

Segmentectomy of the liver

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Abstract Segmentectomy is anatomical resection of segments based on the classification of Couinaud. This procedure is performed mainly for hepatocellular carcinoma. Invasion of portal vein and intrahepatic metastases often occur with hepatocellular carcinoma. Thus, it is desirable to perform anatomical resection of the cancer-bearing areas for curative purpose. However, segmentectomy is selected when extensive resection must be avoided to preserve liver function. There are major differences between segmentectomy of the left hemiliver (Sg 2–4) and right hemiliver (Sg 5–8). In the former, the branches (third-order branches) arising from the umbilical portion of the portal vein can be ligated prior to liver resection. In the latter, manipulation is difficult. Therefore, ultrasonically guided segmental staining is performed by puncturing the portal branch and injecting a dye. This report described techniques for segmentectomy.

Keywords Segmentectomy · Liver · Hepatectomy · Hepatocellular carcinoma

Introduction

In the segmental anatomy of the liver, the classification conventionally used in Europe is the system of Couinaud [1, 2] and that in the US and Japan is the system of Healey and Schroy [3, 4]. Confusion can easily occur because the same terms are used in these systems for different areas. In this report, the term segmentectomy is used to mean anatomical resection of segments 1–8 (Sg 1–8) in the classification of Couinaud (Fig. 1).

Segmentectomy is a procedure that Makuuchi et al. [5] used for hepatocellular carcinoma (HCC) and reported in 1985. This procedure is clearly different from partial hepatectomy. Invasion of portal vein and intrahepatic metastases often occur with HCC even for small-sized tumors. Thus, it is desirable to perform anatomical resection of the cancer-bearing areas for curative purpose [6–9]. Many patients with HCC experience chronic hepatitis and cirrhosis. Therefore, extensive resection, such as sectionectomy and hemihepatectomy, must be avoided to preserve liver function. Segmentectomy was devised for curative purpose and preservation of liver function. It is one of the standard operative procedures for HCC.

Segmentectomy is a complete resection of an area supplied by a segmental branch of the portal vein. To perform segmentectomy, it is important to understand the basic branching patterns of the portal vein. The first-order branches of the portal vein include the left and right main branches. The second-order branches include the right paramedian sectoral branch, right lateral sectoral branch, left umbilical branch, and caudate branch. The third-order branches include the segmental branches. Caution is required for the third-order branches of the portal vein in the right hemiliver. The diagram based on the classification of Couinaud (Fig. 1) depicts the right anterior portal vein

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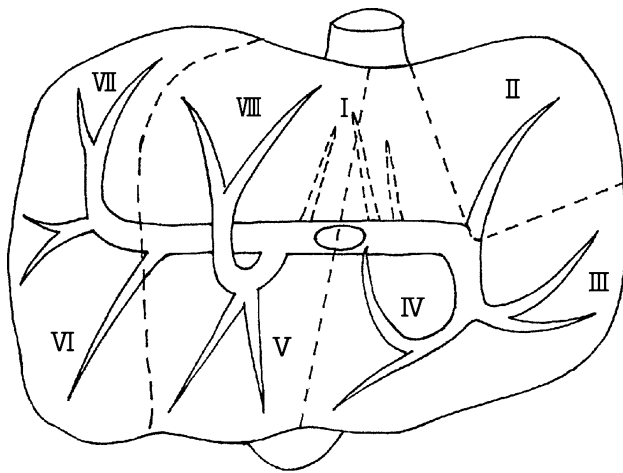


Fig. 1 The segmental anatomy of the Couinaud's classification

bifurcating into P5 and P8 and the right posterior portal vein bifurcating into P6 and P7. However, each segment has two or more third-order branches in many cases [10]. There are also many variations in the portal vein branching patterns, so it is important to confirm the pattern in each case by detailed preoperative imaging and intraoperative ultrasonography (IOUS).

Indications for segmentectomy are tumor extension confined to one segment in diagnostic imaging and satisfaction of the following conditions for liver function: absence of ascites, serum total bilirubin level of 1.0 mg/dL or less, and indocyanine green retention rate at 15 min (ICG-R15) of less than 30% [11].

