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Laparoscopic cholecystectomy, Calot's triangle, and variations in cystic arterial supply

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Abstract
Background: The extrahepatic biliary tree with the exact anatomic features of the arterial supply observed by laparoscopic means has not been described heretofore. Iatrogenic injuries of the extrahepatic biliary tree and neighboring blood vessels are not rare. Accidents involving vessels or the common bile duct during laparoscopic cholecystectomy, with or without choledocotomy, can be avoided by careful dissection of Calot's triangle and the hepatoduodenal ligament.
Methods: We performed 244 laparoscopic cholecystectomies over a 2-year period between January 1, 1995 and January 1, 1997.
Results: In 187 of 244 consecutive cases (76.6%), we found a typical 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%).
Conclusion: Young surgeons who are not yet familiar with the handling of an anatomically abnormal cystic blood supply need to be more aware of the precise anatomy of the extrahepatic biliary tree.

Key words: Calot's triangle — Cystic artery — Laparoscopic Cholecystectomy — Gallbladder

Previous reports in the literature describing anomalies of the cystic artery have been solely based on specimens obtained at autopsy [1, 2, 4–9]. Heretofore, no description has been published of the anomalies of the arterial supply in laparoscopic operative cases. Herein we present our laparoscopic operative findings on the cystic artery and its relation to Calot's triangle. In fact, conventional textbook descriptions of the regional blood supply are not adequate to serve as a surgical guide for cholecystectomy [7], specifically in the laparoscopic procedure.

During laparoscopic cholecystectomy, careful blunt dissection of Calot's triangle is necessary in order to identify the structures in or around this region and avoid any accidental injury to the extrahepatic biliary tree and blood vessels. The instruments are one of the major factors contributing to a clean-cut dissection of this area. The electrocoagulating hook may cause unidentifiable iatrogenic burns in the extrahepatic biliary tree or the vessels around Calot's triangle. The instruments used in the present study have been reported previously [10] and are easy to handle for young surgeons in this field.

As has been reported, in about one-fourth of cases, the superficial and deep branch of the cystic artery have separate origins; the deep cystic artery, as a rule, arises from the right hepatic, while the superficial cystic one arises from the right hepatic, middle hepatic, left hepatic, gastroduodenal, or retroduodenal [1, 6, 7]. Therefore, a dual blood supply to the gallbladder is not uncommon.

We performed 244 consecutive laparoscopic cholecystectomies using instruments developed in our department without encountering any problems in the identification of structures in or around Calot's triangle. This study focuses on the pattern of the cystic arterial supply found in Calot's triangle during laparoscopic cholecystectomy.

Materials and methods

Laparoscopic cholecystectomy following fine dissection of structures in the hepatoduodenal ligament was carried out in 244 cases in our department with a Tohoku dissector, forceps, and long and short mantis [10] over a 2-year period from January 1, 1995 to January 1, 1997.

Because each case was recorded on videotape, repeated operative images were obtained quickly and used to create a detailed study of Calot's triangle. Drawings were made using images captured as described in order to emphasize the important variations of the regional anatomy.

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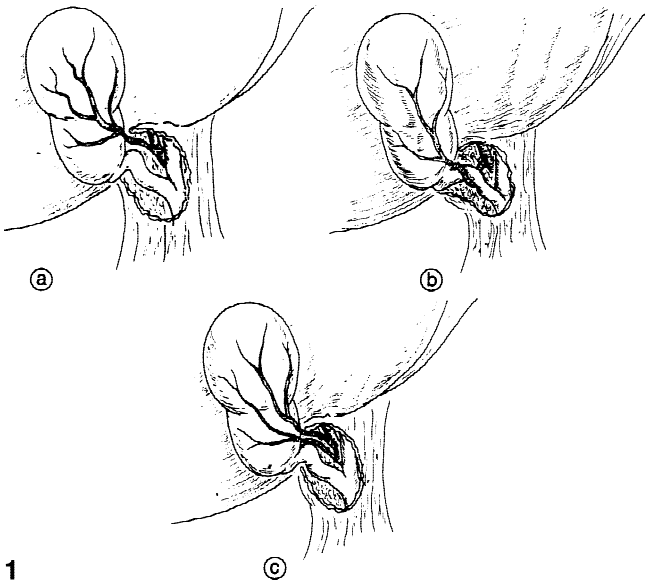

