

CLINICAL RESEARCH

## Left-sided gallbladder: Its clinical significance and imaging presentations

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venous and biliary anomalies. It should be considered in US, CT and angiography images that demonstrate no definite segment IV, absence of umbilical portion of the portal vein in the left lobe, and club-shaped right anterior portal vein.

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**Key words:** Left-sided gallbladder; Angiography; Computed tomography; Ultrasound

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### Abstract

**AIM:** To assess the importance of preoperative diagnosis and presentation of left-sided gallbladder using ultrasound (US), CT and angiography.

**METHODS:** Retrospective review of 1482 patients who underwent enhanced CT scanning was performed. Left-sided gallbladder was diagnosed if a right-sided ligamentum teres was present. The image presentations on US, CT and angiography were also reviewed.

**RESULTS:** Left-sided gallbladder was diagnosed in nine patients. The associated abnormalities on CT imaging included portal vein anomalies, absence of umbilical portion of the portal vein in the left lobe of the liver, club-shaped portal vein in the right lobe of the liver, and difficulty in identifying segment IV. Angiography in six of nine patients demonstrated abnormal portal venous system (trifurcation type in four of six patients). The main hepatic arteries followed the portal veins in all six patients. The segment IV artery was identified in four of six patients using angiography, although segment IV was difficult to define on CT imaging. Hepatectomy was performed in three patients with concomitant liver tumor and the diagnosis of left-sided gallbladder was confirmed intraoperatively.

**CONCLUSION:** Left-sided gallbladder is an important clinical entity in hepatectomy due to its associated portal

### INTRODUCTION

Left-sided gallbladder is defined as a gallbladder located to the left side of the ligamentum teres. This anomaly can be divided into three anatomic abnormalities: a situs inversus, an ectopic left-sided gallbladder, and a right-sided ligamentum teres<sup>[1-4]</sup>. Left-sided gallbladder with right-sided ligamentum teres has been a rare anomaly since Hochstetter's first description in 1886. Its characteristic description is a "gallbladder lying over the left side of the ligamentum teres"<sup>[1,4,5]</sup>. The associated anomalies with left-sided gallbladder include portal vein anomalies, biliary system anomalies, and segment IV atrophy<sup>[5-9]</sup>. The complex anomalies associated with left-sided gallbladder are important during hepatectomy, particularly in living donor liver transplantation. Preoperative survey of the anomalies of the portal triad is important in minimizing the incidence of postoperative biliary and vascular complications. Unknowingly, ligation of the left branch of the portal vein and bile duct that contribute to three-quarters of the liver hemodynamics will cause hepatic failure, biliary congestion and leakage<sup>[7,8,10-12]</sup>. This series reports nine cases of left-sided gallbladder with right-sided ligamentum teres. Its associated anomalies and significance during hepatectomy are identified and discussed.

### MATERIALS AND METHODS

We reviewed 1528 enhanced CT scans performed

Table 1 Patient profiles and imaging results

Patient number	Clinical status and history	Club-shaped form portal vein (ultrasound finding <sup>1</sup> )	Left lateral segment of liver (computed tomography finding <sup>2</sup> )	Segment IV artery (angiogram finding)	Portal vein configuration (angio-portogram finding)
1	HCV, HCC, right hepatectomy	Over right lobe liver	Hypertrophic	From RHA	Trifurcation type
2	HCC, HBV and HCV	Not clear	Normal size	Not obvious	Other type
3	Right lobe HCC	Over right lobe liver	Mild hypertrophic	From RHA	Trifurcation type
4	Right lobe HCC, HBV	Over right lobe liver	Normal size	> From RHA	Trifurcation type
5	Hysterectomy, abdominal pain	Not clear	Normal size	NA	Not available
6	Liver tumor, HBV	Not clear	Mild hypertrophic	NA	Not available
7	Multiple HCC	Over right lobe liver	Normal size	NA	Not available
8	HCC, left lateral partial segmentectomy	Not clear	Normal size	From LHA	Trifurcation type
9	HCC, left lateral segmentectomy	NA	Normal size	Not obvious	Other type

