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The Anatomical Variation of Cystic Artery and its Clinical Relevance

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ABSTRACT:

Background and Aim: In present time the laparoscopic cholecystectomy is more preferable for the treatment of the cholelithiasis and other gallbladder conditions. The cystic artery is the main source of blood supply of the gallbladder. It is normally originated from right hepatic artery and lies within the calot's triangle.(1)The cystic artery is the one of main structures which is ligated during cholecystectomy either laparoscopic or conventional. Variations of its anatomy like origin, termination and relation causes intraoperative bleeding which causes problem for the surgeons. The knowledge of variations of cystic artery is helpful for surgeons during carrying out the cholecystectomy.

Materials and Methods: The study was carried out on 130 human cadavers in department of Anatomy at various medical colleges of Gujarat region, India over the period of 4 years from January 2015 to December 2019. Permission taken from ethical committee for carried out the work. The cadavers are dissected and open the abdomen remove the lesser omentum and clean the area by fine dissection observe the variations of cystic artery. Findings were noted and take the photographs of variations.

Results: Out of 130 specimens single cystic artery present in 117 specimens (90%) and double in 13 specimens (10 %).In 79 (67.52%) specimens the cystic artery was seen inside the calot's triangle and in 38 (32.47%) specimens it was outside the calot's triangle.

Key words: Calot's triangle, Cystic artery, Laparoscopic cholecystectomy, Gallbladder.

Introduction: In modern time laparoscopic cholecystectomy is widely accepted method for treatment of cholelithiasis. The cystic artery is the key structure which is ligated during cholecystectomy either laparoscopic or conventional.(2)

The cystic artery is most commonly known for variations in its origin, branching pattern and termination. This is attributed to the developmental changes occurring in the primitive ventral splanchnic arteries.(3)

The normally cystic artery arises from the right hepatic artery in the calot's triangle immediately to the right of common hepatic duct. After origin it passes behind to common hepatic or common bile duct and reaching up to gallbladder, divides into superficial and deep branches to supply the inferior and superior surfaces of gallbladder.(4)

Calot's triangle is an anatomical landmark of special value in cholecystectomy. First described by Jean-Francois Calot as an "isosceles" triangle in his doctoral thesis in 1891, this anatomical space requires careful dissection before the ligation and division of the cystic artery and cystic duct during cholecystectomy. The structures within calot's triangle and their anatomical relations can causes problem for surgeons during surgery specifically when anatomical variations are encounter.(5

The triangular space formed between the cystic duct, the common hepatic duct and the inferior surface of segment

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V of the liver (Suzuki et al. 2000), is commonly referred to as Calot's triangle. In 1981, Rocko drew attention to possible variations in the region of calot's triangle bordered by the cystic duct, common hepatic duct and lower edge of the liver.(6)
In 1992, Hugh suggested Calot's triangle should be renamed the hepatobiliary triangle, with the small cystic artery branches supplying the cystic duct being called calot's arteries. Appreciation of the variations in ductal and arterial anatomy as they relate to the triangle are of considerable importance during excision of the gallbladder in order to avoid mistakenly ligating the common hepatic or common bile duct.(7)
If uncontrolled bleeding from cystic artery is encountered during laparoscopic cholecystectomy which increase the chances of conversion to open cholecystectomy. Thomson reported rate of conversion from laparoscopic to open cholecystectomy due to injury of blood vessels is 0%-1.9%.(8) Knowledge of relevant anatomy is important for the safe execution of operative procedure like cholecystectomy, because it has been observed that misinterpretation of normal anatomy as well as presence of anatomical variations contribute to the incidences of major intraoperative and postoperative complications.(9)

Materials and Methods:
This study was a cross sectional study. The study was conducted on 130 liver specimens with intact gallbladder and extrahepatic duct system of human cadavers at department of anatomy in various Medical Colleges of Gujarat region (India) over the period of four years from January 2015 to December 2019.
The data are collected by dissection of 130 cadavers irrespective of sex. After the opening of abdominal cavity lesser omentum cut from lesser curvature of the stomach, prevent the hepatodudenal ligament. Identified and traced the cystic duct, right & left hepatic duct, common bile duct and dissected out. Identified the boundary of calot's triangle and right gastric artery to the common hepatic artery. The common hepatic artery dissected till the gastroduodenal artery given off and proper hepatic artery defined. The right and left hepatic arteries identified and trace cystic artery.(10)
After identification of cystic artery it was cleaned and observed the following parameter:
Various sources of origin and number of cystic artery.
The branching pattern and mode of termination.
Measure the length of cystic artery from origin to termination.
Relation of cystic artery with calot's triangle and extrahepatic ducts system.