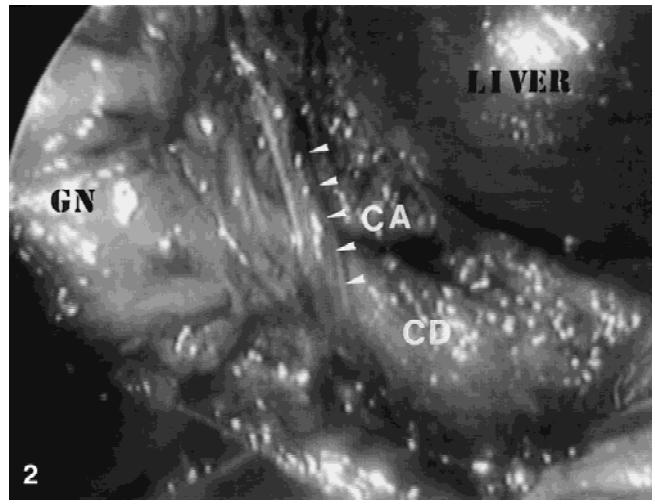

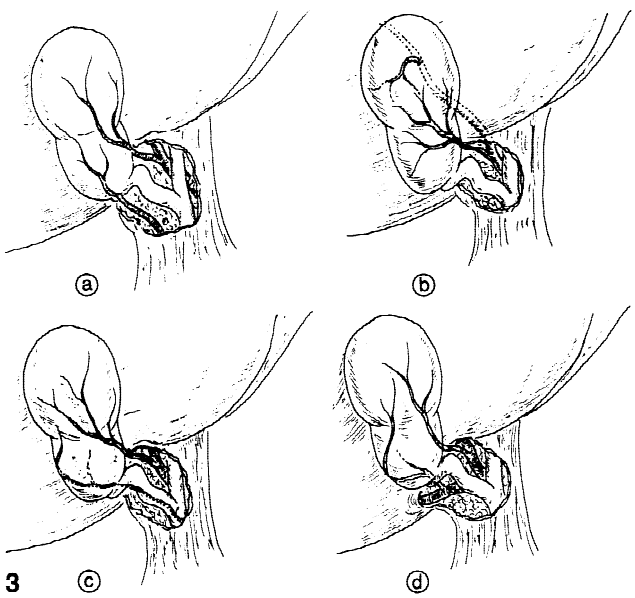

Fig. 1. A single typical cystic artery in Calot's triangle was found in 76.6% of the cases **(a).** A single artery in Calot's triangle hooking round the cystic duct was seen in 2.5% of the cases ("the cystic artery syndrome") **(b).** Double cystic arteries in Calot's triangle were seen in 2.5% of cases **(c).**

Fig. 2. A 37-year-old man with chronic cholecystitis caused by cystic artery variation ("the cystic artery syndrome") underwent laparoscopic cholecystectomy. A single cystic artery originating from the right hepatic and then hooking round the cystic duct from behind reappears at the peritoneal surface near the neck of the gallbladder (GN, gallbladder neck; CA, cystic artery; CD, cystic duct).

Fig. 3. One artery is typically present in Calot's triangle but there are also accessory arteries from different origins: **a** from below and lateral to the cystic duct in 5.3% of cases, **b** piercing the gallbladder bed near the fundus in 1.2% of cases, **c** along and posterior to the cystic duct in 0.4% of cases, and **d** just below Hartmann's pouch in 0.4% of cases.

Results

The different patterns of the arterial supply of the gallbladder observed during laparoscopic surgery were divided into three groups.