<sup>1</sup>No umbilical portion over left lobe liver in all patients whose US results were available; <sup>2</sup>Club-shaped form portal vein over right side of the liver, no umbilical portion over left lobe of the liver. No defined segment IV in any patients. HBV: Hepatitis B carrier; HCV: Hepatitis C carrier; NA: Not available; RHA: Right hepatic artery.

for survey of liver tumors, other abdominal tumors, retroperitoneal tumors and abdominal pain at Chang Gung Memorial Hospital, Kaohsiung, Taiwan from 1999 to 2004. Forty-six patients were excluded because the gallbladder position or fossa could not be determined from previous hepatectomy or cholecystectomy. Of the remaining 1482 patients, nine were diagnosed to have left-sided gallbladder due to the presence of a right-sided ligament teres on enhanced CT. Among these patients, one underwent right hepatectomy and cholecystectomy for segment IV hepatocellular carcinoma (HCC). The other two patients underwent left lateral segmentectomy and partial hepatectomy for left lateral segment HCC, respectively.

## RESULTS

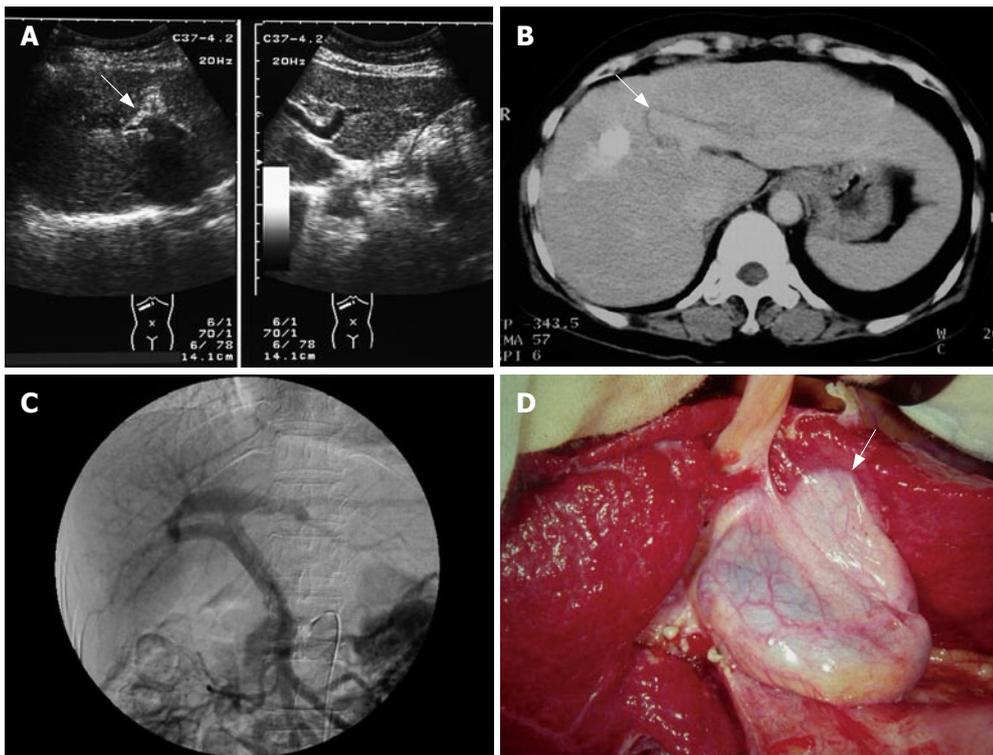
Nine patients from a screening population of 1482 patients (0.6%) were diagnosed with left-sided gallbladder with enhanced CT. Ultrasound (US) was performed in eight of the nine patients, and angiography was done because of liver tumors in six patients. The clinical status and imaging findings are listed in Table 1. US demonstrated no umbilical portion of the portal vein over the left lobe of the liver in eight patients, of whom, four had an abnormal club-shaped portal vein over the right side of the liver (Figure 1A), whereas the other four patients did not clearly show a dilated portion of the portal vein on the right side of the liver. Enhanced CT demonstrated absence of the umbilical portion of the portal vein over the left lobe of the liver, and an abnormal umbilical portion of the portal vein over the right lobe of the liver, as in the US findings. Segment IV of the liver was difficult to define on CT imaging in all nine patients (Figure 1B). Angiography was performed in six of the nine patients. In four patients, the portal veins ramified to the right and left portal tributaries, and the left tributary of the portal vein diverged into lateral and medial portions. The medial portion veered to the ventral side and formed the umbilical portion, which finally joined the ligamentum teres (trifurcation type) (Figure 1C). The other two patients had the portal veins ramified to the

