# Vascular and Gallbladder Variations in Laparoscopic Cholecystectomy

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## Abstract

Most laparoscopic cholecystectomies are performed after ultrasound examination in combination with clinical and biochemical parameters. The most reliable method to assess anatomy in living people is during the surgery, so a clean dissection, accurate visual identification, and a profound knowledge of expected variations are essential. In order to alert the surgeon and to reduce the incidence of complications, we describe the clinical anatomy of vascular and gallbladder variations faced during fifty laparoscopic cholecystectomies. Vascular anomalies were present in 18% of the patients; they include: caterpillar hump of the right hepatic artery, early division of cystic artery, low-inserted cystic artery, cystic artery originating from proper hepatic artery, and a rare anatomical variation whereby the right hepatic artery was found in the gallbladder bed. Gallbladder anomalies were present in 14% of the patients; they include: intrahepatic gallbladder, "Phrygian cap" gallbladder, and a case of situs inversus.

The incidence, surgical anatomy, and operative maneuvers of the anomalous cases were discussed.

**التفاوتات الوعائية والخاصة بالمرارة في جراحة استئصال المرارة بواسطة تنظير البطن**

**الخلاصة**

معظم عمليات جراحة استئصال المرارة بوساطة تنظير البطن تجرى بعد استكمال فحوصات السونار للبطن بالاضافة الى التقييم السريري والمختبري . ان الطريقة المفضلة لدى الجراحين خلال عملية تنظير البطن هي ملاحظة او رؤية التشريح العياني خلال عملية التنظير وهذا يتطلب اجراء تشريح واضح ونظيف وصحيح للمنطقة ومعرفة كاملة للتفاوتات التشريحية

المتوقعة اثناء تشريح المنطقة . ومن اجل لفت انتباه الجراح لغرض تقليل حدوث المضاعفات تم وصف التشريح السريري للتفاوتات الوعائية والخاصة بالمرارة من خلال اجراء خمسين عملية استئصال للمرارة بوساطة تنظير البطن.

شكلت التفاوتات الوعائية 18% من ( 50)مريض التي اجريت لهم عملية التنظير. اشتملت التفاوتات الوعائية على وجود الشكل اليسروعي لل شريان الكبدي الايمن ، مع وجود شرايين للقناة المرارية مسبقة الانقسام ، او منخفضة الانغراز ، او ناشئة من الشريان الكبدي المخصوص ، مع وجود الشريان الكبدي الايمن في مضجع المرارة وهذا نادر الحدوث من الناحية التشريحية.

اما التفاوتات المتعلقة بالمرارة فقد شكلت 14% من ال (50) مريض التي اجريت لهم عملية التنظير فقد تضمنت : المرارة داخل الكبد وشكل القلنسوة الفريجية وحالة نادرة من الاحشاء مقلوبة الموضع .

لقد تم مناقشة حدوث هذه التفاوتات من الناحية التشريحية والوعائية.

## Introduction

Laparoscopic cholecystectomy has largely replaced open cholecystectomy as the method of symptomatic gallbladder removal [17]. Apart from its advantages [30], the procedure is influenced greatly by the training and judgment of the surgeon performing the procedure [29]. Beside technical skill and experience, good knowledge of the clinical anatomy of variations is required to reduce the incidence of operative and post-operative biliary complications. The anatomy facing a surgeon during laparoscopic cholecystectomy involves complex relationships between the hepatic artery, extrahepatic biliary tree, and gallbladder. Calot's triangle represents an important anatomical landmark during laparoscopic cholecystectomy. The triangle is formed by the cystic duct and gallbladder below, the inferior surface of segment V of the liver above, and the common hepatic duct medially [8]. Over the years, the triangle described originally by Calot in 1891 has enlarged. For Calot, the upper boundary was the cystic artery; today, it is the lower border of the right lobe of the liver [25]. Within the boundaries of the triangle, a number of structures may be identified including: the right hepatic artery, the cystic artery, the cystic lymph node, connective tissue, and lymphatics. Occasionally it may contain accessory hepatic ducts and arteries [24]. In reality, it may be a small potential space rather than a large triangle making the dissection of its contents without damaging the bordering structures the most challenging step of a cholecystectomy [22]. This study aims at describing some anatomical variations that were faced during fifty

