014 British Biomedical Bulletin. All rights reserved

## Introduction

The cystic artery is the chief source of blood supply to gallbladder, cystic duct, common hepatic duct and the upper part of the bile duct. The lower part of bile duct is supplied by ascending marginal vessels derived from the postero-superior

pancreaticoduodenal artery. The right and left hepatic ducts are supplied by the right and left hepatic arteries and their sectoral or segmental branches.<sup>1,2</sup>

Knowledge of relevant anatomy is important for the safe execution of any

operative procedure. Specifically, in the context of a cholecystectomy, it has been recognized since long that misinterpretation of normal anatomy as well as the presence of anatomical variations contribute to the occurrence of major postoperative complications especially biliary injuries. There is now a fair amount of data to suggest that the acceptance of laparoscopic cholecystectomy as the standard procedure has led to an increase in bile duct injuries. This seems partly related to the different anatomical exposure of the area around the gallbladder especially the Calot's triangle during the laparoscopic procedure as opposed to the open procedure.<sup>3</sup>

The Calot's triangle is an anatomical space bounded superiorly by the inferior border of the liver, inferiorly by the cystic duct and medially by the right hepatic duct. The most common variant of Calot's triangle, which is bounded medially by the common hepatic duct, was adopted, and currently the name 'hepatobiliary triangle' is suggested.<sup>4</sup>

Major importance of knowledge of blood supply of extrahepatic biliary system may well lie in the understanding of the etiology of postoperative bile duct strictures and in their prevention.<sup>5</sup>

## Materials and Methods

The present study of the blood supply of extrahepatic biliary ductal system has been conducted on 30 cases: Cadavers (15) in the Departments of Anatomy, Maulana Azad Medical College and Bodies (15) undergoing post-mortem in the Department of Forensic Medicine and Toxicology, Maulana Azad Medical College, New Delhi. Before the commencement of study, the research proposal was reviewed and approved by a human research ethics committee of college. In cadavers, all the observations were taken when the abdomen was opened for

dissection for academic purpose, before the disturbance of liver and extrahepatic biliary ductal system by students. Abdominal cavity was exposed by making a midline incision from xiphoid process to the pubic symphysis and carrying this incision to the right anterior superior iliac spine. After exposing the abdominal cavity and removing peritoneal fat, extrahepatic biliary system was carefully dissected and relevant photographs were taken. Special attention was given to the relationship of the cystic artery to the Calot's triangle. Along with the arteries, the variations in the venous drainage were also noted. In post-mortem cases, all the observations were taken before removal of abdominal viscera for post mortem examination. These observations were taken in similar manner to those taken in cadavers.

## Observation and Results

The cystic artery was the chief source of blood supply to cystic duct, common hepatic duct and the upper part of the common bile duct. The lower part of common bile duct was supplied by the branches of gastroduodenal artery and posterosuperior pancreaticoduodenal artery. Our study showed that in all the cases the right and left hepatic ducts were in the substance of liver. Hence their blood supply was not included in the study. The origins of the cystic artery were from the right hepatic artery in half of the cases (50%) which was very low as compared to other studies. In other cases (50%), the cystic arteries arose from the hepatic artery proper (40%), the common hepatic artery (3.3%), the celiac trunk (3.3%), or the gastroduodenal artery (3.3%) (**Figure 1-2**).

In 86.6 % (26 out of 30) of all the cases studied, the cystic artery coursed through the Calot's triangle to reach the gallbladder. Only in 13.3% (4 out of 30) of the cases did the cystic artery not pass

through the triangle. In our study 36.6 % (11 out of 30) of all the cystic arteries ran posterior to the common hepatic duct as they entered the Calot's triangle. 40 % (12 out of 30) of the cystic arteries ran anterior to the common hepatic duct. 23.3 % (7 out of 30) of cystic arteries were not related to common hepatic duct. Our study have shown that the cystic artery was a single vessel in as much as 93.3% (28 out of 30 cases). Our study showed double cystic artery in 6.6% (2 out of 30) (Figure 3).