Operative techniques

There are major differences in operative procedures for segmentectomy of the left hemiliver and right hemiliver. In segmentectomy of the left hemiliver, the third-order branches arising from the umbilical portion of the portal vein can be ligated prior to liver resection. In segmentectomy of the right hemiliver, staining is generally used due to the difficulty of manipulation. This report will describe the techniques of segmentectomy 3, which is an example of segmentectomy of the left hemiliver, and techniques of segmentectomy 8, which is a typical segmentectomy of the right hemiliver.

Segmentectomy 3

An inverted T-shaped skin incision is made (Fig. 2a), and the absence of intraperitoneal dissemination is confirmed. The falciform ligament is divided near the hepatic parenchyma up to the anterior surface of the inferior vena cava, and the degree of tumor extension is confirmed by IOUS.

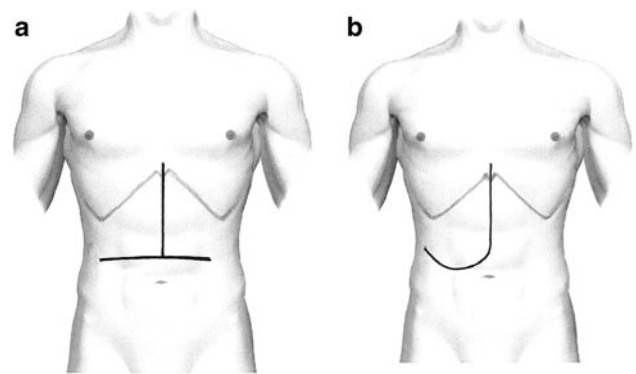


Fig. 2 **a** Inverted T-shaped skin incision. **b** J-shaped skin incision

If avoidance of total hepatic vascular occlusion is desired from the perspective of liver function, the left hepatic artery and the left branch of the portal vein are taped and preparations are made for hemihepatic vascular occlusion.

The left coronary ligament is divided along the hepatic parenchyma using electrocautery, and then the left triangular ligament is divided. In many cases, small vessels and the bile duct run in the same area. Therefore, ligation is always performed before division.

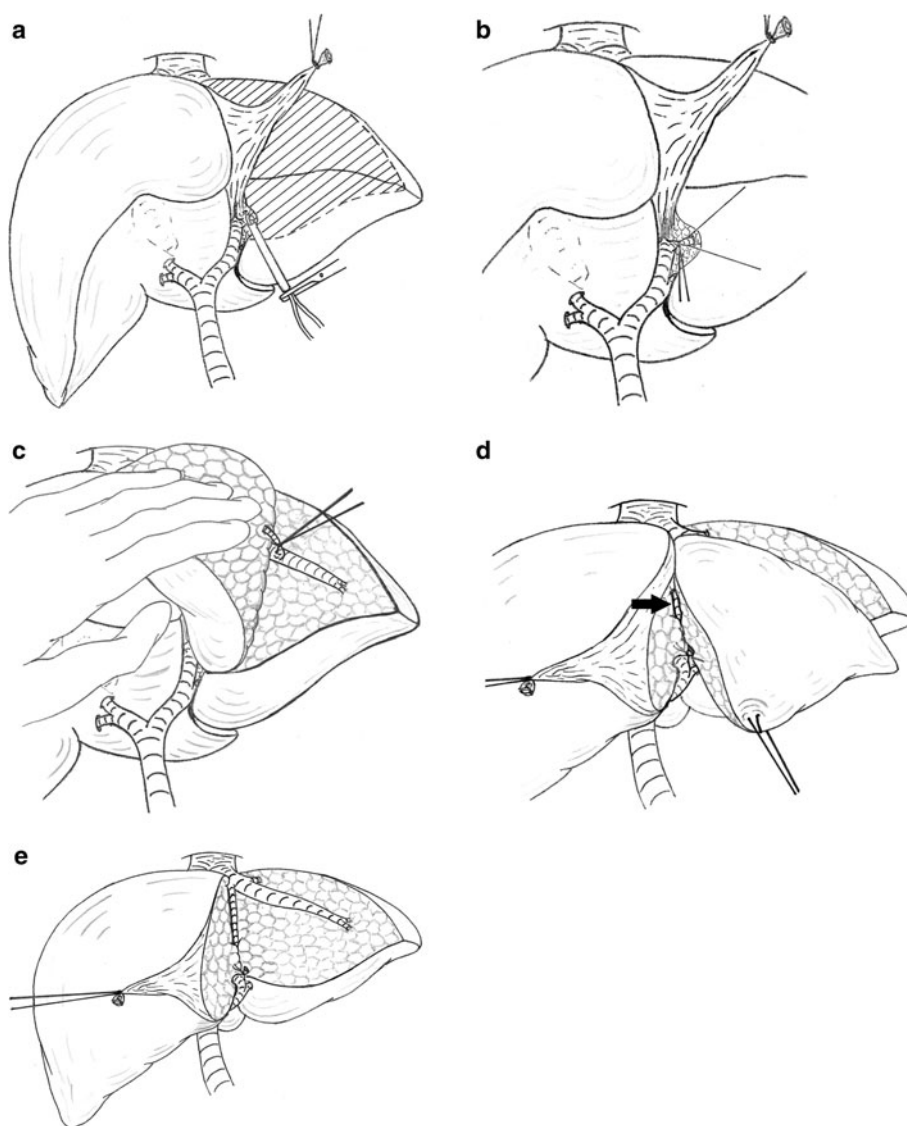
Next, the left side of the umbilical portion of the portal vein is dissected and then the Sg 3 Glisson's sheath including P3 is taped in one bundle. This Glisson's sheath is clamped, and the liver surface is marked along the resulting discoloration using electrocautery (Fig. 3a). If the left margin of the discolored area does not match the attachment of the falciform ligament, a small branch likely exists in the cranial side of the umbilical portion of the portal vein. This branch runs toward the borders of Sg 3 and Sg 4, and it is also ligated and divided.