laparoscopic cholecystectomies. The variations include two categories: vascular and gallbladder variations. Some of the variations are not particularly mentioned in anatomy textbooks (e.g. caterpillar hump of the right hepatic artery and an early division of the cystic artery); owing to their surgical significance within the small laparoscopic cholecystectomy surgical field, they are gaining more attention from the surgeon and the anatomist as well.The usual arterial anatomy is that the right hepatic artery enters Calot's triangle posterior to the common hepatic duct in 87% of the cases and anterior to it in 13% of the cases. An aberrant right hepatic artery has been found in 18% of cadavers accessory to the normal right hepatic artery or replacing it [20].

A caterpillar hump of the right hepatic artery is described when the right hepatic artery is tortuous rendering the cystic artery short. In a postmortem study, the caterpillar hump right hepatic artery was found in 12.9% of the cases [6].The cystic artery usually arises from the normal or aberrant right hepatic artery within Calot's triangle. At the neck of the gallbladder, the cystic artery divides into a superficial (anterior) branch to the serosal surface and a deep (posterior) branch to the hepatic surface of the gallbladder. This pattern is found in 61-87% of individuals. In few cases, the cystic artery arises from the right hepatic artery to the left of the common hepatic duct or from the left hepatic artery. In such instances, the cystic artery enters the triangle of Calot by passing anterior to the duct. If the origin is from the common hepatic artery or from the gastroduodenal artery, the cystic artery enters the triangle from below [25].

Duplication of the cystic artery is found in as many as 25% of individuals. The two vessels may arise from adjacent or separate sisters. This duplication usually represents separation of the superficial and deep branches [25].

Atypical blood supply and accessory arteries have been observed in 7.4% of cases undergoing laparoscopic cholecystectomy [27]. In spite of differences in nomenclature, two main groups of variations of the cystic artery are presented: in the first group, the cystic artery is situated within the hepatobiliary triangle where it might be

doubled or originating from an aberrant right hepatic artery. In the second group the cystic artery cannot be found within hepatobiliary triangle during laparoscopic dissection. It might originate from the gastroduodenal artery or from the left hepatic artery [3].

Several variations have been described relating to the shape and position of the gallbladder. For a detailed review of gallbladder anomalies, please consult the online site of "Illustrated Encyclopedia of Human Anatomic Variation" [7]. In this study, three such variations are going to be described: intrahepatic gallbladder, "Phrygian cap" shape, and situs inversus.

The term intrahepatic gallbladder refers to a gallbladder that is partially embedded within the liver parenchyma. The "Phrygian cap" gallbladder is described when the fundus of the gallbladder folds upon itself and may be mistaken for a pathological deformity of the organ [16]. Situs inversus is a rare autosomal recessive condition with an incidence of 1/10,000 [18]. Laparoscopic cholecystectomy has been rarely reported in situs inversus with the first case being reported in 1991 [9].

The blood supply and gallbladder anatomy during laparoscopic cholecystectomy are often the source of major challenge to unprepared and unaware surgeon which necessitates constant revisions and improved knowledge.

## Patients, materials, and methods

The study involved fifty patients (42 females and 8 males) with an age range of 20-69 years. They underwent laparoscopic cholecystectomy during a period of six months at Kadhmiya Teaching Hospital (Baghdad),(35 cases) and at AL-Hilla General Hospital – Babylon governorate(15 cases). All the patients had a history of symptomatic cholelithiasis. Investigations including, liver function tests and ultrasound of the abdomen were performed.

The laparoscopic equipments used were produced by Richard Wolf (Germany). The American technique was employed. After insertion of the ports, initial inspection of the entire abdomen was made to exclude injury or bleeding during creation of pneumoperitoneum and to identify any gross additional diseases, position, and shape of the gallbladder.

