Anatomical Study of Variations of Cystic Artery and Contents of Calot's Triangle in South Kerala - A Cross Sectional Study

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ABSTRACT

BACKGROUND

Cystic artery originates from right hepatic artery which is a branch of hepatic artery proper of coeliac trunk from abdominal aorta. Variations in the origin and course of cystic artery were observed in this study. Contents of Calot's triangle were also studied. Knowledge of normal anatomy, variations of the biliary apparatus and the arterial supply to the gallbladder is important for surgeon.

METHODS

Descriptive cross-sectional study was done from April 2008 to January 2010 in 180 adult specimens and 50 foetal specimens in the Departments of Anatomy, Forensic Medicine and Pathology in Government Medical College, Thiruvananthapuram. The abdominal wall was incised and hepatobiliary region was identified and dissected. The gallbladder and coeliac trunk were identified. Cystic artery and Calot's triangle were studied.

RESULTS

More than 90 percent of the cystic artery originates from the right hepatic artery in both sexes. Cystic artery originated from left hepatic artery in 4 cases, common hepatic artery in 5 cases and from middle hepatic artery in 1 case. The cystic artery within Calot's triangle was observed in 41 %. Right hepatic artery was content in 29.9 %. Both the arteries were content in 19 %. Cystic artery and accessory hepatic duct were content of Calot's triangle in 2.2 %. Double cystic artery was content of the triangle in 1 cadaver. Artery or duct was seen outside the Calot's triangle in 16 cadavers.

CONCLUSIONS

It is important for surgeons to know the variations of cystic artery and Calot's triangle during surgical interventions of the hepato biliary region. "Cystic artery syndrome" is a condition where cystic artery is seen winding around cystic duct although it originates from right hepatic artery. Knowledge of these variations is important for surgeons and helps in better surgical outcome.

KEYWORDS

Cystic Artery, Calot's Triangle, Right Hepatic, Gall Bladder, Coeliac Trunk

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BACKGROUND

Cystic artery is a key anatomical structure usually isolated and ligated during conventional cholecystectomy or laparoscopic cholecystectomy. There is possibility of haemorrhage from cytic artery during surgery. Injuries to the duct when in close proximity can also occur in hepatobiliary surgeries. Cystic artery most commonly arises from right hepatic artery which is a branch of hepatic artery proper. Hepatic artery proper is a branch of common hepatic artery which arises form coeliac trunk. It is the major artery supplying gallbladder. Cystic artery usually pass posterior to the common hepatic duct and anterior to the cystic duct. It divides into superficial and deep branches at superior surface of neck of gallbladder. The superficial branch lies on the inferior surface of body of gallbladder and deep branch on the superior surface. Cystic artery gives fine branches which supply common and lobar hepatic ducts and upper part of common bile duct where they anastomose. In 25 % of subjects, the superficial and deep branches of the cystic artery have separate origins and Michels[1] called them double cystic artery. Variations in the origin and course of cystic artery is commonly seen and encountered during hepatobiliary surgeries as well as in cadavers. Following variations are seen

a. Accessory cystic artery from common hepatic artery or right hepatic artery
b. Cystic artery between hepatic ducts
c. Cystic artery behind common hepatic duct
d. Accessory cystic artery from left hepatic artery and posterior to left hepatic duct, or both cystic arteries from left hepatic artery.

Calot's Triangle

There is a triangular space formed between the cystic duct, the common hepatic duct, and inferior surface of segment v of liver referred to as Calot's triangle or cystic triangle. Cystic artery passes through this triangle.

The calot's triangle presents the following surgical hazards:

1) A fissured area supplied by a long cystic-like artery
2) Two large hepatic branches of the right hepatic artery, the lower giving off the superficial cystic artery which leaves the triangle, the upper giving off the deep cystic artery which is largely hidden
3) An accessory hepatic duct which crosses the lower branch of the right hepatic artery at a higher point but is crossed by the deep cystic artery.

Various origins of cystic artery and its course with respect to hepatobiliary triangle require attention of surgeons in order to avoid iatrogenic injury of bile duct and vessels. Study of arterial variations by Daseler E [2] (1947), Nicholas A Michels[1] (1951) in 200 specimens, Milakar B, Gadzijev E M[3] (2003) in 280 bodies and Loukas M, Fergurson A, Louis R G, Colborn G L[4] (2006), were appreciable. Right hepatic artery was studied by Brewer G E[5] (1903), Flint E R[6] (1923), Thompson I M[7] (1933), Browne[8] (1940) and Daseler E[2] (1947).