The gastroduodenal artery was a source of the cystic artery in 3.3% (1 out of 30) cases. The origin of the cystic artery from the trunk of the proper hepatic artery, was observed in this research in 40 % (12 out of 30) cases, which is very high as compared to other studies. The common hepatic artery was a source of the cystic artery in 3.3% (1 out of 30) cases. The celiac trunk was a source of the cystic artery in 3.3% (1 out of 30) cases. Derivation of the cystic artery from the left hepatic artery was not seen in any of our cases. In most of the cases two cystic veins were draining the venous blood from the gall bladder (93.3%). These cystic veins entered the liver in most of the cases (89.2%). In some cases the veins drained into the portal vein outside the liver (10.7%). The common hepatic duct, cystic duct and common bile duct drained directly into portal vein through small veins in all the cases. The venous drainage of RHD and LHD cannot be studied because the ducts were present in the substance of liver and common hepatic duct was form within the liver. (Figure 4)

## Discussion

Arteries distributed to the extrahepatic biliary system show great variability in size and it is difficult to treat hemorrhages during or after biliary operations. The cystic artery originates from the following sources: right hepatic (63.9%), hepatic trunk (26.9 %), left hepatic (5.5%), gastroduodenal (2.6%),

superior pancreaticoduodenal (0.3%), right gastric (0.1 %), celiac trunk (0.3 %) and superior mesenteric artery (0.8%).<sup>6,7</sup>

The cystic artery may arise from any of the above-mentioned arteries, but it usually arises from the right hepatic artery, which is one of the terminal branches of the proper hepatic artery. The cystic artery from the right hepatic artery is usually given off in the Calot's triangle. It has a variable length and enters the gallbladder in the neck or body area. The course and length of the cystic artery in the Calot's triangle is variable. Although classically the artery traverses the triangle almost through its center, it can occasionally be very close or even lower than the cystic duct. The cystic artery passes behind the common hepatic duct (CHD) to the superior aspect of the gallbladder's neck, where it descends to the body of gallbladder. It bifurcates into a superficial branch, running along the peritoneal surface (subserously) of the gallbladder, and a deep branch, which runs between the gallbladder and the gallbladder fossa. The two arteries anastomose and yield small branches that enter the gallbladder parenchyma.<sup>3,6,8</sup>

During development, the extra-hepatic biliary system arises from an intestinal diverticulum, which carries a rich supply of vessels from the aorta, coeliac trunk and superior mesenteric artery. Later most of these vessels are absorbed, leaving in place the mature vascular system. As the pattern of absorption is highly variable, it is not unusual for the cystic artery and its branches to derive from any other artery in the vicinity (Nowak, 1977).<sup>7</sup>

In our study the origins of the cystic artery were from the right hepatic artery in half of the cases (50%). In other cases (50%), these arose from the hepatic artery proper, the common hepatic artery, the celiac trunk, or the gastroduodenal artery. Table 1 shows the origin of cystic artery in different studies.

Out of the 30 cases we studied, 21 cases were male while rests of the 9 cases were female cadavers. In 21 cases of male cadavers, cystic artery arose from right hepatic artery in 10 cases, from hepatic artery proper in 9 cases and from gastroduodenal artery and common hepatic artery in 1 cases each. Out of the 9 cases in female cadavers, cystic artery originated from the right hepatic artery in 5 cases, from hepatic artery proper in 3 cases and from celiac trunk in 1 case.

In 86.6 % (26 out of 30) of all the cases studied, the cystic artery coursed through the Calot's triangle to reach the gallbladder. Only in 13.3% (4 out of 30) of the cases did the cystic artery not pass through the triangle. In 89.2% (25 out of 28) of the cases in which the cystic artery originated from the hepatic artery (the right, proper, or common hepatic arteries), it ran through the Calot's triangle. In the rest of the 10.8% (3 out of 28) cases it did not pass through the triangle. In those cases where the cystic arteries originated from the right hepatic artery, 86.6 % (13 out of 15) coursed through the Calot's triangle and 13.4 % (2 out of 15) did not passed through the Calot's triangle. In 91.7% (11 out of 12) of the cases in which the cystic artery originated from the hepatic artery proper, the cystic artery ran through the Calot's triangle. Only in 8.3% (1 out of 12) of the cases in which the cystic artery originated from the hepatic artery proper did the cystic artery not pass through the triangle. However, in the only case in which the cystic artery originated from gastroduodenal artery, it did not passed through the Calot's triangle. Table 2 shows the relation of cystic artery to calot's triangle in different studies.