right, and small left portal tributaries. In these patients, the right portal vein formed the umbilical portion with some tributaries, and finally joined the ligamentum teres. The type of portal vein ramification could not be defined from conventional descriptions in these two patients (Figure 2). The main hepatic arteries ran alongside with the main portal venous tributaries in all six patients, of whom four had well-defined segment IV artery (Figure 3). One patient underwent right hepatectomy and cholecystectomy due to HCC over the right lobe of the liver. Another two patients receive left lateral segmentectomy. In these cases, the left-sided gallbladder was well-demonstrated intraoperatively (Figure 1D).

## DISCUSSION

Left-sided gallbladder with right-sided ligamentum teres is rarely reported. However, with advances in diagnostic imaging modalities, such as US, CT, MRI and angiography, left-sided gallbladder is increasingly being reported to be associated with right-sided ligamentum teres, accompanied by abnormal intrahepatic portal venous branching. An initial impression of left-sided gallbladder is made when the ligamentum teres is deviated to the right side, and a right-sided umbilical portion of the portal vein is present with difficulty in defining segment IV anatomy<sup>[5,6,8]</sup>. Our survey of nine cases is the largest report to date, and revealed an incidence of 0.6% of this anomaly, which is consistent with the previously reported incidence of 0.1%–1.2%<sup>[5,7,8,13,14]</sup>.

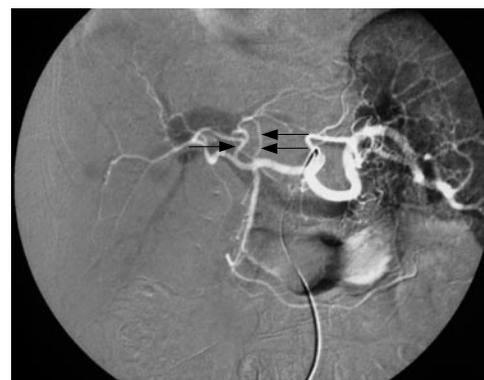
There are several explanations for the development of left-sided gallbladder without situs inversus. First, the normal gallbladder bud may migrate to the left lobe instead of the right, and lies on the left side of the ligamentum teres<sup>[15]</sup>. In this situation, the portal vein, biliary tree and hepatic artery should be in the normal location and classified into ectopic gallbladder. Second, the gallbladder may develop directly from the left hepatic duct, and is accompanied by failure in development of the normal structure on the right side<sup>[7,15]</sup>. Our literature review



**Figure 1** A 50-year-old woman with chronic hepatitis C. Right trisegmentectomy and cholecystectomy were performed due to the right lobe liver tumor. **A:** US demonstrated a club-shaped portal vein (arrow) over the right lobe of the liver and no umbilical portion over the left lobe of the liver; **B:** Enhanced CT demonstrated enlarged left lateral segment and a club-shaped portal vein (arrow) over the right side of the liver; **C:** Angiography demonstrated trifurcation type of the portal vein; **D:** Intraoperative photography demonstrated gallbladder over left side of ligamentum teres and adhesions on the left lateral segment (arrow).