Daseler[2] et al. in 1947 had a brief study on the variations in biliary duct system. Main work was directed to the arterial pattern of the hepatic pedicle including right hepatic artery, left hepatic artery, common hepatic artery, gastroduodenal artery and cystic artery. Johnston et al. studied the vascular relations of biliary ducts in 1952. The hepatic, cystic, retroduodenal arteries and their relation to biliary ducts were studied by Nicholas A Michels[1] in 1951. Cystic artery was also studied by Moosman D A[9] in 1951. Osemlak J, Siwek R[10] in 1984 studied the arterial supply of extrahepatic biliary ducts in newborns and infants.

Bergamasci R, Ignnjatovic D[11] in April 2000 studied third structure in Calot's triangle in 90 postmortem specimens. Postmortem corrosion casting, arteriography and cholangiography was done. Suzuki et al.[12] described a condition known as "Cystic artery syndrome", in which the cystic artery originates from the right hepatic artery, but uncommonly has a course that wraps across the cystic duct in 2000. In 187 of 244 consecutive cases (76.6 %), Suzuki et al. found arterial supply anteromedial to the cystic duct, near the sentinel cystic lymph node. In the other cases, there was an atypical arterial supply, and 27 of these cases (11.1 %) had no cystic artery in Calot's triangle. A typical blood supply and accessory arteries were observed in 18 cases (7.4 %).

Chen TH, Shyu J F, Chen C H, Ma K H et al.[13] in June 2000 studied the origin and course of cystic artery related to Calot's triangle in Chinese adults. In this study, 86.1 % coursed through Calot's triangle. All the cystic arteries originating from right hepatic artery passed through the Calot's triangle. However, only 54 % of the cystic arteries that originated from the left, bifurcation, proper, and common hepatic arteries passed through the triangle. 72.7 % of the cystic arteries that originated from the right hepatic artery passed beneath the common hepatic duct (CHD) as they entered the Calot triangle, the rest ran anterior to the CHD. Considering the cystic arteries that arose from locations other than the right hepatic artery, 29.4 % passes posterior to the CHD, and 11.8 % passed anterior to the CHD.

Futara G, Ali A, Kinfu Y[14] 2001 studied the variations in cystic artery in Ethiopians in 2001. The cystic artery mainly arose from the right hepatic artery (75.5 %) but also took origin from the middle hepatic artery (12.7 %), gastroduodenal artery (7.3 %) or the left hepatic artery (4.5 %). In cases where cystic artery was to left of common hepatic artery at its origin, it crossed from left to right anterior to common hepatic duct in 28.2 % or posterior to duct in 10.9 %. Irrespective of its relationship with the common hepatic duct, the cystic artery passed in Calot's triangle in 89 cases. There were 11 accessory cystic arteries among which 6 originated from right hepatic artery 3 from middle hepatic artery and 2 from left hepatic artery.

The cystic artery was studied in human foetuses by Piotr Flisiński, Michał Szpinda, Mariusz Flisinski[15] in 2003. Cystic artery was mostly a single vessel (97.06 %) in the study except in one case where it was adouble vessel (2.94 %). It originated mostly (82.34 %) from the proper hepatic artery. Other origins were from its trunk (8.82 %) or left hepatic artery (5.88 %) and most rarely (2.94 %) from the gastroduodenal artery. Cystic artery passed through the triangle in all cases except one. Cystic artery which passed

out of Calot's triangle was originating from the gastroduodenal artery (2.94 %). The cystic artery most frequently (67.66 %) ran behind the common hepatic duct. However, in (29.40 %) cystic artery passed over the common hepatic duct and most rarely (2.94 %) on the left side of the cystic duct. In the material examined, the cystic artery was not observed running in front of the common hepatic duct. The short type of cystic artery trunk (52.93 %) was observed more frequently than the long one (44.13 %).