In group 1, the cystic artery was seen in Calot's triangle, and no other source of supply was present. Group 1 was subdivided into two subgroups indicating single (1a) and double arterial supply (1b), respectively. A single arterial supply, considered to be a normal anatomical feature (Fig. 1a), was present in 187 cases.

Six cases had a very interesting type of supply—namely, a single cystic artery originating from the right hepatic and then hooking round the cystic duct from behind, reappearing at the peritoneal surface near the neck of the gallbladder (Fig. 1b). We have named this feature "the cystic artery syndrome." We assume that the main cause of stone formation was the poor bile flow due to partial or complete obstruction of the cystic duct (Fig. 2). In group 1b, there was a double supply, with the same origin as in the typical one in 6 cases (Fig. 1c).

In group 2, there was more than one blood supply. One is observed in the normal position in Calot's triangle, and the other exists outside the triangle (Fig. 3a–d). In this series, accessory arteries were traced from the caudal to the cystic duct in 13 cases (5.3%), piercing the gallbladder bed in three cases (1.2%), along with the cystic duct in one case (0.4%), and from the right lateral aspect of the common hepatic duct and below the cystic duct in one case (0.4%).

Group 3 comprised the cases in which cystic arteries were observed outside Calot's triangle. This group was also subdivided (3a and 3b) based on the number of arterial supplies to the gallbladder. In group 3a (Figs. 4 and 5a), there were 14 cases (5.7%) in which the cystic artery approached the gallbladder along the course of the cystic duct but below it and right-lateral to the common hepatic duct (Fig. 4a). In six cases, the artery extended along the cystic duct; in four cases (0.8%) it was posterior to the duct (Fig.