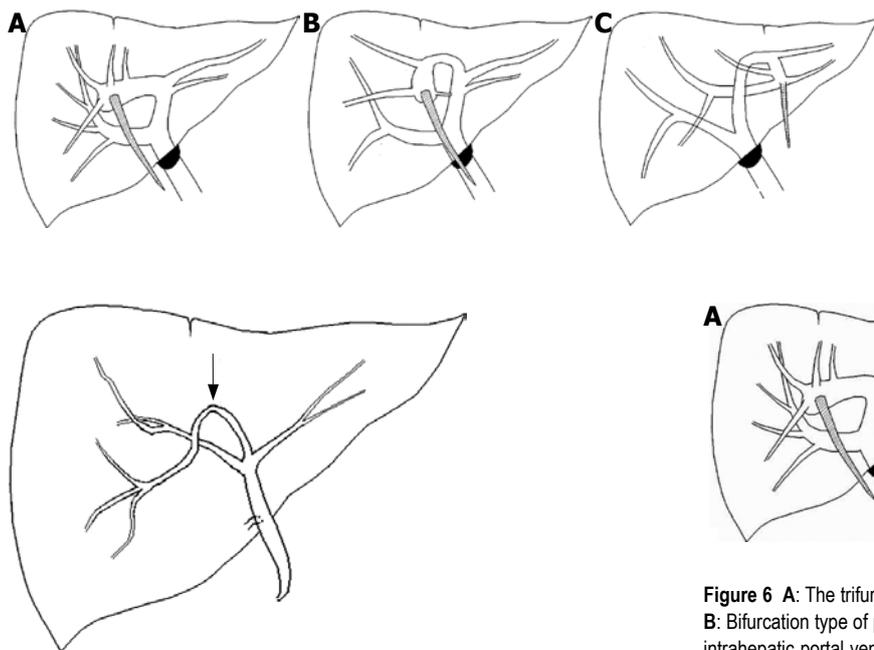
**Figure 2** A 55-year-old man with HCC, chronic hepatitis B and C. Angioportography demonstrated bifurcation with a small branch of the left portal vein (black arrow), segmental IV branch of the portal vein (white arrow), and a club-shaped form of the right portal vein with many branches.



**Figure 3** A 59-year-old woman with HCC in the segment VI of the liver and chronic hepatitis C. Angioportography with substrate on arterial phase. The hepatic arteries (white vessels) followed the portal veins (black vessels). The segmental IV artery (arrow) was demonstrated. Right anterior side liver parenchyma was supplied from the segmental IV artery. The left hepatic artery (double arrows) originated from the common hepatic artery near the orifice of the gastroduodenal artery.

showed<sup>[5-7,11,15,16]</sup> only one case of left-sided gallbladder in which the cystic duct originated from the left hepatic duct<sup>[16]</sup>. The proposal of left-sided gallbladder development due to a second gallbladder originating directly from the left hepatic duct was not favored in those cases. Third, the left umbilical vein disappears and right umbilical vein partly remains. The peripheral (or placental) and central portions of the latter develop into the ligamentum teres and ligamentum venosum, respectively (Matsumoto's hypothesis)<sup>[13,17]</sup>. According to this hypothesis, the right umbilical portion should lie to the right of the gallbladder bed, but the gallbladder bed lay astride the ligamentum teres, as reported in four previous cases<sup>[7,18]</sup>. Nevertheless, this explanation also does not fit with our cases. Fourth, the gallbladder is on the left side of the ligamentum teres simply because the latter deviated to the right<sup>[5,7,16]</sup>. Maetini *et al*<sup>[7]</sup> have stated that there are three types of portal

vein anomalies with the umbilical portion supplying the right anterior portion. In type A, the umbilical portion is to the right of the Cantlie line, whereas the umbilical portion lies on and to the left of the Cantlie line in types B and type C, respectively (Figure 4). They have also found that in the cases of left-sided gallbladder, the right posterior segmental duct joins the common duct distal to the bifurcation, and the aberrant right anterior segmental duct lies in the groove for the ligamentum teres, at which it forms a reverse U-shaped segment similar to the portal vein (Figure 5). They believe that the gallbladder on the left side of the ligamentum teres is there simply because the latter deviated to the right. As the right lobe of the liver becomes atrophied, we propose that the ligamentum teres moves from the left (type C) to the right (type A).

