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More than two structures in Calot's triangle

A postmortem study

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Abstract
Background: Large laparoscopic cholecystectomy series often fail to report the rate at which a third structure is encountered in Calot's triangle.
Methods: During a 6-month period, the liver and hepatoduodenal ligament of 90 consecutive human cadavers underwent corrosion casting ($n = 50$), postmortem arteriography ($n = 20$), and postmortem cholangiography ($n = 20$).
Results: Third structures within Calot's triangle were arteries (0.6–5.7 mm diameter) in 36.2% (early division of the right hepatic artery, 8.6%; caterpillar hump right hepatic artery, 12.9%; liver branch of the cystic artery, 10%; double cystic arteries, 5.7%), bile ducts (0.3–1.6 mm diameter) in 5.7% (small-caliber sectoral ducts, 1.4%; right posterior hepatic ducts, 4.3%), and veins (0.9–1.6 mm diameter) merging with the portal vein in 4% of the specimens.
Conclusion: Knowledge of the aforementioned anatomy is critical to surgeons facing more than two structures within Calot's triangle during laparoscopic cholecystectomy.

Key words: Anatomy — Complications — Laparoscopic cholecystectomy

Large series of patients surgically treated with laparoscopic cholecystectomy [3, 7, 13, 14, 16] often fail to report the rate of anatomic variations encountered in Calot's triangle that might have played a role in the occurrence of intra- and postoperative complications. On the other hand, case reports of late complications caused by right hepatic artery ligation [17] and unrecognized sectoral bile duct [1, 2] have appeared in the literature. Available data on anatomic variations of arteries [6, 15] and bile ducts [4, 8, 9, 19] in Calot's triangle are based on the surgeon's interpretation of laparoscopic anatomy and on intraoperative cholangiography, respectively.

The aim of this postmortem study was to provide anatomic data critical to the correct handling of more than two structures within Calot's triangle during laparoscopic cholecystectomy.

Materials and methods

In Belgrade, 90 consecutive fresh (<24-h-old) human autopsy specimens from patients (47 men and 43 women) with a mean age of 59 years (range 26–83 years) were obtained from January to September 1997. Nine cadavers with macroscopic pathologic changes in the liver (metastatic disease [$n = 5$], cirrhosis [$n = 1$], echinococcus cyst [$n = 1$], trauma [$n = 2$] were excluded from the study. The liver and hepatoduodenal ligament were removed *en bloc* through a midline incision of the anterior abdominal wall. The inferior vena cava was divided cranially to the mobilized liver. The duodenum was dissected free from the retroperitoneum, and the hepatic artery proper, common bile duct, and portal vein were transected close to the head of the pancreas. The inferior vena cava then was divided caudally to the liver.

Specimens then were placed into a 0.9% NaCl normotonic solution (37°C).

Of these specimens, 50 underwent corrosion casting, 20 postmortem arteriography, and 20 postmortem cholangiography. The hepatic artery proper was identified, and a 10-French polyethylene catheter was placed in it and secured with a suture. The artery then was irrigated with 0.9% saline solution to wash out all blood clots and to identify collateral vessels. Branches of the artery were identified and ligated to prevent leakage of cold polymerizing methyl acrylate during injection. The common bile duct was prepared in a similar manner.

After placement of the 10-French catheter, irrigation was performed to remove sludge from the bile ducts, particularly the cystic duct. Ligation of bile duct branches was not performed. All blood clots were removed with forceps from the portal vein lumen, which then was thoroughly irrigated through a polyethylene catheter until clear saline solution was derived from the inferior vena cava. The identification and ligation of collateral vessels (right gastric vein, umbilical veins, and others) were performed during portal vein irrigation.

