

Sectionectomy of the liver

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Abstract Anatomic resection of the liver, which refers to the systemic elimination of the main tumor with micrometastases, preserves liver function and is highly recommended. Tumors located centrally or in the vicinity of major portal pedicles or hepatic veins, however, tend to require extensive hepatectomy. Anatomic sectionectomy of the liver might represent an alternative to such extensive resection. Preoperative simulation, external landmarks, selective devascularization, and intraoperative ultrasound are useful to achieve anatomic sectionectomy. Anatomic resection requires division of the relevant portal vein, hepatic artery, and bile duct. This may be achieved by individual isolation of the three elements or by mass isolation of all three in their surrounding fibrous sheath (Glisson's capsule). Both approaches are equally effective for extensive resections. When sectionectomy is performed, however, the isolation of individual vasculobiliary elements is sometimes difficult and dangerous compared with the isolation of the sectional portal pedicles. By identifying the portal pedicles to individual anatomic sections, it is possible to control the inflow to the section that

is intended for resection. Anatomic sectionectomy is a safe alternative to extensive liver resection in selected patients, avoiding unnecessary sacrifice of functional liver parenchyma and increasing the opportunity to perform repeat resections in cases of recurrence.

Keywords Anatomic hepatectomy · Sectionectomy · Curative resection · 3D-CT · Simulation

Introduction

An increased incidence of primary liver cancer has been reported in Australia, Central Europe, Japan, North America, and the United Kingdom [1]. Hepatocellular carcinoma (HCC) accounts for 84% of primary liver cancers in the United States and 95% in Japan [2, 3]. Liver resection is the only treatment that offers the prospect of long-term survival and potential cure to patients with liver cancer. The treatment of small peripheral lesions by segmentectomies and of large tumors by extensive hepatectomies is the standard. However, particularly for lesions located deep in the right or left lobe, an extensive resection might be required, only because of their location and vascular connections. In such instances, anatomic sectionectomies can also achieve curative resection.

Sectionectomy offers a variety of advantages over both classical major resections and non-anatomic resections. Sectionectomy conserves functional liver parenchyma and reduces the physiologic impact of liver resection. This is of particular benefit in cirrhotic patients with impaired hepatocellular function. Most patients with HCC have impaired hepatic function due to associated chronic liver disease [4, 5]. Therefore, anatomic sectionectomy could represent an alternative to extensive hepatectomies in patients with

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tumors located centrally or in the vicinity of major portal pedicles or hepatic veins. Advantages also include increased opportunity to perform repeat resections in cases of recurrent malignancy.

Anatomic sectionectomies can be performed based on an accurate knowledge of the anatomy of liver sections and segments, including their inflow as well as outflow supplies. Right posterior sectionectomy requires access to the right posterior sectional portal pedicle and preservation of the right hepatic vein. Right anterior sectionectomy requires access to the right anterior sectional portal pedicle and resects the territory drained by the middle and right hepatic veins. Therefore, these operations are technically demanding. They require more extensive dissection of vascular pedicles, expertise in intraoperative ultrasound, and larger transection surfaces. Posterior or central tumors, which otherwise would require right or left hepatectomy, can be treated by right posterior, right anterior, or left medial sectionectomy, thus sparing 2 liver segments.

Detailed understanding of the intrahepatic anatomy and advances in imaging technology have facilitated an approach to hepatic resection based on the removal of hepatic sections and segments. We have reported that the vascular anatomy, liver resection volume, and surgical margin can be predicted before open hepatectomy by using a three-dimensional (3D) virtual hepatectomy program based on the hepatic circulation [6, 7]. We herein review reports and our experience with regard to techniques of anatomic sectionectomies.

Methods

Anatomic sectionectomies are defined according to the International Hepato-Pancreato-Biliary Association (IHPBA) terminology derived from Couinaud's classification [8].