Results:

Out of 130 specimens single cystic artery present in 117 specimens (90%) and double in 13 specimens (10 %).The single cystic artery and double cystic arteries specimens observed separately.
Out of 117 origin of the cystic artery was normal in 96 (82.85%) specimens and variations are seen in remaining 21 (17.93%). Out of these variations origin of cystic artery from Proper hepatic artery in 3 (2.56%) specimens, Segmental branch of right hepatic artery in 11.11% specimens, Superior mesenteric artery in 1 (0.85%) specimen, Left hepatic artery in 1 (0.85%) specimen and Common hepatic artery in 3 (2.56%) specimens.
102 (87.17%) specimens showed termination of the cystic artery by dividing into superficial and deep branch. The artery continued as superficial branch in12 (10.25 %) specimens and continued as deep branch in 3(2.56%) specimens. The level of termination was seen close to the neck of gall bladder in 95 (81.19%) and away from the neck in 6 (5.98%) specimens.
In 79 (67.52%) specimens the cystic artery was seen inside the calot's triangle and in 38 (32.47%) specimens it was outside the calot's triangle.

Cystic artery was lies anterior in 2(1.71%) and posterior 2 (1.71%) specimens to the cystic duct, anterior to the common hepatic duct was found in 23.93% and posterior in 1.71% specimens. Cystic artery was anterior to the common bile duct in 2 (1.71 %) specimens.
The mean length of cystic artery was 18.19 mm, minimum length 2 mm and maximum length is 56 mm. observed. Short cystic artery lies in 21 specimens, which means length of cystic artery is less than 1cm. In case of short cystic artery mean length was 0.64cm, max. length 0.9cm and min. length 0.2cm.

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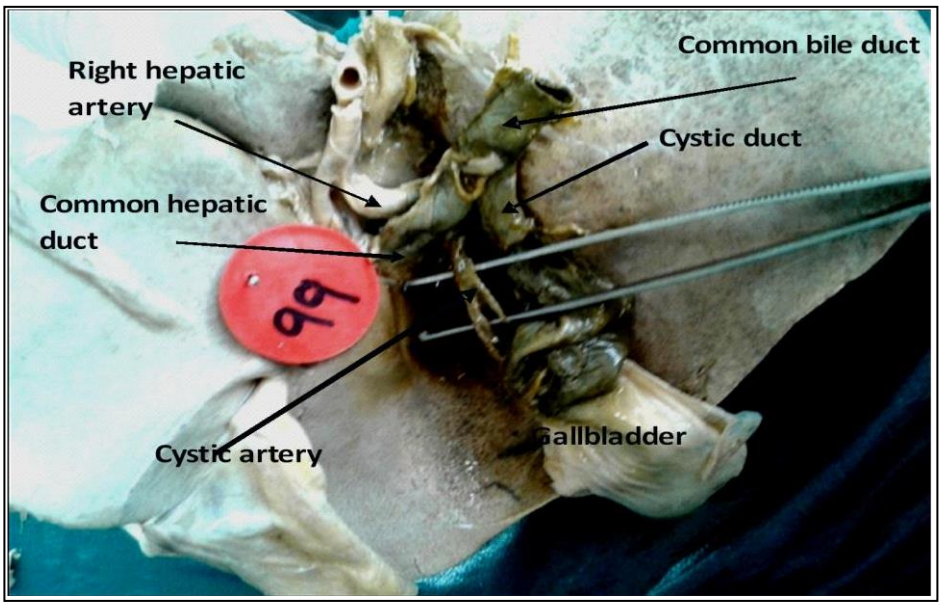

Figure-1: Origin of Cystic artery from Right hepatic artery within calot' triangle &posterior to Common hepatic duct.