The fundus of the gallbladder was grasped by the assistant and flipped upward over the inferior edge of right lobe of the liver. Dissection of cystic pedicle was carried out starting with the superior leaf of the cystic pedicle then traction on Hartmann's pouch was altered in an upward and medial direction.

Clipping and division of the cystic duct was performed. The cystic artery was identified, clipped, and then divided.

Further traction on the fundus of the gallbladder was performed to bring into view the proper plane for dissection between the liver and the gallbladder. The separation of the gallbladder from the liver bed was performed close to the gallbladder side to avoid injury of the liver.

Once the gall bladder was freed, it was extracted through the epigastric port. The subhepatic and the right subphrenic spaces were inspected and irrigated with saline until the returning fluid was clear. Inspection and irrigation of the stump of the cystic artery, cystic duct, and gallbladder fossa was performed.

## Results

Seventeen (34%) of the cases demonstrated anomalous anatomy pertaining to the gallbladder and its arterial supply. In two patients there was an overlap in the anatomical variations. In one case there was a “Phrygian cap” gallbladder anomaly associated with a low inserted cystic artery. In the second case the “Phrygian cap” anomaly was associated with a caterpillar configuration of the right hepatic artery.

*Vascular anomalies:*

Nine (18%) of the patients showed vascular anomalies. Table-1 shows the types and distribution of vascular anomalies observed in this study.

The usual configuration of an anterior cystic duct close to the laparoscopic view and appearing larger than the cystic artery which lies postero-superior was present in about (84%) of the patients (Fig.1).

In the caterpillar configuration, the loop of the right hepatic artery came close to the gallbladder and cystic duct, resulting in a short cystic artery (Fig.2).

In the early divided cystic artery, the anterior and posterior branches of the cystic artery, which commonly divide upon reaching the neck of the gallbladder, divided before reaching Calot's triangle so that the two arteries traversed the triangle (Fig.3a). Further traction of the gallbladder and dissection of the peritoneum showed that the two arteries stemming from a single cystic artery in a Y-shaped configuration (Fig.3b).

In a low-inserted cystic artery (Fig.4), the artery originated from vessels other than the right hepatic artery. The low inserted cystic artery, in order to reach its final destination, passed anterior in one case and inferior to cystic duct in the other case, but not posterior to it. The operation field in laparoscopic cholecystectomy and its technique hindered further dissection till confirming the origin of the variant vessel.

When the cystic artery originated from proper hepatic artery (Fig.5), its relation to the cystic duct was the common posterior relation. In both low-inserted cystic artery and when the cystic artery originated from the proper hepatic artery, the cystic artery ran a long course before reaching the gallbladder.

A rare anatomical variation encountered in this study was a right hepatic artery found in the bed of gallbladder where it gave off the cystic artery (Fig.6).

*Gallbladder anomalies*

Seven (14%) of the patients in this study showed gallbladder anomalies. These anomalies involved site, shape, and laterality of the gallbladder (Table-2).

In the intrahepatic cases, the gallbladder was partially embedded within the liver parenchyma at the gallbladder fossa on the visceral surface of the right lobe of the liver (Fig.7). In those patients, the intrahepatic site of the gallbladder was faced accidentally during the operation since the preoperative ultrasound was insufficient alone to indicate the partial intrahepatic position of the gallbladder.

The "Phrygian cap" gallbladder (Fig.8), characterized by a folded fundus, was also faced accidentally during the operation.

In the patient with left sided gallbladder, the anomaly was part of a known case of situs inversus. On planning the entry ports the trocar of the epigastric

port was introduced to the left side of the falciform ligament. Needless to say, the mid-clavicular and the mid-axillary ports were planned in corresponding locations on the left side of the subcostal region (Fig.9).