Preoperative simulation of liver resection

Three-dimensional virtual hepatectomy simulation software has recently been developed, which enables accurate preoperative recognition of the anatomic relationships between tumors and the vessels in the liver [9–11]. This 3D simulation based on data obtained by multidetector-row computed tomography is useful for planning liver resection [6, 12] (Fig. 1). It is also effective for preoperative estimation of the liver volumes to be resected and preserved [7].

General technical principles

A J-shaped incision is indicated for surgery of the right lobe and provides good access to the area around the junction between the inferior vena cava (IVC) and the right

hepatic vein. The costal arches on both sides are retracted cranially and laterally. For left-sided lesions, a bilateral subcostal incision is made with a median incision along the xyphoid process. Intraoperative ultrasonography (IOUS) of the liver is performed to screen the liver for undiagnosed lesions and to confirm the hepatic vascular anatomy in relation to the tumor [13]. After mobilization of the liver, the surgeon should proceed with vascular inflow control.

It is recommended that resections are performed anatomically. Intraoperative anatomic definition of the limits of sections to be resected is obtained by a combination of: (1) external anatomic landmarks including the umbilical fissure (i.e., the round and falciform ligaments) and gallbladder fossa; (2) selective devascularization or clamping to create ischemic demarcation lines; and (3) IOUS used to identify the plane of the middle and right hepatic veins and the plane of portal bifurcation.