Corrosion casting was carried out by injecting cold polymerizing methyl acrylate (dyed with different colors) through the catheters. During injection, specimens were immersed in water to regain their original shape. Acrylate was first injected into the hepatic artery proper and then into the portal vein. Once the solidification occurred in the arteries and veins, the

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cystic duct was identified and ligated at the gallbladder neck to prevent filling of the gallbladder, which otherwise would have broken the specimen (because of the weight of the gallbladder cast). The bile ducts then were injected. Corrosion was performed in a heated 35% potassium hydroxide solution to accelerate saponification. The casts were rinsed in water until all remnants of organic tissue disappeared, then mounted on stands.

Postmortem cholangiography was performed without ligature of the cystic duct. Once the 10-French polyethylene catheter was placed and sutured to the common bile duct, irrigation was carried out. Postmortem arteriography was performed after the placement of the 10-French catheter and ligation of collateral vessels. In both procedures, barium sulfate suspension was injected through the catheter and x-rays were taken. A metallic ethalon was used during radiography for comparative measurements.

Photographs and measurements of corrotion casts and x-ray films were made at the Department of Surgery, SSSF Hospital, Forde. The size and length of arteries, veins, and bile ducts were measured by a nonius scalable ruler and flexible copper wire, respectively. If the location of a structure was deep, surrounding vessels were shaved off to allow measuring. In the case of double cystic artery, the artery with the smallest diameter or an unusual course was named second cystic artery. Additional bile ducts that arose from the liver and merged with the cystic or common hepatic duct were referred to as sectoral ducts [20]. External diameters of arteries, veins, and bile ducts were assumed to correspond to a 20% increase of the inner values because of the methodology used.

Results

Arteries

Data on arteries were drawn from 50 casts and 20 arteriographies. The right hepatic artery was identified in 70 cadavers (mean length 44.0 mm, range 20–78 mm; mean diameter 4.0 mm, range 3.0–5.7 mm). The division of this artery into two branches (anterior segmental artery: mean diameter 2.7, range 1.9–3.4 mm; and posterior segmental artery: mean diameter 2.6, range 1.4–3.2 mm) was intrahepatic in 64 of 70 specimens (91.4%). The right hepatic artery gave early rise to two similar branches within the Calot's triangle of 6 of 70 cadavers (8.6%) (Fig. 1). The mean length of these six right hepatic arteries was 24.1 mm (range 20–31 mm). The mean diameter of the early divided anterior and posterior branches was 2.5 (range 1.8–3.1) mm and 2.4 (range 1.3–2.9) mm, respectively. The right hepatic artery ran parallel to the cystic duct, made a caterpillar-like loop (Fig. 2) close to the gallbladder neck, and gave origin to a short cystic artery in 9 of 70 specimens (12.9%).

Cystic arteries were identified in 70 cadavers. A single artery was found in 59 of 70 specimens (84.3%), which ran through the Calot's triangle in all but one case. The mean diameter and length of single cystic arteries were 1.4 mm and 19.7 mm (range 4–54 mm), respectively. A double cystic artery was recorded in 10 of 70 (cadavers) (14.3%). In addition to the first artery, a second cystic artery ran through the Calot's triangle of 4 of 10 specimens (40%). This was not the case with the remaining 6 of 10 cadavers. Second cystic arteries originating from the right ($n = 2$) and left ($n = 2$) hepatic artery ran only through Calot's triangle (Table 1). The mean diameter and length of second cystic arteries were 0.9 mm and 9.3 mm (range 2–14 mm), respectively. Five of 10 second cystic arteries were shorter than 5 mm. One of 70 specimens (1.4%) had three cystic arteries that all ran through Calot's triangle (Fig. 3). This triple artery arose from the right hepatic (length 14 mm, diameter 0.9 mm), the left hepatic (length 17 mm, diameter 0.5 mm) and the hepatic artery proper (length 16 mm, diameter 0.6 mm).

A branch of the cystic artery (Fig. 4) was identified in 7 of 70 cadavers (10%). These branches ran underneath the lateral peritoneum of Calot's triangle and entered the anterior segment of the right liver lobe. Their mean diameter and length were 0.8 (range 0.6–1.9 mm) and 11.4 (range 5–22 mm), respectively. Anastomotic communications with intrahepatic liver arteries were not found.