Study of cystic artery was done by Balija M, Huis M, Stulhofer M, Nikolic V[16] in 2001, Milakar B, Gadzijev E M, Ravnik D, Hribernik M[3] in 2003, Ignjatovic D, Zivanovic V, Vasic G[17] et al. in 2006. A case of multiple variations of hepatobiliary vasculature including double cystic arteries, accessory left hepatic artery and hepatosplenic trunk was reported by Loukas M, Fergurson A, Louis R G, Colborn GL[4] in 2006. Saidi[18] et al. studied the anatomy of cystic artery in adult Kenyans. Anatomical variations in cystic artery was studied in detail during laperoscopic cholecystectomy by You-Ming Ding et al. in 2007. Gawali R A[19] studied the origin and course of cystic artery in 2014 and Usha Dandekar[20] et al. in 2016

Roopashree[21] et al. in 2019 observed that origin of the cystic artery was normal in 92 % of cases and variations were seen in approximately 8 % cases. In 92 % of cases cystic artery originated from the right hepatic artery. The cystic artery showed normal division into superficial and deep branches in 97 % cases. In the rest, the artery continued as a superficial branch and the deep branch was seen to be replaced by accessory cystic artery. The cystic artery was content of Calot's triangle in 64 % cases, whereas in 36 % it was seen outside Calot's triangle. Cystic artery was medial to cystic duct in 67 % and in 63 % cases lateral to common hepatic duct. In 30 % of the cases the cystic artery passed anterior to the cystic duct. Incidence of accessory cystic arteries in this study was approximately 4 %.

Cystic artery variations during laparoscopic cholecstectomy were studied by Ding YM et al. in 2007 in 600 patients. They presented a new classification of anatomic variations of the cystic artery and divided into three groups: (1) Calot's triangle type, found in 85.5 %; (2) outside Calot's triangle, found in 13 %; (3) compound type, observed in 1.5 %. Andall R G et al. in 2016 also studied the variations of cystic artery during laparoscopy.

Objectives

1. To find the variations in origin of cystic artery
2. To find the variations in content of Calot's triangle
3. To find the variations in relation of cystic artery with bile duct.

METHODS

Total of 230 specimens (cadaveric - 20, autopsy - 160, foetuses - 50) were used for the study. This was a cross sectional study done in the Departments of Anatomy, Forensic Medicine and Pathology in Government Medical College, Thiruvananthapuram. 160 autopsied, 20 cadaveric and 50 foetal specimens were studied from April 2008 to January 2010. Abdominal wall was opened and hepatobiliary region identified. Cases with disease of hepatobiliary system like cirrhosis, injuries of the hepatobiliary region, death due to poisoning were avoided. The cadavers which were preserved in formalin were used. Fresh specimens were obtained enbloc from the autopsies in mortuary and dissected. Foetal specimens were obtained during foetal autopsies conducted by pathology department. Abdominal wall was reflected. Hepato biliary region was dissected. The origin and course of cystic artery, its relation with ducts, was studied. Calot's triangle was also studied in detail for the contents.

Statistical Analysis

Collected data was entered in excel sheets and presented as descriptive statistics in the form of frequency tables--frequency and proportion for categorical variables. Categorical data was expressed in rates, ratios and proportions. The comparison was done using chi-square test.

RESULTS

Cystic Artery	Number	%
Nil	1	0.4
Common hepatic artery	5	2.2
Left hepatic artery	4	1.7
Middle hepatic artery	1	0.4
Right hepatic artery	219	95.3
Total	**230**	**100.0**

Table 1. Origin of Cystic Artery

More than 90 percent of the cystic artery arose from the right hepatic artery. In 5 specimens, cystic artery originated from common hepatic artery and in 4 cases from left hepatic artery. Cystic artery originated from middle hepatic artery in one case. There was absence of cystic artery in one specimen.

Calot-Content	Number	%
Nil	16	6.9
Double cystic artery	2	0.9
Cystic artery	95	41.1
Cystic artery, Accessory hepatic duct	5	2.2
Cystic artery, Right hepatic artery	44	19.0
Right hepatic artery	69	29.9
Total	**231**	**100.0**

Table 2. Contents of Calot's Triangle

Majority of Calot's triangle had cystic artery as content. But in 69 specimens, right hepatic artery was the content. In 44 specimens, both cystic artery and right hepatic artery was seen inside Calot's triangle. Calot's triangle had no contents in 16 specimens. Cystic artery as well as accessory hepatic duct was seen inside the triangle in 5 specimens. Double cystic artery was seen in two specimens.

The cystic artery had no relation with common bile duct, hepatic duct or cystic duct in majority of cases. Cystic artery was posterior to common hepatic duct in 34 specimens and posterior to cystic duct in 12 specimens. Cystic artery was anterior to common hepatic duct in 5 specimens and anterior

to cystic duct in 5 specimens. Cystic artery was seen anterior to common bile duct in one specimen.