The Sg 3 Glisson's sheath is ligated and divided (Fig. 3b). Total hepatic vascular occlusion or vascular occlusion of the left hemiliver is performed. At the borders of Sg 2 and Sg 3, liver resection is begun from the left side along the markings of the discolored areas. The left hepatic vein is identified. When resection is performed along the ventral side of this left hepatic vein, there will be drainage vein inflow from Sg 3. They are sequentially ligated and divided (Fig. 3c). When resection is performed toward the cranial side, a common trunk of the left and middle hepatic veins is reached.

Hepatic resection is continued from the caudal to cranial side along the markings of discoloration in the medial side (almost matching attachment of the falciform ligament). The umbilical fissure vein (UFV) is exposed which lies between Sg 3 and Sg 4 (Fig. 3d). When hepatic resection is performed cranially along the UFV, the common trunk of the left and middle hepatic veins is reached and segmentectomy 3 is complete. After the completion of

Fig. 3 Segmentectomy 3.

a The Sg 3 Glisson's sheath is clamped, and the liver surface is marked along the resulting discoloration. **b** The Sg 3 Glisson's sheath is ligated and divided. **c** Liver resection is begun from the *left* side. When resection is performed along the ventral side of the left hepatic vein, there will be drainage vein inflow from Sg 3. They are sequentially ligated and divided. **d** Hepatic resection is continued from the caudal to cranial side along the markings of discoloration in the medial side. The umbilical fissure vein (arrow) is exposed which lies between Sg 3 and Sg 4. **e** After the completion of segmentectomy 3, the following structures are exposed at the resected liver surface: left hepatic vein, stump of the Glisson's sheath of Sg 3, UFV, and middle hepatic vein



segmentectomy 3, the following structures are exposed at the resected liver surface: left hepatic vein, stump of the Glisson's sheath of Sg 3, UFV, and middle hepatic vein (Fig. 3e).

Segmentectomy 8

A J-shaped skin incision is made (Fig. 2b), and the degree of tumor extension is confirmed by IOUS. The falciform ligament, right coronary ligament, and right hepatorenal ligament are divided. The right hemiliver is mobilized and then the gall bladder is exposed. Next, an incision is made over the hepatoduodenal ligament. The common bile duct, left and right hepatic arteries, and left and right branches of the portal vein are taped sequentially.