In our study 36.6 % (11 out of 30) of all the cystic arteries ran posterior to the common hepatic duct as they entered the Calot's triangle, 40 % (12 out of 30) ran anterior to the common hepatic duct, while 23.3 % (7 out of 30) were not related to

common hepatic duct. Of the cystic arteries that arose from the right hepatic artery, 20 % (3 out of 15) ran posterior to the common hepatic duct as they entered the Calot's triangle, and 40 % (6 out of 15) ran anterior to the common hepatic duct while 40 % (6 out of 15) were not related to common hepatic duct. Those arteries that arose from the hepatic artery proper, 50 % (6 out of 12) ran posterior to the common hepatic duct and 50% (6 of 12) anterior to the common hepatic duct. The cystic arteries that arose from the common hepatic artery and celiac trunk ran posterior to the common hepatic duct as they entered the Calot's triangle. Table 3 shows the relation of cystic artery to common hepatic duct (CHD) in different studies.

Our study has shown that the cystic artery was a single vessel in 93.3 % (28 out of 30) cases. This number is less compared with Osemlak's and Siwek's result of 99.26%. Our study showed double cystic artery in 6.6% (2 out of 30). Suzuki *et al.* observed a double cystic artery in laparoscopic material in 11.1% of cases, and Balija *et al.* in as many as 21.1%, with one case (0.1%) of a triple cystic artery. Bergamaschi found two cystic arteries in a 4% corrosion cast of human cadavers.<sup>9,10</sup> Table 4 shows the incidence of double cystic artery in different studies.

In the present work we observed that the cystic artery originated from the right hepatic artery in 50 % (15 out of 30) cases which is very less as compared with the results of Osemlak and Siwek (83.7%), Chen *et al.* ( 86.1% ) and Futara *et al.* (75.5%). The origin of the cystic artery from the trunk of the proper hepatic artery, observed in this research is in 40 % (12 out of 30) cases, which is very high as compared to study by Osemlak and Siwek who reported it in 8.15%. Derivation of the cystic artery from the left hepatic artery was not seen in any of our cases. The origin of the cystic artery from left hepatic artery was described by Osemlak and Siwek in 0.74% and Futara *et al.* in 1.8%

of cases. The gastroduodenal artery was a source of the cystic artery from 3.3% (1 out of 30) cases. It should be emphasised that the origin of the cystic artery from the gastroduodenal artery both in our results and in those of Sarkar and Roy involved its long trunk running out of Calot's triangle.<sup>10-12</sup>

Study by Saidi, Karanja and Ogengo suggest a relatively more constant anatomy in their cohort studies than those in an American series where aberrant cystic arteries (origin other than right hepatic artery) occurred in 21% of cases and that for Ethiopians with a 24.5% prevalence of aberrant cystic arteries. The higher prevalence of aberrant cystic artery origins 50 % (15 out of 30) in this study is also at variance with a rate of 23.4% reported among Chinese subjects. These wide variations are due to methodologic differences but possibly also to actual population differences. Mlakar *et al.* (2003) reported an even lower prevalence (53%) for origin from the right hepatic artery in a Slovenian population, but these authors had a separate category for their origins from sectoral branches of the right hepatic artery. Cystic arteries originated from these sectoral vessels in 21% of cases. Saidi, Karanja and Ogengo did not find any subjects with an aberrant origin from the left hepatic, gastroduodenal, celiac, and superior mesenteric arteries, which are said to occur in 20% of dissections.<sup>7,13</sup>

Cystic artery bleeding is a troublesome complication during laparoscopic cholecystectomy, which increases the rate of conversion to open surgery. If surgery is performed incorrectly, injury to the extrahepatic bile duct or intra-abdominal organs is inevitable. The reported incidence of conversion to open surgery because of blood vessel injuries is approximately 0%-1.9% during laparoscopic cholecystectomy, and its mortality is about 0.02%. Safe laparoscopic cholecystectomy

demands a good knowledge of the anatomy of the cystic artery and its variations.<sup>14</sup>