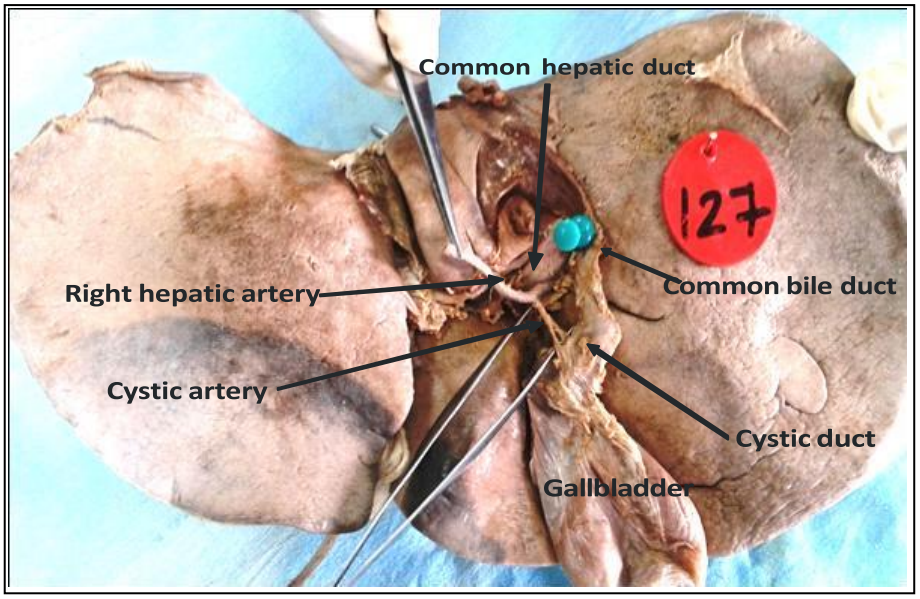

Figure-2: Cystic artery present outside the calot's triangle& anterior to Common hepatic duct.

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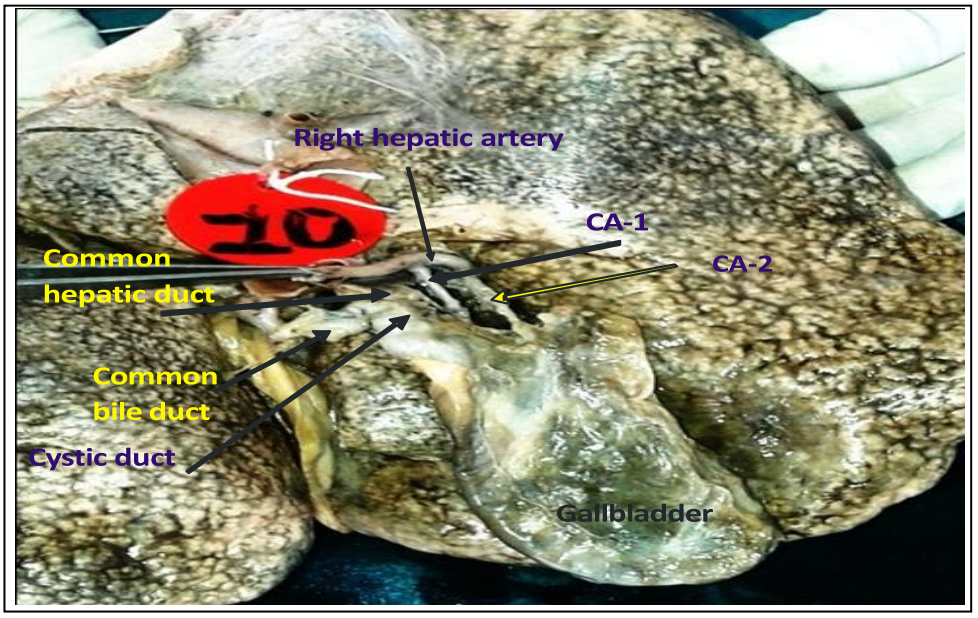

Figure-3: Double cystic arteries arise from right hepatic artery with in calot's triangle. (CA-1=Cystic artery-1, CA-2= Cystic artery-2)

Discussion

Most errors in gallbladder surgery result from failure to appreciate the common variations in the anatomy of the biliary system. The blood supply, ductal variations, and gallbladder anatomy of this area are often the source of major challenge to unprepared and unaware surgeons. The present study was done on 130 specimens of liver, out of that in 117 specimens single cystic artery and in 13 specimens there were double cystic arteries. Out of 117 specimens which has single cystic artery showed that the most common source of origin of the cystic artery is the right hepatic artery in 82.05% specimens. Comparison from other studies done by other authors shown in table-1this results is approximately similar with Gammon Jacob[12] (84.6%), Flinsinski[16] (82.3%), less than Michel NA[11] (89%),Saidi H. et al.[23] (92.2%), Khalil M.et al.[17](90%), higher than Balija et.al[13](73%) and Futara G.et al.[14] (75.5%).Second most common type origin is segmental branch of right hepatic artery in 13 (11.11%) cases this finding is higher than study done by Mlakar B. et al.[15] in (5%) specimens who found segmental arteries for segments 4,5,6 and 8.