## Discussion

In earlier literature, preoperative endoscopic retrograde cholangiography and intraoperative cholangiography were done as a routine to reveal anatomic variations in the biliary tract. They were thought to improve the safety of laparoscopic cholecystectomy [28]. Today, most cholecystectomies are performed after identification of gallstone disease on ultrasound examination in combination with clinical and biochemical parameters. Although on occasion an ultrasound examination or even laparoscopic contact ultrasonography can predict gross distortions of anatomy, in the usual case it does not throw any light on anatomical relations [22]. Although there is a debate on the routine use of intraoperative cholangiography, it seems that most of the investigative procedures are designed to reveal ductal anatomy. Thus knowledge of arterial anatomy in patients is not available to the surgeon preoperatively. The most reliable method to assess anatomy during the surgery is clean dissection, accurate visual identification, and a profound knowledge of expected variations.

**Vascular variations**

Vascular variations were more common than those of the gallbladder. The usual pattern of a cystic artery arising from the right hepatic artery and appearing smaller and farther away from the cystic duct in the laparoscopic view was present in 84% of the patients (Fig.1). Other studies revealed the typical pattern of the cystic artery to be present in 72% [13], 73.5% [2], and 76.6% [27] of patients operated laparoscopically.

The nomenclature of arterial variants and their types vary from one study to another [13][2][27]. Absence of cystic artery in Calot's triangle has been reported in 11.1% [27] and 5.5% [2] of the cases. A cystic artery that runs inferior to the cystic duct was found in 6% of the cases [13]. In this study, the low inserted cystic artery and the cystic artery originating from a right hepatic artery in the liver bed imply absence

of the artery in Calot's triangle; this was observed in 8% of the cases.

The right hepatic artery normally courses behind the bile duct and joins the right pedicle high up in the Calot's triangle. In the caterpillar configuration, the right hepatic artery comes very close to the gallbladder and the cystic duct in the form of a hump. The incidence of this variation has been reported to be 1% [1], 4-15% [7], 12.9 [6], and 6.4% [5]. The incidence of this variation was 4% in this study (Fig.2). If such a hump is present, the cystic artery in turn is very short. In this situation the right hepatic artery is either liable to be mistakenly identified as the cystic artery or torn in attempts to ligate the cystic artery. The ensuing bleeding in turn predisposes to biliary injury [22].

A rare anatomical variation encountered in this study was a right hepatic artery coming very close to the gallbladder so that it was found in its bed (Fig.6). An accessory or replaced right hepatic artery from superior mesenteric artery has been reported in almost 15% of individuals, whereby the right hepatic artery courses through the Calot's triangle and therefore nearer the gallbladder [22]. Nevertheless, a right hepatic artery within the gallbladder bed has not been previously reported.

The presence of such an artery renders the cystic artery short and may require meticulous dissection of the gallbladder from its bed. In addition, right hepatic vascular injury has been reported to lead to liver necrosis in the right liver lobe [15]. The possibility of the presence of a right hepatic artery in the bed of the gallbladder emphasizes the necessity to dissect close to the gallbladder rather than the liver parenchyma.

Accessory cystic arteries have been reported in 7.4% of the cases [27] and doubling of the cystic artery in 22% [13] and 15.5% [2] of the cases. Doubling of the cystic artery has been indicated to be the most common cystic artery variation [2]. In this study, a double cystic artery was found in Calot's triangle in 4% of the cases (Fig.4); however, the double artery was found to originate from a single stem in a Y-shaped configuration. In such circumstances, one may have to separately clip the two branches

(superficial and deep). Also, if the presence of a posterior branch is not appreciated it can cause troublesome bleeding during posterior dissection.

A cystic artery originating from the gastroduodenal artery has been reported in 4.5% of the patients [2]. In this study, a low inserted cystic artery of obscure origin was found in 4% of the cases. The long course of such an artery and its course anterior to structures in the free margin of lesser omentum have been reported [23].