## Conclusion

To facilitate the safe operative procedures on the liver and gall bladder, there is a need of exact and comprehensive knowledge of the varied patterns of hepatic and cystic arteries. Because variations are very common in hepatic and Cystic arteries. Sound knowledge will allow the surgeons to practice safe laparoscopic or open cholecystectomy, liver resections and vascular recombination in transplantation and there by avoid errors and patient morbidity. A good knowledge of Calot's triangle is important for conventional and laparoscopic cholecystectomy

## References

1. Vellar ID. The blood supply of the biliary ductal system and its relevance to vasculobiliary injuries following cholecystectomy. *Aust N Z J Surg*.1999 Nov;69(11):816-20.
2. Standring S. Grays Anatomy 40th Edition; Elsevier Churchill Livingstone 2008. Gallbladder and biliary tree, vascular supply and lymphatic drainage: 1180.
3. Nagral S. Anatomy relevant to cholecystectomy. *Journal of Minimal Access Surgery* 2005 Jun; 1(2):53-8.
4. Torres K, Chroscicki A, Golonka A, Torres A, Staskiewicz G, Palczak R, Ceja-Sanchez J M, Ceccaroni M, Drop A. The course of the cystic artery during laparoscopic cholecystectomy. *Folia Morphol*. 2009;68(3):140-3.
5. Northover J M A, Terblanche J. A new look at the arterial supply of the bile duct in man and its surgical implications. *Br J Surg*; 66 (6):379 – 384.
6. Chen TH, Shyu JF, Chen CH, Ma KH, Wu CW, Lui WY, Liu JC. Variations of the cystic artery in Chinese adults. *Surg Laparosc Endosc Percutan Tech*. 2000 Jun; 10(3):154-7.



7. Sarkar A K, Roy T S. Anatomy of the cystic artery arising from the gastroduodenal artery and its choledochal branch –a case report. *J Anat* 2000;197:503-6.
8. Loukas M, Fergurson A, Louis RG Jr, Colborn GL. Multiple variations of the hepatobiliary vasculature including double cystic arteries, accessory left hepatic artery and hepatosplenic trunk: a case report. *Surg Radiol Anat*. 2006 Oct; 28(5):525-8.
9. Balija M, Huis M, Nikolic V, Stulhofer M. Laparoscopic Visualization of the Cystic Artery Anatomy. *World J Surg*. 1999; 23:703-7.
10. Flisinski P, Szpinda M, Flisinski M. The cystic artery in human fetuses. *Folia Morphol*. 2004; 63(1):47-50.
11. Futara G, Ali A, Kinfu Y. Variations of the hepatic and cystic arteries among Ethiopians. *Ethiop Med J*. 2001 Apr; 39(2):133-42.
12. Chen W J, Ying D J, Liu Z J, He Z P. Analysis of the arterial supply of the extrahepatic bile ducts and its clinical significance. *Clinical anatomy* 1999; 12:245-9.
13. Saidi H, Karanja TM, Ogengo JA. Variant anatomy of the cystic artery in adult Kenyans. *Clin Anat*. 2007 Nov; 20(8):943-5.
14. Ding YM, Wang B, Wang WX, Wang P, Yan JS. New classification of the anatomic variations of cystic artery during laparoscopic cholecystectomy. *World J Gastroenterol*. 2007 Nov 14; 13(42):5629-34.