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S. NO	Studies	No. of Specimens	RHA	PHA	LHA	GDA	CHA	SMA	AB RHA	SEG Br of RHA
1	Michel NA[11] 1951	200	89.00%	-	4.00%	4.00%	3.00%	-	-	-
2	Anson (1963)[12]	800	74.70%	-	5.90%	2.50%	14.90%	0.75%-		
3	Gammon Jacob (1976)[13]	33	84.60%	-	3.80%		3.80%	-	-	-
4	Balija et al. (1999)[14]	200	73.50%	-	1.00%	4.50%	-	-	5.50%	-
5	Futara G et al. (2001)[15]	110	75.50%	-	4.50%	7.30%	-	-	-	-
6	Mlakar B et al.(2003)[16]	81	53%	-	-	-	-	-	-	5%
7	Flinsinski P. et al. (2004)[17]	34	82.30%	8.80%	5.80%	2.90%	-	-	-	-
8	Khalil M. et al. (2008)[18]	60	90.00%	-	3.00%	2.00%	3.00%	-	-	-
9	Tejaswi HL (2013)[19]	100	92.00%	-	1.00%	1.00%	-	-	4.00%	-
10	Aristotle S. (2014)[20]	40	92.50%	-	-	-	2.50%	-	-	-
11	Khaleel AhmedMD.et al. (2015)[21]	60	95.00%	-	-	1.60%	-	-	-	-
12	Present study	130	82.05%	2.56%	0.85%	-	2.56%	0.85	-	11.11%

Table: 1-Comparison of origin of the cystic artery with other study.

(RHA- Right hepatic artery, PHA-Proper hepatic artery, LHA- Left hepatic artery, SMA- superior mesenteric artery, ABRHA- Aberrant Right hepatic artery, SEG Br RHA- Segmental branch of Right hepatic artery)

Comparison of origin of other sources of cystic artery like Proper Hepatic Artery, Superior Mesenteric Artery, Left Hepatic Artery and Common Hepatic Artery from other studies summarized in table-1. Origin from aberrant right hepatic artery was not found in present study.Mode of termination as superficial and deep branches found in 88.03%.This finding is higher than Cedron H. et al.[22] 7.5% cases, Michel NA[11] 75% and Torres K.et al.[23] 77.27%.Cystic artery continues as superficial branch was

found in 9.40 % cases, similar termination found by Cedron H.et al.[22] in2.5%,Torres K.et al.[23] 6.83% and Michel NA [11] in 25% cases. Cystic artery continuing as deep branch was found in 2.56% cases, Torres K.et al.[23]observed in 10.25%.

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Table: 2-Comparison of length and mode of termination of the cystic artery with other study.

S.N	Studies	No. of cases	Mean length - mm	Range -mm	Mode of Termination		
					As superficial & Deep Branch	Continue as Superficial branch	Continue as Deep branch
1	Michel NA (1951)[11]	200			150(75%)	50 (25%)	
2	Cedron H et al.[22](1996)	20	18.34	4.48-42.60	15 (7.5%)	5 (2.5 %)	
3	Torres K.et al. (2009)[23]	88			68 (77.27%)	8 (6.83%)	12 (10.25%)
4	Tejaswi HL[19](2013)	100	17.6	3.7-42			
5	Present Study	117	18.19	2.0-56	103 (88.03%)	11 (9.40%)	3 (2.56%)

Cystic artery terminates at the neck of gall bladder found in 81.19% specimens and away from the neck of gall bladder in 5.98 % specimens. Mean length of the cystic artery in present study is 18.19 mm, minimum length is 2 mm and maximum length is 56 mm. This result is similar with studies done by Cedron H. et al.[22] and Tejaswi HL[19].In case of presence of double cystic artery Veena pai[4] noted in her case report the length of CA- 1 was 2.5 cm and CA- 2 was 2 cm. In present study mean length of CA- 1 was 2.26 cm and CA- 2 was 2.56 cm. This is approximately similar to finding of Veena Pai[4].

Table No.-3: Comparison of relation of the cystic artery with the common hepatic duct, Cystic duct & Common bile duct with other studies.