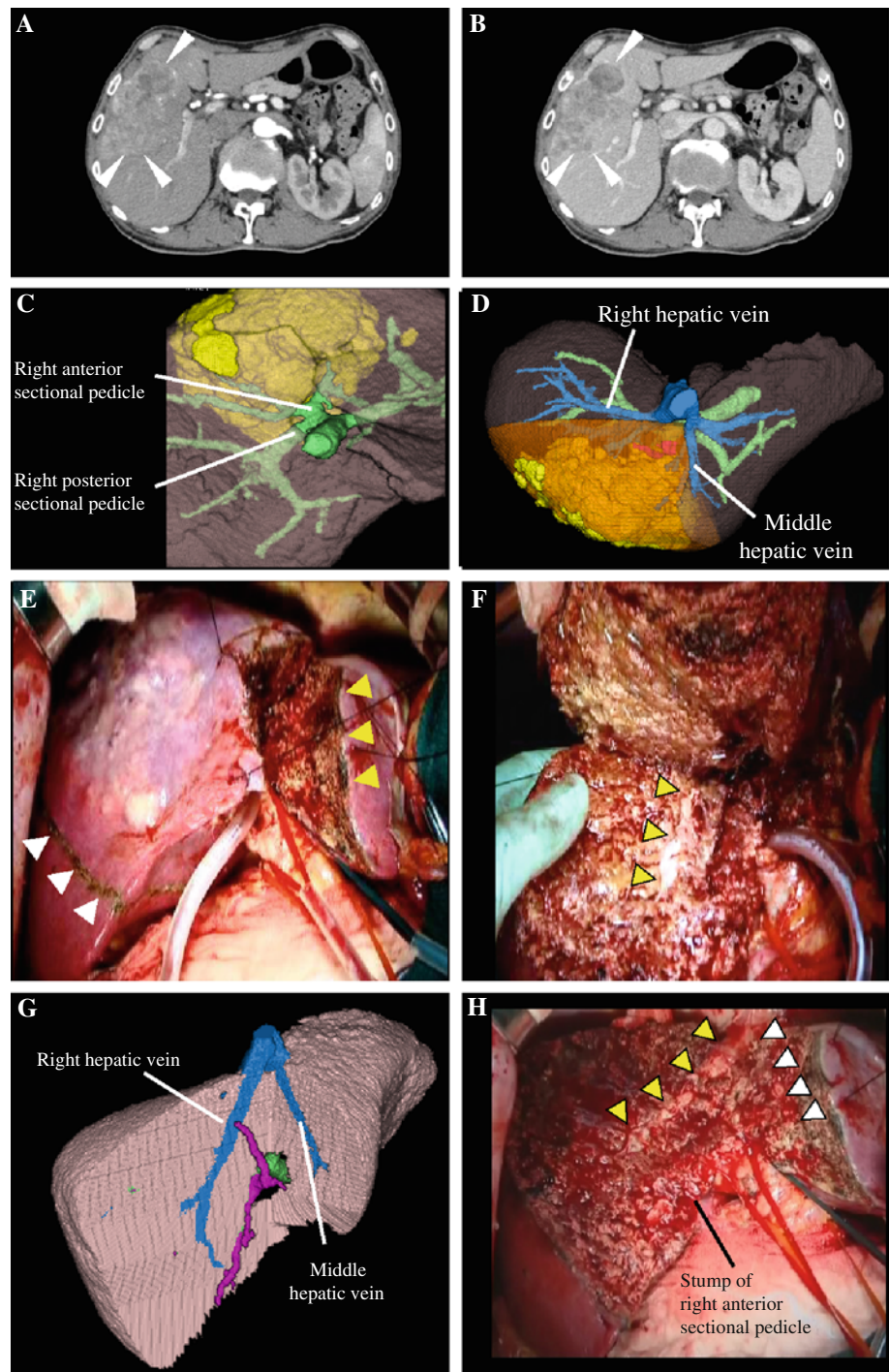
Methods of inflow control

For precise inflow control, the relation between the tumor and the portal pedicle must be clearly defined using preoperative simulation and IOUS. Before dividing the liver parenchyma, a surgeon should isolate and divide (or ligate) the sectional pedicle. After the pedicle is divided or ligated, a clear parenchymal demarcation will appear and delineate the borders of the particular anatomic section. This demarcation facilitates sectional resection by serving as a guide for parenchymal transection. Three general approaches have been described for achieving vascular inflow control: (1) intrahepatic control of the pedicle during parenchymal transection [14]; (2) extrahepatic dissection within the porta hepatis with division of the corresponding sectional hepatic artery and portal vein prior to division of the parenchyma [15]; and (3) extrahepatic control of the corresponding pedicle prior to parenchymal transection [16, 17]. In general, it is not advised to proceed with liver resection before inflow control can be achieved.

Methods of outflow control

Temporary control of the hepatic veins during parenchymal transection assists in minimizing blood loss [18]. Isolation of the right hepatic vein is initiated by completely mobilizing the right liver. The triangular and coronary ligaments are divided and the adrenal gland is dissected off the back of the right liver. The multiple short venous branches are controlled with ligatures. After the vena cava drops away from the posterior surface of the liver, the confluence of the right hepatic vein and the IVC is visualized from above and below. The right hepatic vein is then isolated and temporarily clamped with a pediatric vascular clamp to facilitate parenchymal dissection.

Fig. 1 Preoperative simulation for right anterior sectionectomy in a patient with hepatocellular carcinoma (HCC). Axial computed tomography (CT) shows the HCC in right anterior section (*arrowheads*) during the arterial phase (**a**) and the venous phase (**b**). **c** Integrated three-dimensional (3D) images show the relation between the tumor and the right anterior and posterior portal pedicles. **d** Hepatectomy simulation for right anterior sectionectomy. Note the close relationship between the tumor and the right and middle hepatic veins. **e** Temporary clamping of the right anterior portal pedicle showed a demarcation line among the right anterior, the right posterior, and the left medial sections (*yellow and white arrowheads*). **f** While the right anterior section is lifted up, the right intersectional plane is dissected to expose the right hepatic vein trunk (*arrowheads*). Liver cut surface of right anterior sectionectomy. Note the close proximity between the predicted (**g**) and actual (**h**) cut surfaces. The actual liver cut surface showing the stump of the right anterior portal pedicle, and the right (*yellow arrowheads*) and the middle (*white arrowheads*) hepatic veins



Isolation of the middle and left hepatic veins requires mobilization of the left lobe. Dissection is performed in the region of the ligamentum venosum, between the back of the left lobe and the caudate lobe (see below). Because the left hepatic vein and the middle hepatic vein fuse to form a

common venous trunk in 60% of patients [19], it is essential to visualize the confluence of these two veins precisely before applying a vascular clamp. For temporary occlusion, it is often easier to control both the left and middle veins at their common trunk.