**Table 1:** Origin of cystic artery from different sources

STUDY	CASES	RHA	LHA	HAP	CHA	GDA	CT	SMA	AB RHA
Percentage (%)									
Flint <i>et al</i> 1923 (British )	200	98	0.5	0	0	0.5	0	0	0
Daseler <i>et al</i> 1947 (American)	580	71.7	2.6	0	2.7	2.6	0.35	0.1*	16 *
Michels N A 1953 (American )	200	77.5	4*	0	1.5	4	0	0	12 *
Desilva <i>et al</i> 2001 (Srilanka)	50	96	0	0	0	0	0	0	0
Flisnski <i>et al</i> 2004 (Poland)	34	82.3	2.5	8.8	0	2.9	0	0	0
Khalil M 2008 (Bangladesh)	60	90	2	2	2	2	0	0	0
Present Study 2011 (Indians )	30	50 *	0	40 *	3.3	3.3	3.3 *	0	0

Note –RHA-Right Hepatic Artery, LHA- Left Hepatic Artery, HAP-Hepatic Artery Proper, CHA-Common Hepatic Artery, GDA-Gastroduodenal Artery, CT-Celiac Trunk ,SMA-Superior Mesenteric Artery, AB RHA- Aberrant RHA

**Table 2:** Relation of cystic artery to calot's triangle

Study	Cases	Within Calot's	Outside Calot's
Michels N A, 1953 (American)	200	81%	19%
Daseler <i>et al</i> , 1947 (American)	580	69.8%	31.2%*
Desilva <i>et al</i> , 2001 (Srilanka)	50	86%	14%
Futura <i>et al</i> , 2001, (Ethiopian)	110	89%	11%
Flisnski <i>et al</i> , 2004 (Poland)	34	97.06%	2.94%
Present study, 2011	30	86.6%	13.3%

\*Dissection of Calot's triangle and cystic artery is essential step in cholecystectomy

**Table 3:** Relation of cystic artery to common hepatic duct (CHD)

STUDY	CASES	Anterior to CHD	Posterior to CHD	NOT RELATED
Daseler <i>et al</i> , 1947 (American)	580	21.2%	52.4%	26.4%
Futura <i>et al</i> , 2001, (Ethiopian)	110	28.2%	10.9%	60.9%*
Flisnski <i>et al</i> , 2004 (Poland)	34	29.4%	66.7%*	----
Present study, 2011	30	40 %*	36%*	23.3%

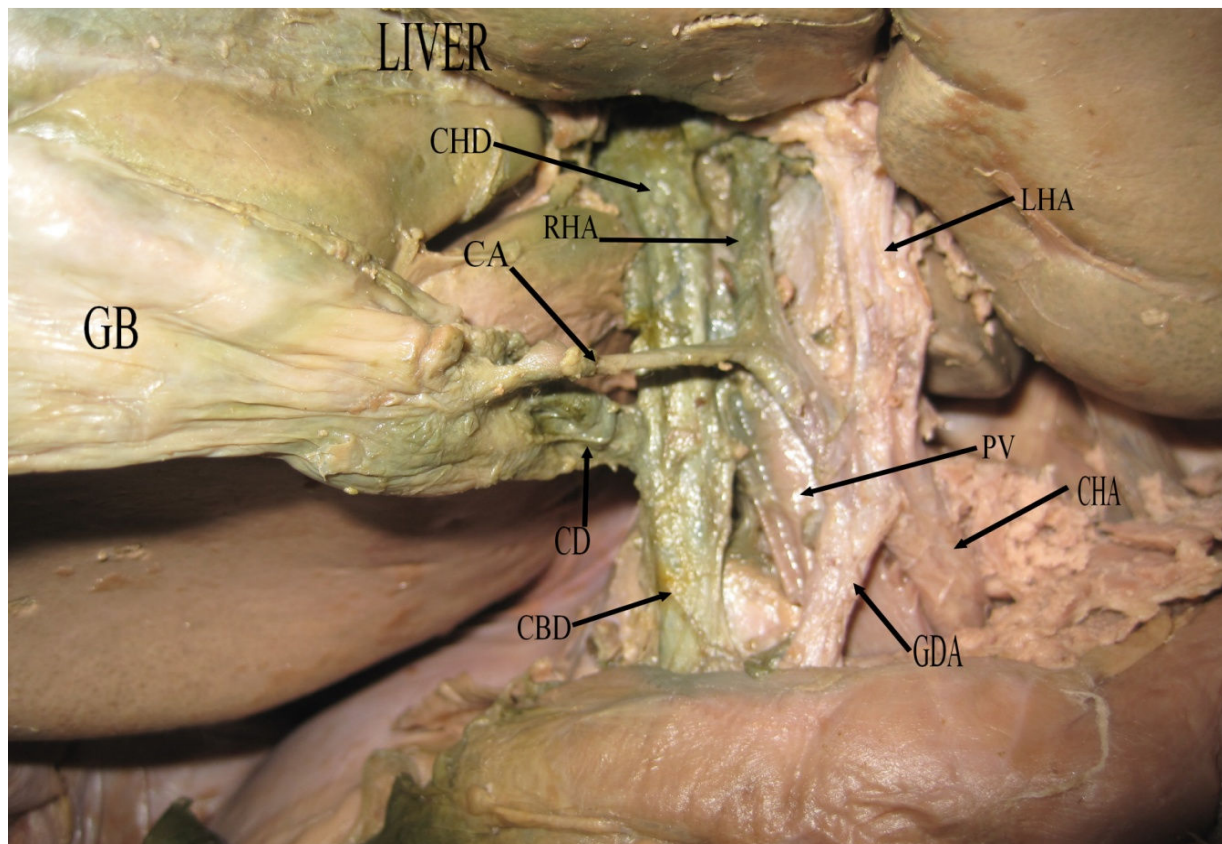
\*CHD are often mistaken for the cystic artery &are accidentally ligated which can lead to life threatening complications