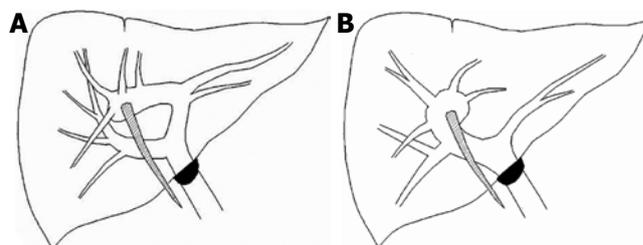


**Figure 5** The right anterior segmental bile duct ran downward and ventrally formed a reverse U-shape (arrow), which followed the right anterior portal vein and lay in the groove for the ligamentum teres in left-sided gallbladder. Maetani *et al* believe that the gallbladder on the left side of the ligamentum teres is simply because the latter deviated to the right.

The gallbladder moves to the left of the ligamentum teres, and the umbilical portion occupies the right side of liver.

Left-sided gallbladders have previously been reported to be associated with portal vein anomalies, biliary system anomalies, and segment IV atrophy. The associated portal vein anomalies are significant in hepatectomy, split liver transplantation, or living donor liver hepatectomy in transplantation, and can be classified into three types: the trifurcation type, bifurcation type and the other type, in which portal vein ramification cannot be defined from conventional descriptions (Figure 6)<sup>[5,19]</sup>. Intrahepatic arteries in left-sided gallbladders have not previously been described in detail<sup>[2,5]</sup>. In principle, the hepatic arteries follow the portal venous tributaries but the hepatic arterial variations and dissociation between the intrahepatic bile duct and portal vein have been reported<sup>[5,11,20,21]</sup>. In our six patients, in general, the hepatic arteries followed the portal venous tributaries (Figure 3). Angiography demonstrated the segment IV hepatic artery (Figures 3 and 7) in four of six patients, although segment IV was difficult to define on CT imaging. Segment IV atrophy is unlikely and we believe that the segment is embedded in the right lobe of the liver, and the true right lobe of the liver is relatively hypoplastic. Hypoplasia of the right lobe of the liver contributes to the ligamentum teres and umbilical portion being deviated to the right and therefore, causing a left-sided gallbladder. The dividing line between segment IV and the right lobe of the liver was not visualized, while segment IV was embedded in the right lobe of the liver. Although biliary tree anatomy was not evaluated in our patients, the bile duct and arterial branches appear to follow the portal venous tributaries of left-sided gallbladders<sup>[5,7,8,11]</sup>. If segment IV is embedded in the right lobe of the liver, the segment IV bile duct

**Figure 4** Maetani *et al* have described three types of portal vein anomalies with the umbilical portion supplying the right anterior portion. In type A, the umbilical portion is over the right side of the Cantlie line. In type B, the umbilical portion lies on the Cantlie line. In type C, the umbilical portion arises from the left portal vein with anterior segmental branches. As the ligamentum teres moves from the type C to the type A, the gallbladder moves to the left of the ligamentum teres.



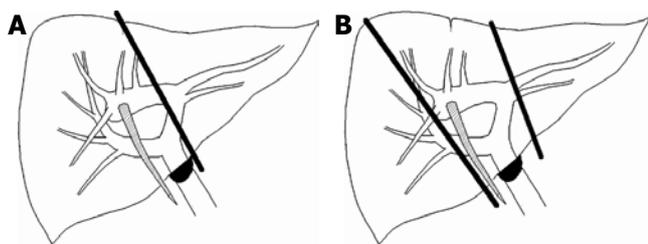
**Figure 6** A: The trifurcation type of portal vein anomaly in a left-sided gallbladder; B: Bifurcation type of portal vein anomaly in a left-sided gallbladder. The abnormal intrahepatic portal venous branches could not be determined into these two types was divided into the other type.