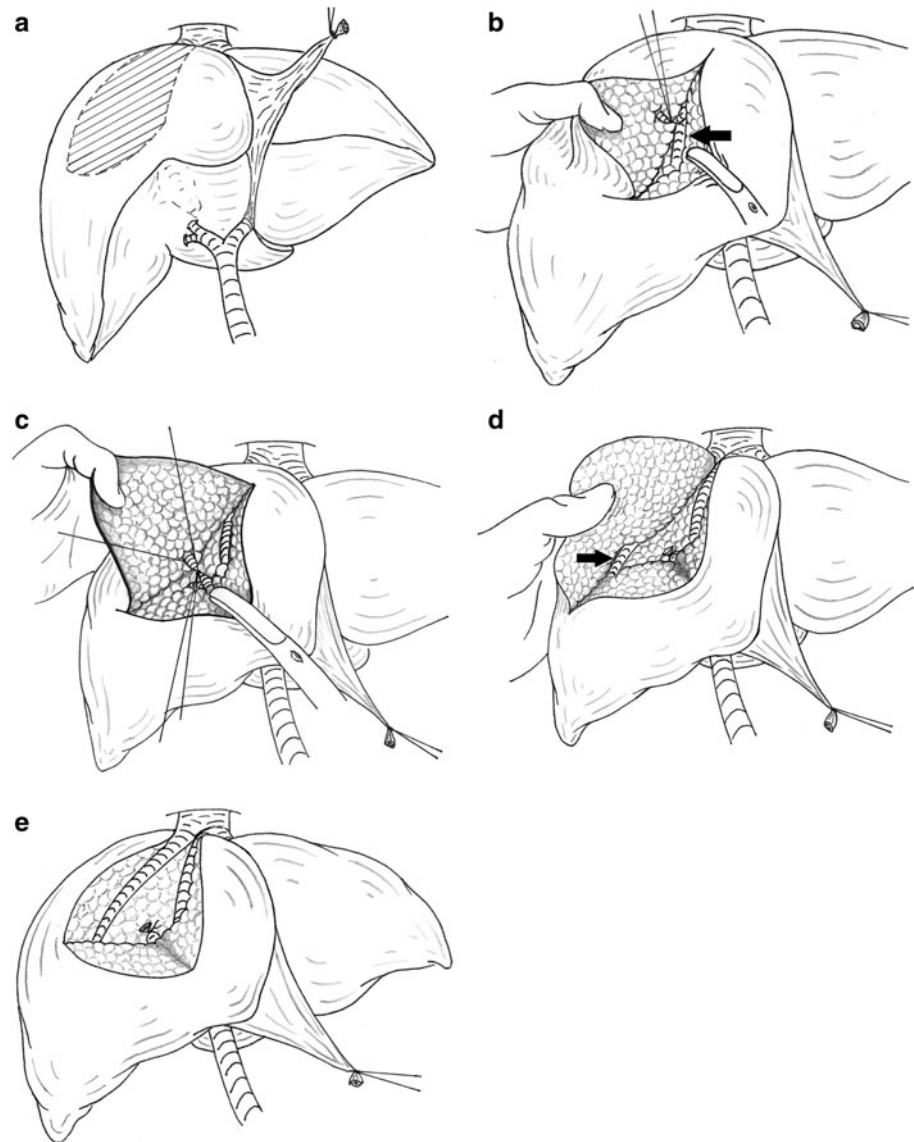
When identifying the branches of the portal vein using IOUS, they are easier to visualize if physiological saline is

sprayed on the liver surface. In many cases, Sg 8 are supplied by two third-order branches, the ventral branch (P8v) and dorsal branch (P8d) of the portal vein. Therefore, each branch is punctured to inject a dye (indigo carmine) and stained. A 23-gauge Cathelin needle is used for puncturing. Puncture of the portal vein is easier when an anesthesiologist stops the patient's breathing. The right hepatic artery is clamped, and the flow of the dye was observed as echogenic microbubbles on the ultrasound screen. Approximately 5 mL of indigo carmine is injected at a speed which prevents regurgitation to the proximal side. The borders of the area with blue staining are marked using electrocautery before the dye disappears (Fig. 4a).