Since the course and length of the cystic artery in the Calot's triangle is variable, we found that the superficial branch of the cystic artery was a good landmark to lead to the site of the parent cystic artery when pathology obscured clear anatomy of the cystic artery.

Uncontrolled arterial bleeding during laparoscopic cholecystectomy is a serious problem and may increase the risk of bile duct damage. Therefore, accurate identification of the anatomy of the cystic artery is important [22]. When in doubt, the surgeon should avoid cutting any duct if its identity has yet to be established. The surgeon should not hesitate to convert the procedure to open surgery.

**Gallbladder anomalies:**

*Intrahepatic gallbladder:*

A gallbladder partially embedded within the liver parenchyma poses difficulties in dissection especially at the gallbladder bed and increases the chance intraoperative complications. In some cases of intrahepatic gallbladder it may be prudent to leave some of the posterior wall of the gallbladder in situ and cauterize it rather than persist with an excessively bloody dissection [12]. On the other hand, intrahepatic gallbladder may result in conversion to open cholecystectomy [21].

Large portal and hepatic venous branches traverse the liver at a depth of around 1cm from the gallbladder. A deep liver tear during the dissection of the gallbladder off its fossa can occasionally bleed profusely [22]. Thus, during the dissection it may be important to err on the side of the gallbladder rather than the liver parenchyma. This is quite important in cases of intrahepatic gallbladder and when gallbladder inflammation was so extensive.

*Phrygian cap gallbladder:*

This anomaly in the shape of the gallbladder is present in 2-6% of population [16]. With its potential for biliary stasis, cholelithiasis, and cholecystitis some have suggested a prophylactic cholecystectomy [26]. Nevertheless, others believe that it is a clinically innocuous entity [16].

Although it may be mistaken for a pathological deformity of gallbladder, and present confusion to the radiologist [26], it did not require any significant surgical maneuver. It was found in 4% of laparoscopically operated patients (Fig.8); its association with other anatomical variations as has been observed in this study (low inserted cystic artery and caterpillar configuration of the right hepatic artery) should alert the surgeon to increase suspicion of the presence of accompanying surgically significant anomalies.

*Situs inversus and laparoscopic cholecystectomy*

Authors have commented on the rarity of the condition and on mental reorientation and readjustment of the usual hand-eye coordination [4][10][19].

The umbilical and epigastric ports were placed as usual but the telescope had to be introduced towards the left upper quadrant; the trocar of the epigastric port had to be angled towards the left, to the left of the left-sided falciform ligament. The two other ports were also introduced as usual except that these were on the left side of the abdomen and not the right.

However, despite the above mentioned readjustments, it has been agreed that laparoscopic cholecystectomy is still quite feasible and safe, and should be offered to these otherwise normal patients [10]. In this study, the case with situs inversus (Fig.9), apart from mirror image anatomy underwent an uneventful operation from the anatomical point of view.

A gallbladder located to the left side of the falciform ligament may also accompany an ectopic position of the gallbladder being attached to the left lobe of the liver. The incidence of such gallbladder has been found to be 0.3% of the cases [14]. It may be discovered accidentally preoperatively. The cystic artery crosses in front of the common bile duct from right to

left. The cystic duct may open on the left or right side of the common hepatic duct. Apart from the modifications of the port sites, the anomaly does not preclude safe laparoscopic cholecystectomy [14].

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**Table-1**: Types and distribution of vascular anomalies

| Vascular anomalies | Number of patients | Percentage |
|---|---|---|
| Caterpillar configuration | 2 | 4% |
| Early divided cystic artery | 2 | 4% |
| Low inserted cystic artery | 2 | 4% |
| Right hepatic artery in the bed of gallbladder | 2 | 4% |
| Cystic artery originated from proper hepatic artery | 1 | 2% |
| **Total** | **9** | **18%** |

**Table-2**: Types and distribution of gallbladder anomalies

| Gallbladder anomalies | Number of patients | Percentage |
|---|---|---|
| Intra-hepatic gallbladder | 4 | 8% |
| Phrygian cap gallbladder | 2 | 4% |
| Left sided gallbladder in a patient with situs inversus | 1 | 2% |
| **Total** | **7** | **14%** |