**Table 4:** Double cystic arteries

STUDY	CASES	INCIDENCE OF DOUBLE CYSTIC ARTERIES
Flint <i>et al</i> , 1923 (British )	200	15.5 %
Daseler <i>et al</i> , 1947 (American)	580	14 %
Michels N A,1953 (American )	200	25 %
Present study, 2011 (Indian )	30	6.6%

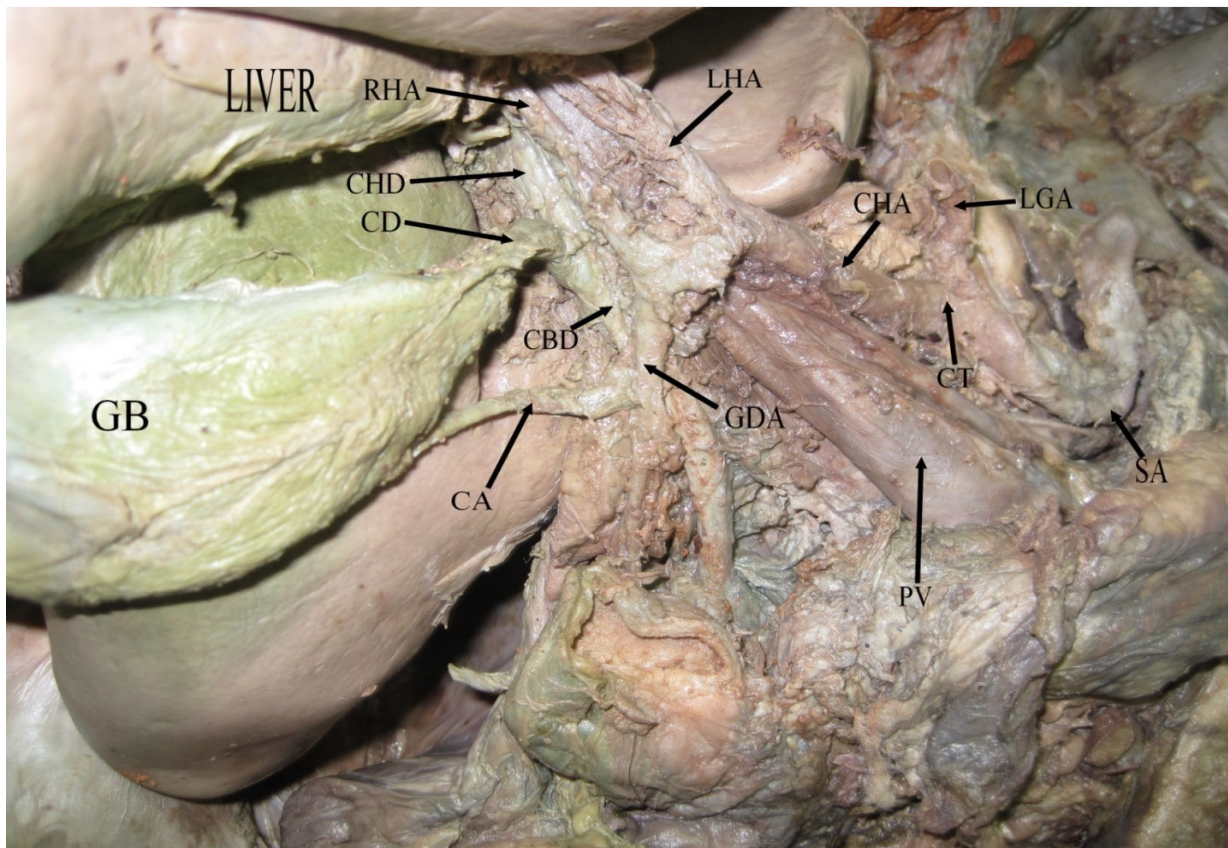
\*Uncontrolled bleeding from the second cystic artery is a serious problem