Cystic Artery	Number	Percentage
Anterior to cystic duct	5	2.2
Posterior to cystic duct	12	5.2
Anterior to CHD	5	2.2
Posterior to CHD	34	14.7
Anterior to CBD	1	0.4
No relation	174	75

Table 3. Vascular Relations

DISCUSSION

Study of arterial variations by Daseler E[2] (1947), Nicholas A Michels[1] (1951) in 200 specimens, Loukas M, Fergurson A, Louis R G, Colborn G L[4] (2006), Milakar B, Gadzijev E M[3] (2003) in 280 bodies were appreciable. The cystic artery in human foetuses was studied by Piotr Flisiński et al.[15.] Cystic artery was single in 94.35 %, double in 5.65 %. Origin of cystic artery from middle hepatic artery and common hepatic artery in total was (2.6 %) less than that reported by Nicholas[1] 5 %, Usha Dandekar[20] 3.7 %, more compared to Michels[1] 1.5 %, Saidi[18] et al. Johnston,[22] Flint,[6] Gawali[19] (nil). Origin from right hepatic artery alone was found to be (95.3 %) more compared to the literature - Milaker,[3] Nicholas, Chen[13] et al. Johnston[22] and Andall, Usha Dandekar[20] 79.3 % Roopashree Ramakrishna[21] 92 %. Origin of cystic artery from superior mesenteric artery was absent in the present study which was seen in 10 % in the study by Nicholas.[1]

Origin of cystic artery from gastroduodenal artery was not seen in present study compared to study by Ding[23] et al. which was 7.5 % and Michels NA[1] 4 %. Right hepatic artery from coeliac trunk gave origin to single or double cystic artery in 94.8 %. This was more compared to the studies by Nicholas[1] (63 %) Balija[17] (43 %) and Johnston[22] (88.5 %). Single replacing cystic artery ie not from typical coeliacal right hepatic artery was seen in 3.9 % which was less than the reports by Moosman[9] - 20.4 %, Nicholas[1] - 19 %, Johnston[22] - 11.4 %, Balija[17] - 5.5 %.

Double cystic artery (fig 1) was observed in 5.7 % in the present study, all of which originated from right hepatic artery. The frequency percentage was less compared to Nicholas[1] - 25 %, Daseler[2] et al. - 14 %, Flint[6] - 15 %, Moosman[9]- 14.4 %, Brewer[5]- 20 %, and Browne[8] 21 %. In the present study, cystic artery was seen anterior to right hepatic duct in 0.4 %. Normal relation anterior to cystic duct was seen only in 2.2 %. Cystic artery posterior to right hepatic duct was more (4.8 %) in our study compared to Browne[8] 0.7 %, Daseler[2] 2.4 % Johnston[22] 2.9 %. Cystic artery passed anterior to common hepatic duct in 5 cases - 2.2 %, less than the reports by Moosman[9] - 17.2 %, Nicholas[1] - 26 %, Chen[13] et al. - 39.1 % and Piotr[15] - 29.4 %, Andall - 17.9 % and lied posterior to common hepatic duct in 14.8 % which was less than that reported by Piotr[15] - 67.66 %, Balija[17] - 58.8 % and Gadzijev[3] - 80 %, Nicholas[1] - 19.5 % but more than Moosman[9] - 1 %. Relation of cystic artery to common bile duct was absent in our study which disagrees with Moosman[9] and Nicholas.[1] Cases of triple cystic artery reported by Balija,[17] Daseler,[2] Brewer[5] and Browne[8] were not seen in the present study. Cystic artery crossed the common bile duct in a smaller number of cases 0.4 % in the present study as against Thompson[7] who reported 2.3 %, Johnston[22] - 22.86 % and Andall[24] - 5.4 %. Cystic artery or accessory cystic artery crossed behind common hepatic duct in 3.5 %, which was more compared to studies by Browne[8] 0.7 %, Daseler[2] 2.4 %, Johnston [22]2.9 % and less compared to Nicholas[1] 26 %, Balija[17] - 58.8 %, Chen[13] et al - 72.7 % Gadzijev[3] - 80 %. In cases where cystic artery was found in relation to the bile duct, either it was due to early origin from right hepatic artery or origin from left hepatic artery or common hepatic artery. Site of crossing was supraduodenal in all cases in present study whereas it was at retroduodenal level in 87.5 %, and 12.5 % at supraduodenal level in Johnston's[22] study. There is a sure hazard of arterial injury during exploration of the duct.