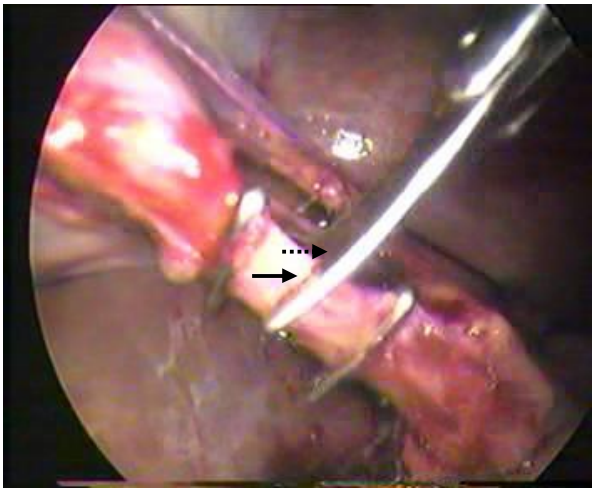

**Fig.1**: The most common configuration of cystic duct and artery encountered in this study. Cystic duct ( **à** ), cystic artery (interrupted arrow).

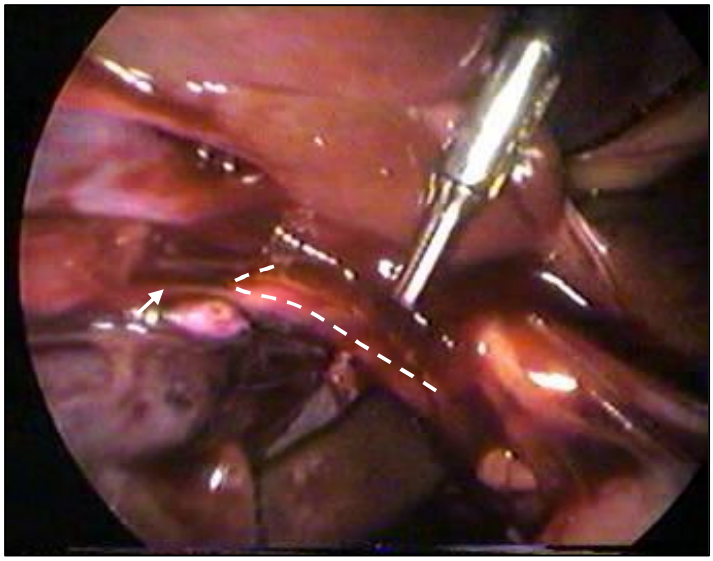

**Fig.2**: Short cystic artery ( **à** ) arising from caterpillar right hepatic artery (interrupted line).

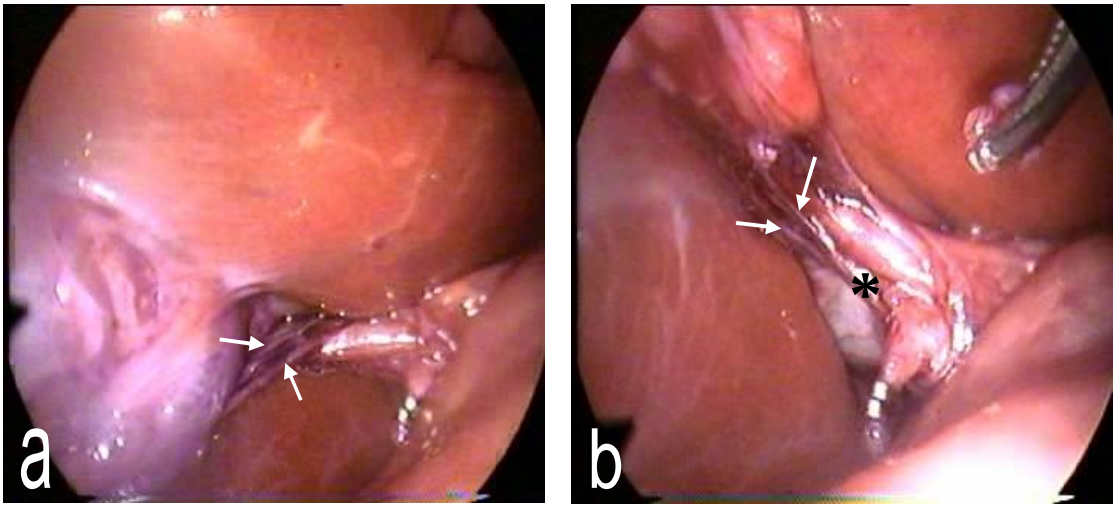


**Fig.3**: Early divided cystic artery. (a) The anterior and posterior branches of the cystic artery (arrows) traverse Calot's triangle. (b) Further traction of the gallbladder