S.N	Studies	No. of Specimens	Common hepatic duct		Cystic duct		Common bile duct	
			Ant.	Post.	Ant.	Post.	Ant.	Post.
1	Flisinski.et al. (2004)[17]	34	29.4%	66.70%	2.94%	-		
2	Saidi H. et al. (2007)[24]	102	45.1%	46.1%	-	-	2.9%	3.9%
3	Bakheit M.A. (2009)[25]	160	7%	-	53.12%	13%	2%	-
4	Ash Aktonz.et al. (1975)[26]	75	20%	2.4%	4%			
5	UshaDandeker (2016)[3]	82	26.8%	6.1%	-	-	1.2%	3.7%
6	Present study	117	23.93%	1.71%	1.71%	1.71%	1.71%	-

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The position of cystic artery was 1.71% anterior and 1.71 % posterior to the cystic duct. Comparison from previous studies done by other authors shown in table-3 Bakheit M.A[25] found 53.12%, anterior to duct & 13% posterior to duct which is much higher than present study. Flisinski et al.[17] and Ash Akton Z.et al.[26] found 2.94% and 4% cases respectively anterior to cystic duct. Cystic artery was found to be anterior to common hepatic duct in (23.93%) specimens compared with other authors mentioned in table -3. This difference may be due to variation of the number of specimens. Cystic artery was found anterior to the bile duct in 1.71% cases but Ibingira[27] found this relation in 15.4% .

Table No.-4: Comparison of presence of Double cystic artery with other studies

S. No.	Studies	No. of Specimens	Single Cystic Artery	Double Cystic Artery
1	Michel NA[11] (1951)	200	150 (75.00%)	50 (25.00%)
2	Gammon K Jacob [13] (1976)	33	26 (78.80%)	7 (21.20%)
3	Balija M.et al. [14](1999)	200	169 (84.50%)	31 (15.56%)
4	Mlakar B. et al.[16] (2003)	81	70 (86.00%)	11 (14.00%)
5	Present Study(2015)	130	117 (90.00%)	13 (10.00%)

In the present study double cystic arteries was observed in 10 % cases. This is lower than findings of Michel NA.[11] (25%), Gammon K Jacob [13] (21%) as mentioned in table-4.

Comparison of the cystic artery relation of calot's triangle with other studies

Cystic artery was found within the calot's triangle in (67.52%) cases. The parameters of other authors who observed cystic artery with in calot's triangle are mention in table -5

Cystic artery was present outside the calot's triangle in 32.47%, study done by Gammon K Jacob,[13] Tejaswi HL. et al.[19],Usha Dandekar,[3] who found the cystic artery outside the calot's triangle in 38.46% and 35%,37.8% cases respectively. This is higher than the study done by Michel NA.[11] (8%), Cedron H. et al.[22] (10%), Suzuki M. et al.[28](11.06%), Futara G et al.[15] (19.09%),You Ming Ding et al.[8] (13%)

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Table No.-5: Comparison of the cystic artery relation of calot's triangle with other studies

S. NO.	**Studies**	**No. of Specimens**	**Inside Calot's triangle**	**Outside Calot's triangle**
1	Michel NA[11] (1951)	150	138 (92%)	12 (8%)
2	Gammon K Jacob[13] (1976)	26	16 (61.53%)	10 (38.46%)
3	Cedron H. et al.[22] (1996)	20	18 (90%)	2 (10%)
4	Suzuki et al[28] (2000)	244	217 (88.93%)	27 (11.06%)
5	Futara G et al[15].(2001)	110	89 (80.90%)	21 (19.09%)
6	You Ming Ding et al.[8](2007)	600	513 (85.5%)	78 (13%)
7	Tejaswi HL. et al.[19](2013)	100	65 (65%)	35 (35%)
8	UshaDandeker [3](2016)	82	62.2%	37.8%
9	Present study(2015)	130	79(67.52%)	38 (32.47%)

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Clinical relevance

- Misinterpretations of the variable origin of cystic artery, unusual position, pattern of termination, and numbers create the major post-operative complications and make the cystic artery susceptible to injury during laparoscopic cholecystectomy.[7]

- If surgeons don't look for the presence of separate superficial or deep branch, accessory cystic artery, termination level and length of cystic artery during cholecystectomy, it can lead to troublesome bleeding during procedure.[23]
- Hence surgeon should always look for the presence of cystic artery either within or outside the calot's triangle for safe dissection. If surgeons are unaware about the position of cystic artery can lead to hemorrhage.[5]
- Surgeons should also be aware of short cystic artery, because these short cystic arteries may create confusion as double cystic artery.[9]

Conclusion

The present study gives ideas of possible variations and provides valuable information for surgeons during gall bladder surgeries before starting the procedure and radiologists while performing an intraoperative cystic angiogram during hepatobiliary surgery. In view of the importance of anatomy of cystic artery and its variations causing injuries during cholecystectomy, it is logical to look at the possibilities of assessing the anatomy accurately with the help of imaging like ultrasound, before the performance of cholecystectomy.

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