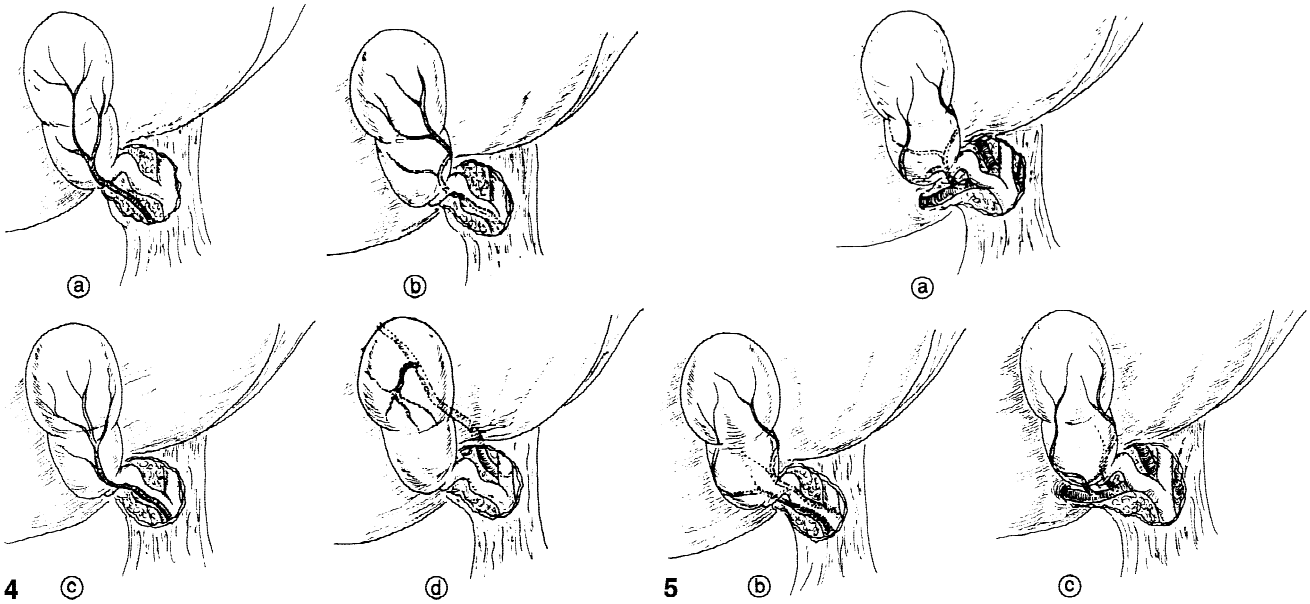

Fig. 4. Cases with no cystic artery in Calot's triangle: **a** a single artery from below and lateral to the cystic duct in 5.7% of the cases, **b** a single artery along and posterior to the cystic duct in 1.6% of the cases, **c** a single artery along and anterior to the cystic duct in 0.8% of cases, and **d** piercing the gallbladder bed near the fundus in 0.4% of cases.

Fig. 5. Single or double arteries outside Calot's triangle: **a** a single artery supplying the gallbladder, just below Hartmann's pouch in 1.3% of cases, **b** double arteries along and posterior to the cystic duct in 0.8% of cases, and **c** double arteries just below Hartmann's pouch in 0.4% of cases.

4b); and in two cases (0.4%), it was anterior to the duct (Fig. 4c). In one case, a single artery was found to supply the gallbladder by piercing the hepatic parenchyma approaching the bladder from the gallbladder bed (Fig. 4d). In three cases (1.2%), a single artery was approaching just below Hartmann's pouch, arising perpendicularly from the right inferior branch of the hepatic artery (Fig. 5a). Group 3b comprised the double blood supply cases outside Calot's triangle. In two cases (0.8%), both arteries extended along the cystic duct but posterior to it (Fig. 5b), with a double supply below Hartmann's pouch (Fig. 5c).

Discussion

Since laparoscopic cholecystectomy has almost completely replaced open cholecystectomy, it is important for every laparoscopic surgeon to be familiar with the variations in the anatomic features of the extrahepatic biliary tree and those of the arterial supply of the gallbladder. Accidental injury due to unpredictable anomalies may cause hemorrhage or bile leakage during the procedure.

In our study, the distribution of the cystic artery was typical in only 187 (76.6%) of 244 cases, with arteries supplying the gallbladder specifically present within Calot's triangle, but there were also 27 cases (11.1%) with a double cystic arterial supply. Surprisingly, in 27 cases (11.1%), no artery was present in Calot's triangle (Fig. 3).

In 18 cases (7.4%), there was a typical blood supply in Calot's triangle with another accessory from different sites. From among these, in 13 cases (5.3%), the second artery was approaching the gallbladder from below and right-lateral to the cystic and common hepatic duct; in three cases (1.2%), it was piercing the gallbladder bed near the fundus, in one case (0.4%), it was posterior along the duct; and in one case (0.4%), it comprised a double supply, one of which was just below Hartmann's pouch. It is of particular importance to be aware of situations when no artery is seen in Calot's triangle, because various abnormal positions may exist, and overlooking them can result in severe hemorrhage, necessitating conversion of the procedure. Therefore, after carefully clipping one artery, the surgeon must search carefully for another supply, which may have any source of origin, as was seen in this study (i.e., in group 2 and group 3).

We are introducing a new entity, the cystic artery syndrome, which resembles the right hepatic artery syndrome reported by Edmund et al. in 1961 [3]. In this condition, acute cholecystitis and obstructive jaundice are caused by compression of the common bile duct by the right hepatic artery, which crosses it ventrally. The notion of a cystic artery syndrome adds to our understanding of the etiology of gallstone formation. Namely, we speculate that poor bile flow from the gallbladder, due to partial or complete obstruction of the cystic duct by an aberrant artery, causes bile stasis in the gallbladder, leading to stone formation.

Finally, since the incidence of abnormalities in the cystic artery is not negligible, it is important to be familiar with the anatomical features of the extrahepatic region of the gallbladder when performing laparoscopic cholecystectomy. In our procedures, we encountered no difficulties in dealing with an abnormal blood supply or other anomalies of the extrahepatic biliary tree because very fine dissection of the area and clear-cut identification of the structures was made possible by use of the Tohoku dissector developed by our group.

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