reveals the two arteries (arrows) arising from a single cystic artery (*) in a Y-shaped configuration.

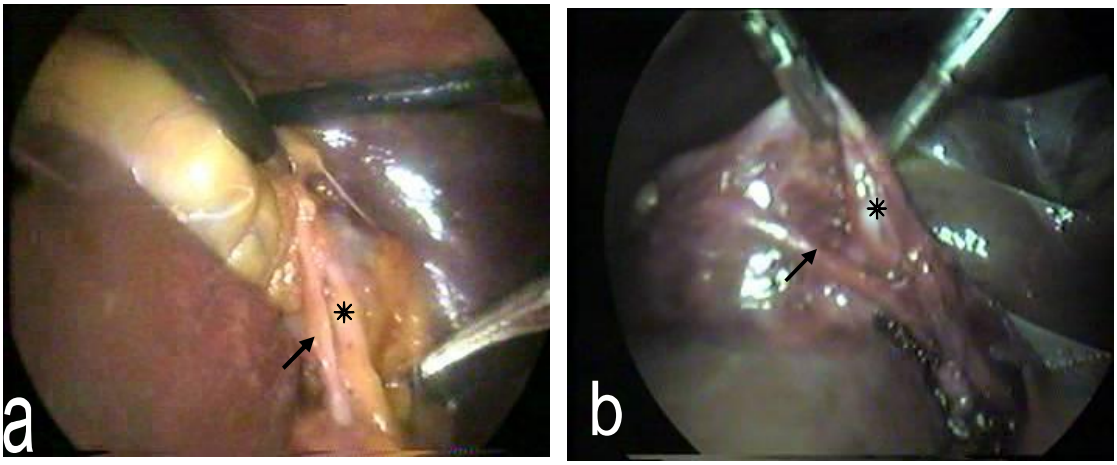


**Fig.4**: Relation of a low inserted cystic artery to the cystic duct. (a):Low inserted cystic artery ( **à** ) passing in front of the cystic duct (*); (b) Low inserted cystic artery ( **à** ) passing inferior to the cystic duct (*).

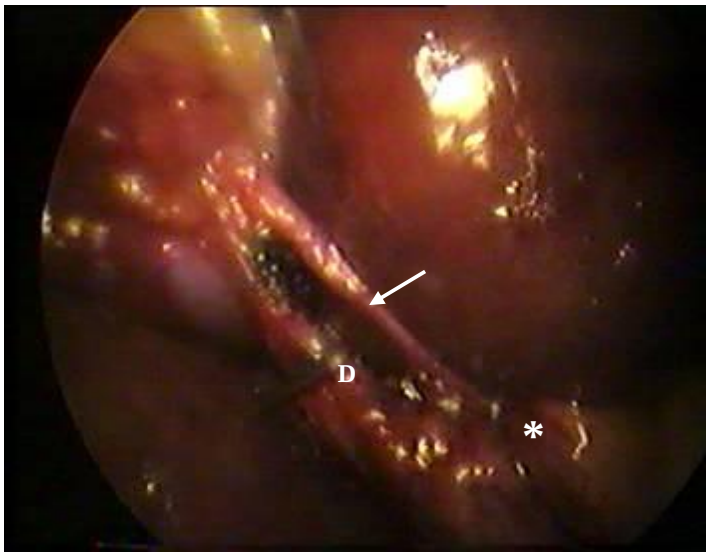

**Fig.5**: Cystic artery ( **à** ) originated from proper hepatic artery (*). Note that the cystic artery lies posterior to the cystic duct (D).