Under vascular occlusion of the left hemiliver, liver resection is begun along the left marked line (almost matching the Rex-Cantlie line), slightly on the side of the left hemiliver. The terminal branches of the middle hepatic

Fig. 4 Segmentectomy 8.

a Ultrasonically guided puncture of the portal branch and injection of dye is performed. The borders of the area with blue staining are marked. **b** Liver resection is begun along the left marked line. When liver resection is continued further cranially along the middle hepatic vein (arrow), V8v, which drains the ventral portion of Sg 8, exists in many cases. V8v is ligated and divided. **c** Liver resection is continued along the caudal marked line, and the Glisson's sheath of the ventral branch of Sg 8 is ligated and separated. **d** Liver resection is performed from the divided area of the Glisson's sheath of the dorsal branch of Sg 8 toward the right side. Subsequently, the right hepatic vein is exposed (arrow). **e** After the completion of segmentectomy 8, the following structures are exposed at the resected liver surface: middle hepatic vein, stump of the Glisson's sheath of Sg 8, and right hepatic vein



vein are identified. The resection is continued in the cranial direction tracing the course of the middle hepatic vein to reach its main trunk. When liver resection is continued further cranially along the middle hepatic vein, V8v, which drains the ventral portion of Sg 8, exists in many cases. V8v is ligated and divided (Fig. 4b).

Next, P8v is confirmed by IOUS. Liver resection is continued along the caudal marked line under vascular occlusion of the right hemiliver, and the Glisson's sheath of the ventral branch of Sg 8 is ligated and separated (Fig. 4c). As a landmark, the area around the Glisson's sheath should be marked by tattoo at the time of portal vein branch puncture. Since the dorsal branch of the Glisson's sheath exists just below the ventral branch, it is also ligated and divided.

Liver resection is performed along the main trunk of the middle hepatic vein under vascular occlusion of the left

hemiliver, and dissection is performed up to the inflow area of the inferior vena cava. The anterior fissure vein exists near this area and runs close to the middle of the right paramedian sector [12]. It is important to ligate and divide this vein and to reach the junction of the middle and right hepatic vein.

Under vascular occlusion of the right hemiliver, liver resection is performed from the divided area of the Glisson's sheath of the dorsal branch of Sg 8 toward the right side. Subsequently, the right hepatic vein is exposed. Liver resection of the right lateral side is performed in the cranial direction along the markings in the stained area, and the main trunk of the right hepatic vein is exposed (Fig. 4d). V8d, which drains the dorsal portion of Sg 8, exists near the inflow area of the inferior vena cava. V8d is ligated and divided to complete segmentectomy 8. After the completion of segmentectomy 8, the following structures are

exposed at the resected liver surface: middle hepatic vein, stump of the Glisson's sheath of Sg 8, and right hepatic vein (Fig. 4e).

Discussion

There are various concepts of the segmental anatomy of the liver and classifications based on such concepts. The classification of Couinaud is the most logical classification from the embryological perspective. It is considered to be based on portal segmentation. However, this classification divides the right liver into segments cranial to the main portal arch (Sg 8 and Sg 7) and those caudal to it (Sg 5 and Sg 6). Thus, the classification for the right liver does not follow portal segmentation. In many cases, there are two or more branches of the portal vein that feed into each segment. In particular, there are many variations of branching patterns for P5. Thus, modifications are necessary when performing segmentectomy using a staining method. Specifically, if it is difficult to puncture and stain all third-order branches of the portal vein that feed the segments to be resected, a counterstaining identification technique of Takayama et al. [13] is effective. For example, when segmentectomy 5 is performed, P8 and the posterior segmental branch of the portal vein are punctured under IIOUS guidance to stain the Sg 8 and right lateral sector. The counterstaining identification technique enables the identification of the entire Sg 5 as a non-stained region. This technique is also useful in cases with portal vein tumor thrombosis that have no desirable portal venous lumen for puncturing, and in cases with poor staining.

Blockage of hepatic arterial blood flow is important for successful staining. When hepatic arterial flow is blocked during dye injection, washout is prolonged for a dye injected into the portal vein. Therefore, distinct dark staining can be obtained [14]. Even in the presence of an arteriportal shunt, the flow from the hepatic artery into the portal vein is prevented. Therefore, regurgitation of the dye in the portal vein can be prevented.

In our report, we described segmentectomy techniques including staining. These techniques are also effective for anatomical liver resection of less than one segment. Segmentectomy is considered difficult in cases with compromised liver function. It enables anatomical liver resection (without partial hepatectomy) by selective puncture of the

portal vein branch supplying the cancer-bearing area and staining of it.

Conflict of interest The authors declare that they have no conflict of interest.

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