**Figure 1.** Cystic artery arising from right hepatic artery, passing anterior to the common hepatic duct, running through the Calot's triangle and reaching gall bladder. Common hepatic artery arising from celiac trunk dividing into right hepatic artery, left hepatic artery and gastroduodenal artery. Hepatic artery proper is not present.

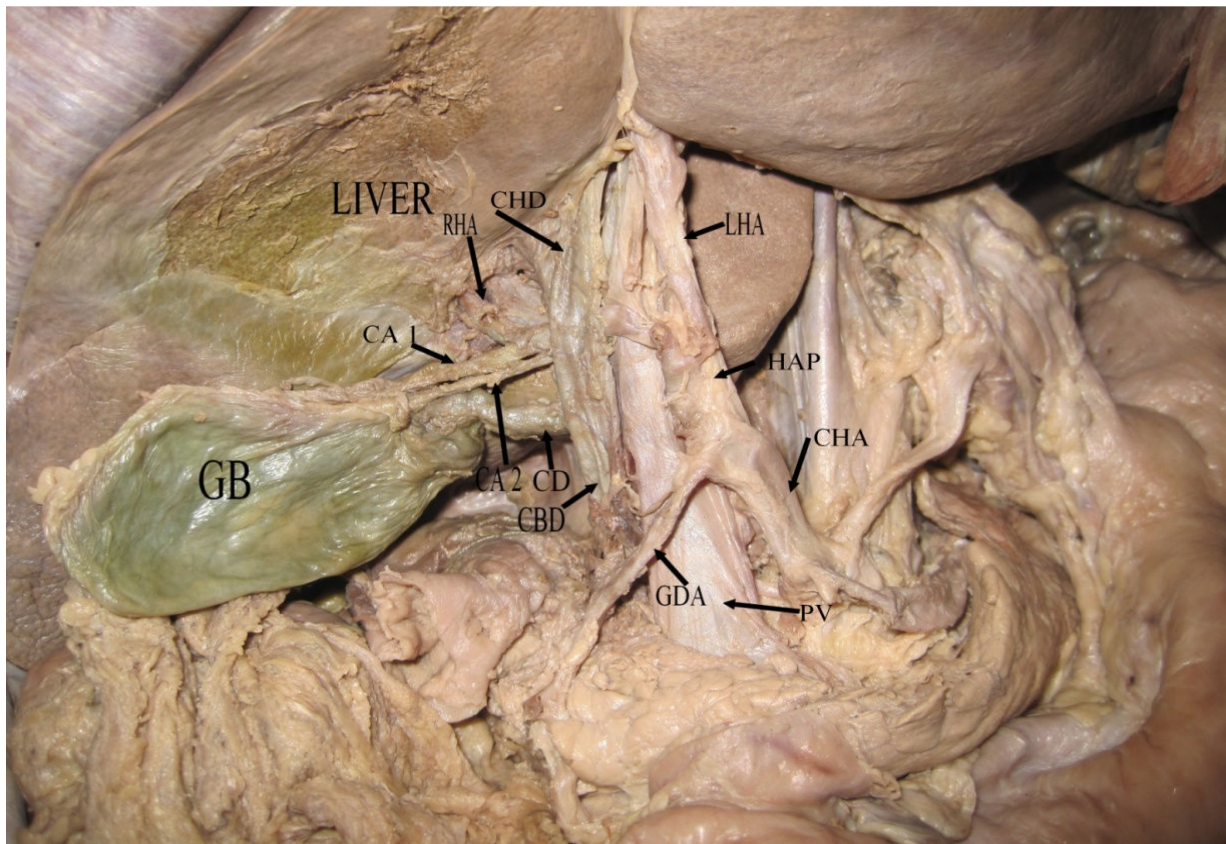
**Note:** CA—cystic artery, RHA-right hepatic artery, LHA- left hepatic artery, CHA-common hepatic artery, CD-cystic duct, GB-Gallbladder, PV-portal vein, GDA-gastroduodenal artery, CHD-common hepatic duct, CBD-common bile duct