**Fig.6**: Cystic artery (interrupted arrow) arising from the right hepatic artery ( **à** ) within the bed of the gallbladder (*).

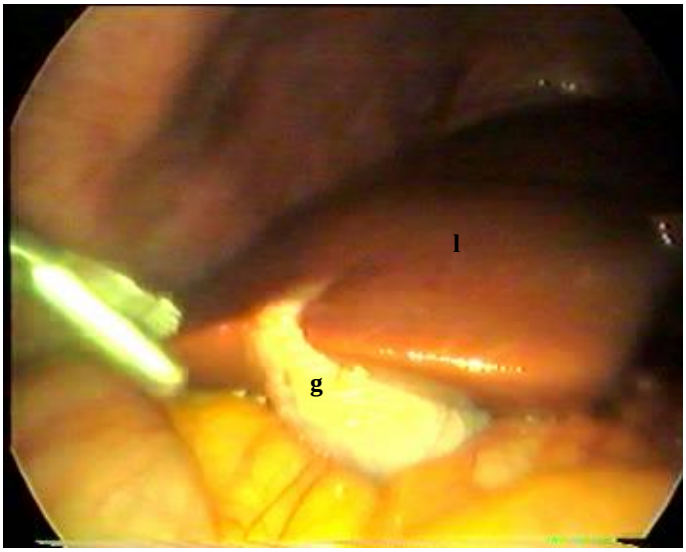


**Fig.7**: Intrahepatic gallbladder. (g): gallbladder; (l): diaphragmatic surface of the liver.

**Fig.8**: Phrygian cap anomaly

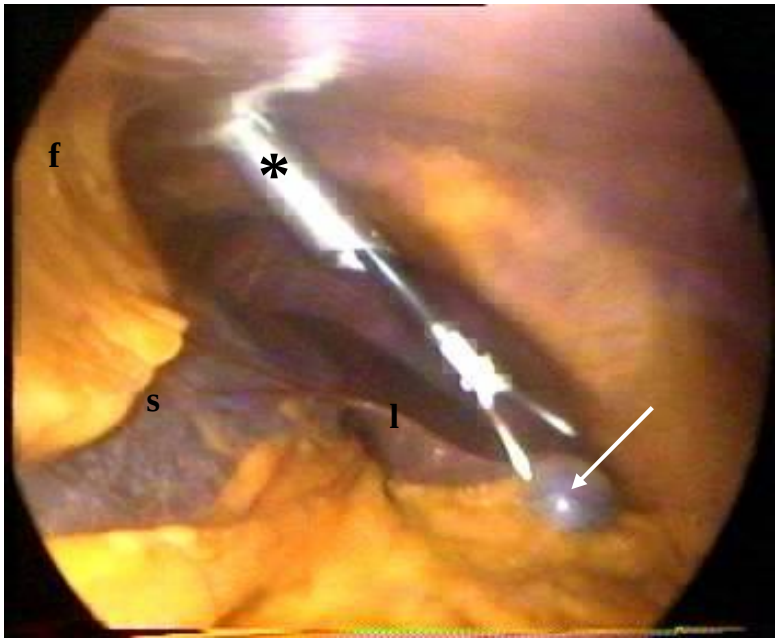


**Fig.9**: Left sided gallbladder ( **à** ) in a patient with situs inversus. Note that the trocar in the epigastric port (*) is introduced to the left of the falciform ligament (f). (l): liver; (s): stomach.