In the present study, in 97 % of the cases the cystic artery terminated by dividing into the superficial and deep branches (fig 2). In the rest, the artery continued as a superficial branch, the deep branch being replaced by the accessory cystic artery.

The cystic artery within Calot's triangle was observed in 41.1 % which was less compared to the reports by Piotr Flisiński[15] et al. (97.06 %), Balija[17] (58.8 %), Gadzijev[3] (80 %) and Nicholas[1] (81 %) and study by Ding[23] (87 %) Roopashree Ramakrishna[21] et al. 64 %, Michels (81 %), Gawali (90 %), Usha Dandekar (62.2 %) and Flint (84 %) and more compared to the studies by Saidi et al. Among this single cystic artery was seen in 41.1 %, less compared to the study by Suzuki[12] (76.6 %), double cystic artery in 0.9 % less than the reports by Suzuki[12] (2.5 %) and Bergamasci R [11] (5.7 %). Cystic artery was out of Calot's triangle in 58.9 % which was more compared to the studies by Michels (19 %), Flint (16 %), Gawali (10 %), Usha Dandekar (37.8 %) and Roopashree et al. (64 %) and less compared to the study by Saidi et al.

Authors	In Calot Triangle	Out of Calot Triangle
Michels	81	19
Saidi et al.	2	98
Flint	84	16
Gawali	90	10
Usha Dandekar	62.2	37.8
Roopashree et al.	64	36
Present study	41.1	58.9

Table 4. Cystic Artery in/out of Calot

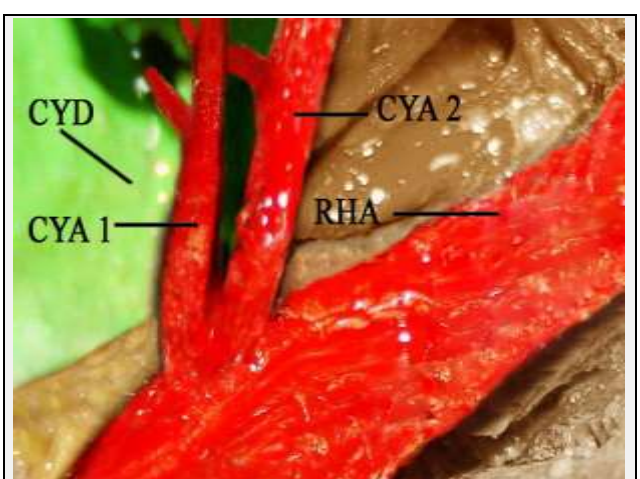

Figure 1. Double Cystic Artery from Right Hepatic Artery

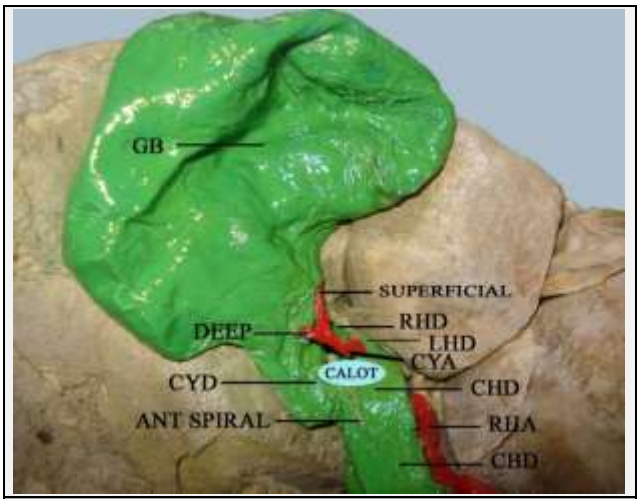

Figure 2. Cystic Artery Dividing into Superficial and Deep Branches Anterior Spiral-Anterior Spiral Union

CONCLUSIONS

A better understanding of anatomy of biliary apparatus and cystic artery can help decrease the surgical mortality in cholecystectomy. Calot's triangle is an important area from surgical point of view. The study stresses the fact that anomalies of duct and vascular components of hepatic pedicle are common. In Moynihan's hump the right hepatic artery is liable to be mistakenly identified as the cystic artery. Adequate knowledge of variations in origin of cystic artery and Calot's triangle, relation of artery with duct can prevent accidental injury to the structures while doing a hepatobiliary surgery.

Data sharing statement provided by the authors is available with the full text of this article at jebmh.com.
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