**Figure 7** A 64-year-old man with HCC. The segment IV artery (arrow) from the left hepatic artery is demonstrated.

originated from left main intrahepatic duct ran downward and ventrally formed a reverse U-shaped right anterior segmental bile duct because of the intrahepatic duct following the portal vein. The segment IV bile duct can reasonably explain the formation of a reverse U-shaped right anterior segmental duct that joins the left hepatic duct and lies in the groove for the ligamentum teres, as reported by Maetani *et al* and Newcombe *et al*<sup>[7,22,23]</sup>.

A left-sided gallbladder is an important entity during liver resection, particularly in left hepatectomy for tumors, complicated hepatolithiasis, and in liver transplantation<sup>[7,8,24]</sup>. Our experience of one patient who underwent hepatectomy for liver tumor in the segment IV with diagnosis of left-sided gallbladder and trifurcation type of portal vein anomaly aided in planning for resection (Figure 1A-D). As a result, an extended right instead of a left hepatectomy was performed. If this anomaly had not been recognized preoperatively, left hepatectomy could have been performed, and the portal vein supplying three-quarters of the liver may have been ligated, leading to



**Figure 8** Trifurcation type of portal vein anomaly. **A:** If left hepatectomy is performed, the portal veins draining three-quarters of the liver parenchyma will be ligated. Hepatic necrosis may occur over right anterior portion of the liver parenchyma and contribute to hepatic failure; **B:** Left lateral segmentectomy or right hepatectomy is safe in this type portal vein anomaly.

hepatic failure, biliary congestion or bile leakage<sup>[7,8,11,12]</sup>. In two other patients, a tumor was located over the lateral segment; left hepatectomy was considered risky and only a left lateral segmental or partial hepatectomy was acceptable in both cases (Figure 8). All patients were discharged uneventfully post-hepatectomy.

Prior knowledge of a left-sided gallbladder is also important in living donor liver transplantation. In right lobe living donor liver transplantation, right lobe graft harvesting encounters double right portal veins in a patient with a left-sided gallbladder. Hepatic venoplasty or vein graft interposition for the reconstruction of the portal veins must be performed, thereby contributing to the complexity of surgery. In left lobe living donor liver transplantation, left-sided gallbladders with trifurcation-type portal vein anomaly are more technically demanding because only the left lateral segment can be used, and separation of the right anterior portal and left portal vein is mandatory<sup>[12,25-27]</sup>. The volume of the left lateral segment instead of the whole lateral lobe is calculated to determine left liver volume suitable for donation. In some cases, there is no common trunk of the left portal veins, which leads to difficulty in portal vein reconstruction and the possibility of portal vein thrombosis<sup>[8]</sup>.

Anatomical variations associated with left-sided gallbladders are also important in split liver transplantation<sup>[12,25-27]</sup>. There are two ways of splitting the liver parenchyma suitable for transplantation: (1) dividing the right and left lobes of the liver into anatomical right or left lobes; and (2) separating the liver between the left medial segment and left lateral segment. During division of the right and left lobes of the liver, the portal venous pedicle is separated at the hepatic hilar region, with the left portal vein free and the right portal vein continuous with the main portal vein, or the double right portal veins free and the left portal vein continuous with the main portal vein. Hepatic venoplasty or vein graft interpositions are necessary to reconstruct these anomalous vessels. When separating the liver between the left medial and left lateral segments, the portal venous pedicle is usually divided at the hepatic hilar region, with the left portal vein free and the right portal vein continuous with the main portal vein. This conventional approach can preserve the right lobe, but the volume of left lateral segment may not be sufficient for donation from donors with a left-sided gallbladder. Preoperative evaluation of the left lateral

segment volume is, therefore, critical in donors with a left-sided gallbladder.