**Figure 2.** Cystic artery arising from gastroduodenal artery ,passing anterior to the common bile duct running outside the Calot's triangle and reaching gall bladder. Common hepatic artery arising from celiac trunk dividing into, left hepatic artery and gastroduodenal artery. Right hepatic artery arising from gastroduodenal artery. Hepatic artery proper is not present.

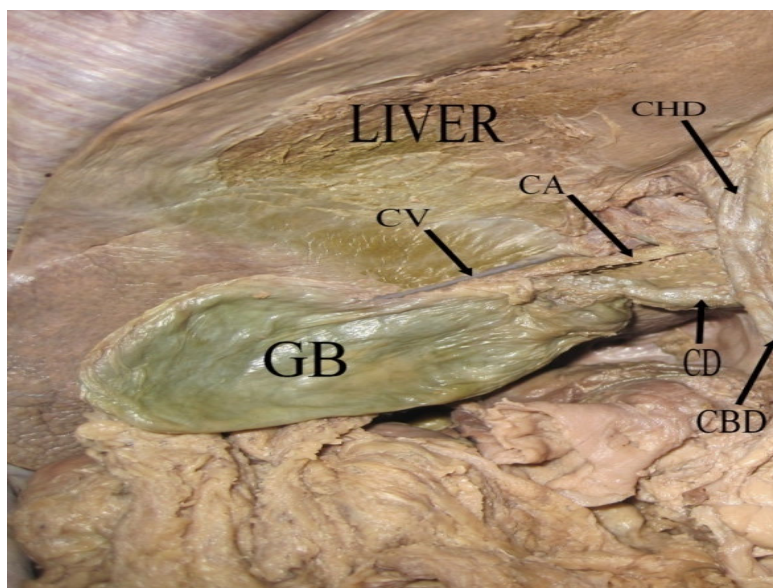
**Note:** CA—cystic artery, RHA-right hepatic artery, LHA- left hepatic artery, CHA-common hepatic artery, CD-cystic duct ,GB-gallbladder, LGA-left gastric artery ,SA-splenic artery, ,PV-portal vein, GDA-gastroduodenal artery, CHD-common hepatic duct CBD-common bile duct, CT-celiac trunk





**Figure 3.** Two Cystic arteries arising from right hepatic artery, passing posterior to the common hepatic duct, running through the Calot's triangle and reaching gall bladder. Common hepatic artery arising from celiac trunk dividing into hepatic artery proper and gastroduodenal artery. Hepatic artery proper further dividing into left and right hepatic arteries.

**Note:** CA-1—first cystic artery, CA-2—second cystic artery, RHA-right hepatic artery, LHA-left hepatic artery, HAP-hepatic artery proper, CHA-common hepatic artery, CD-cystic duct, PV-portal vein, GDA-gastroduodenal artery, GB-Gallbladder, CHD-common hepatic duct, CBD-common bile duct.



**Figure 4.** Single cystic vein from the gallbladder is seen entering the substance of liver.

**Note:** CV- cystic vein, CA-cystic artery, CD-cystic duct, GB-gallbladder, PV-portal vein, , CHD-common hepatic duct ,CBD-common bile duct.