Bile ducts

Data on bile ducts were drawn from 50 casts and 20 cholangiographies. Additional bile ducts passing through Calot's triangle were identified in 4 of 70 cadavers (5.7%) One sectoral duct arose from the anterior segment of the right liver lobe, ran through Calot's triangle parallel to the common hepatic duct, and entered the cystic duct 7 mm from the junction to the common bile duct. The length and inner diameter of this duct were 37 mm and 0.3 mm, respectively. Three other sectoral bile ducts arose from the posterior segment of the right liver lobe, ran through the most cranial part of Calot's triangle, and entered the common hepatic duct (at an acute angle) 6 mm, 11 mm, and 9 mm from the hepatic duct junction. Two of these ducts drained the posterior liver segment in part (length and diameter 14 mm and 12 mm; and 0.7 mm and 0.9 mm, respectively), whereas one was a right posterior hepatic duct draining the entire posterior live segment (length and diameter 16 mm and 1.6 mm, respectively) (Fig. 5).

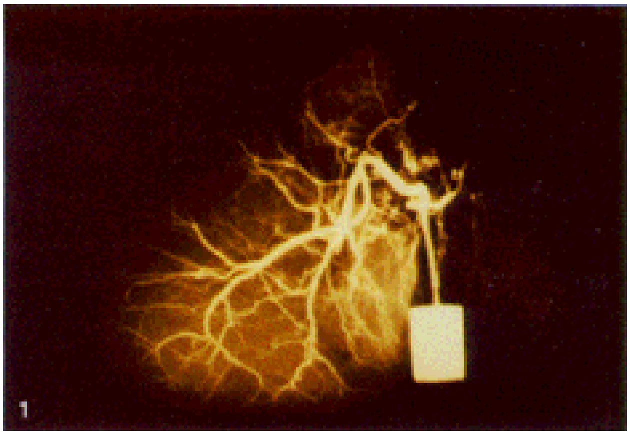
Veins

Data on gallbladder veins were drawn from 50 casts. Gallbladder veins were identified in the Calot's triangle of 50 cadavers. These veins were smaller than 0.3 mm in diameter, ran underneath the medial peritoneum of the caudal part of Calot's triangle, and entered the peribiliary venous plexus in 48 of 50 specimens (96%). Any attempt to measure their inner diameter and length failed because of limitations of the scalable ruler and because of their plexus branching pattern, respectively. One vein and two veins were found in 37 of 48 casts (77%) and 11/48 casts (23%), respectively.

A gallbladder vein larger than 0.3 mm in diameter was identified in the Calot's triangle in 2 of 50 cadavers (4%). Both veins arose from the gallbladder neck, whereas their inlets were either on the trunc or on the right branch of the portal vein, extrahepatically. Both veins ran underneath the lateral peritoneum of the caudal part of Calot's triangle, laterally and posteriorly to both the cystic duct and artery (Fig. 6). Their length and inner diameter were 14 mm and 18 mm; 0.9 mm and 1.6 mm, respectively.

Discussion

The right hepatic artery can be ligated inadvertently during laparoscopic cholecystectomy when it runs through Calot's triangle quite close to the juncture of the gallbladder neck and the cystic duct. This is likely to occur in the case of caterpillar hump deformity and early division of the artery. The former has been reported to occur in 4% to 16% of



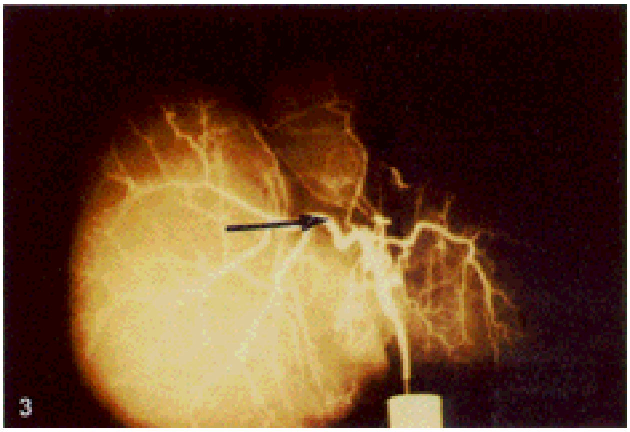


Fig. 1. Early division of the right hepatic artery at postmortem arteriography.