Right anterior hepatic duct joining the left hepatic duct is a common variation in left-sided gallbladders. Its angle is too acute for possible dilatation in the treatment of the postoperative residual hepatolithiasis, with eventual stenting through the T-tube tract. Percutaneous transhepatic cholangioscopic lithotomy via the left intrahepatic duct should be considered and can provide a more favorable anatomy<sup>[24,28,29]</sup>. Left-sided gallbladders are overlapped by both the ligamentum teres and falciform ligaments, as well as by the left lobe of the liver. Although laparoscopic cholecystectomy can be performed with the standard port sites with a falciform lift, more medial positioning of the gallbladder-retracting port, and placement of the right-hand operating port to the left of the midline is suggested for laparoscopic removal of left-sided gallbladders<sup>[6,30,31]</sup>.

In conclusion, left-sided gallbladders are a rare anomaly. Judicious preoperative planning is important to identify associated anomalies necessary for the safe conduct of laparoscopic cholecystectomy, hepatectomy, split liver transplantation, or living donor liver hepatectomy in transplantation. If a left-sided gallbladder is found on enhanced CT imaging, further study such as angiography, CT angiography or MRI studies can provide more detailed vascular and even biliary anomalies for preoperative planning. Although left-sided gallbladders with segment IV atrophy have been reported<sup>[5,6,8]</sup>, we propose that segment IV is not atrophic but embedded in the hypoplastic right lobe. However, not all cases in our study were defined by CT and angiography.

## COMMENTS

### Background

Left-sided gallbladders with right-sided ligamentum teres are a rare anomaly associated portal vein anomalies, biliary system anomalies, and the absence of segment IV. The associated anomalies are important entities during liver resection, complicated hepatolithiasis, and in liver transplantation. Preoperative diagnosis of left-sided gallbladders with associated anomalies is indispensable to minimize the incidence of operative complications.

### Research frontiers

Although preoperative diagnosis of left-sided gallbladders is important, there are only a few reported case series of left-sided gallbladders. We assessed the imaging presentation on US, CT and angiography of left-sided gallbladders, which was diagnosed if a right-sided ligamentum teres was present on CT.

### Innovations and breakthroughs

This study of nine cases is the largest reported to date with detailed imaging presentation by US, CT and angiography. The etiology of left-sided gallbladders was investigated with the imaging presentations of hepatic vein anomalies, hepatic artery anomalies, biliary anomalies and the absence of segment IV of the liver.

### Applications

Awareness of the special imaging presentations of left-sided gallbladders on US, CT and angiography is important to make an accurate diagnosis. Identification of the associated anomalies will prevent dangerous maneuvers in hepatectomy, split liver transplantation, or living donor liver hepatectomy in transplantation.

### Terminology

A left-sided gallbladder is defined as a gallbladder located to the left side of the ligamentum teres. The anomalies associated with left-sided gallbladders, including

portal vein anomalies, biliary system anomalies, and segment IV atrophy, were reported. Segment IV is one of three hepatic segments that constitute the left lobe of the liver. It lies between the falciform ligament and the vertical plane of the right hepatic vein, and is demarcated on the diaphragmatic surface of the liver by a line extrapolated from the fossa for the gallbladder to the inferior vena cava; the medial segment is supplied by medial branches of the umbilical part of the left branch of the portal vein.

### Peer review

The authors assessed the importance of preoperative diagnosis and presentation of left-sided gallbladders using US, CT and angiography. They concluded that left-sided gallbladders are an important clinical entity in hepatectomy, because of their associated portal venous and biliary anomalies. It should be considered in US, CT and angiography images that demonstrate no definite segment IV, absence of umbilical portion of the portal vein in the left lobe, and club-shaped right anterior portal vein.

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