Fig. 2. Caterpillar-like loop of the right hepatic artery gives origin to a short cystic artery. **A** Cystic artery. **B** Caterpillar-like loop. **C** Cystic duct.

Fig. 3. Triple cystic artery at postmortem arteriography. The arrow the three arteries passing through Calot's triangle.

Fig. 4. A branch of the cystic artery enters the liver. **A** Branch of the cystic artery. **B** Cystic artery.

Fig. 5. Sectoral bile duct. **A** Posterior segmental duct. **B** Common bile duct. **C** Left hepatic duct. **D** Right hepatic duct.

Fig. 6. Single cystic vein. **A** Cystic vein. **B** Right hepatic artery. **C** Common bile duct. **D** Right branch of portal vein.

cases [15], which is in accordance with the 13% rate in the current study. The occurrence of the latter was 9% in this study and otherwise is not mentioned in the literature.

A branch of the cystic artery (running through Calot's triangle to enter the liver) [12] can at times be approximately the same caliber as segmental hepatic vessels resulting from early division of the right hepatic artery, as shown by the current results. The outcome of ligating one of these arteries inadvertently may range from an uneventful course [5] to liver infarction, either necessitating [10] or not necessitating [17] liver resection.

A double cystic artery has been reported to occur in 11%

Table 1. Arteries giving rise to a second cystic artery in 70 specimens

	n
Gastroduodenal artery	1
Left hepatic artery	2
Right hepatic artery	2
Segmental branch of the right hepatic artery	5

to 25% of subjects [11], which accords with our 14% rate. However, whether both cystic arteries are running through Calot's triangle is not reported [6]. The current data show that both arteries were found within the triangle in only 40% of cadavers with double arteries, which is a lower rate than a previously published 58% [11]. An additional hazard is the length of the second cystic artery, which was less than 5 mm in half of the current specimens.

Data on venous drainage of the gallbladder are scarce [18]. A cystic vein the same caliber as that of additional arteries or bile ducts running through Calot's triangle was noted in 4% of the current specimens. Such a vein may challenge the surgeon because it constitutes the third structure within Calot's triangle in addition to the cystic duct and artery. These vessels, when inadequately electrocoagulated, may cause low-pressure bleeding leading to secondary laparotomy [3, 7] if they merge with the portal vein.

Sectoral bile ducts were observed in 14% of cadavers in a previous postmortem study [11]. Dissimilarly, data from clinical studies based on intraoperative cholangiography have shown rates ranging from 0.3% to 8.4% [4, 7–9, 14, 19]. Our 5.7% rate of additional bile ducts passing through Calot's triangle was based on both corrotion casts and postmortem cholangiography. Sectoral ducts may be the only drainage path for that particular part of hepatic tissue having no apparent interductal communication within the liver [9, 19]. They merge with either the cystic or the common hepatic duct [9, 10, 20]. However, the bottom line is not their inlet but rather their size [9, 10]. In fact, additional ducts may be either sectoral ducts draining a liver segment only in part or right posterior hepatic ducts draining the whole posterior liver segment [10]. This in turn makes it likely that ligation of small-caliber sectoral ducts or right posterior hepatic ducts will result in an uneventful outcome [2, 19] and bile leakage [10], respectively. On the other hand, inadvertent lesion of the former may result in a spontaneously recovering bile leak [1], whereas major reconstructive surgery often is required when a lesion occurs in the latter [10].

Knowledge of the aforementioned anatomy is critical to surgeons facing more than two structures within Calot's triangle during laparoscopic cholecystectomy.

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