Specific technical features

Right anterior sectionectomy

Patients with right lobe lesions that involve both segments 5 and 8 may be treated with a right anterior sectionectomy [15]. After a J-shaped incision is made and the right liver is mobilized, IOUS is performed to confirm the preoperatively defined anatomical configuration of the tumor and of the major vessels. The suprahepatic bare area of the liver is exposed to display the middle hepatic vein and suprahepatic IVC. Inflow control can be obtained by individual dissection of the right anterior hepatic artery and portal vein. An important alternative to this individual dissection of the hilar structures is the Glisson's pedicle transection technique, using the extrahepatic approach [16, 20, 21]. Division of the right anterior sectional pedicle establishes inflow control.

After cholecystectomy, connective tissue (cystic plate) covering the right portal pedicle is removed from the liver bed to expose the hepatic hilum. Dissection is carried out between the right and left portal pedicles. Fine portal branches are ligated and divided to avoid bleeding. Further dissection is performed behind the right main portal pedicle, which is then taped (Fig. 2). Special care should be taken not to damage the first branch of the right portal pedicle, which comes off early and posteroinferiorly to supply the right paracaval portion of the caudate lobe. As described by Batignani [17], portal structures passing to the caudate lobe can be avoided by palpation with the tip of the clamp. Dissection of the liver tissue covering the right main portal pedicle facilitates exposure of the right anterior pedicle. Curved forceps are gently passed around the right anterior pedicle under direct vision. At the time of taping, it is important not to damage the right posterior bile duct, which usually runs behind the origin of the right anterior portal vein. Thus, the right anterior sectional pedicle is taped (Fig. 2). When the right anterior sectional pedicle is

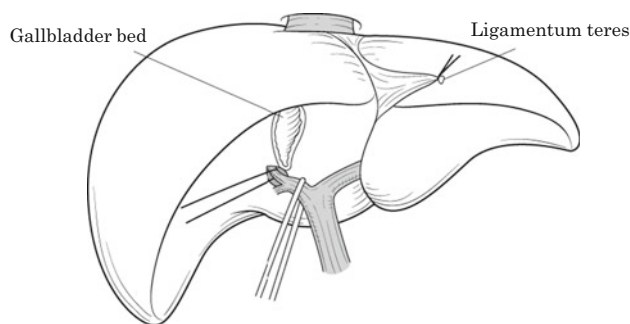


Fig. 2 Dissection of the hepatic hilum. The right main portal pedicle and the right anterior portal pedicle are detached from the inferior liver parenchyma of segments 4 and 5. The right main and the right anterior portal pedicles are encircled en masse

clamped and the right posterior sectional pedicle is left intact, 2 lines of demarcation extending along the right intersectional plane and the principal plane (Rex–Cantlie's line) will develop (Fig. 3). The liver parenchyma is ready for transection along both ischemic lines, resulting in 2 cut surfaces. After single ligation of the anterior pedicle, its division may be left until the final stage of parenchymal dissection, especially in the case of a large tumor occupying the hepatic hilum. The hilar structures, especially bile ducts displaced by a large tumor, may be safely divided later during parenchymal transection.

The resultant demarcation of liver parenchyma provides an accurate guide for parenchymal transection. Inflow control is obtained by an intermittent Pringle maneuver (15-min clamping periods separated by 5-min intervals). In patients with liver cirrhosis, alternative selective clamping of the left and right portal pedicles may be performed to avoid the prolonged liver ischemia that would be produced by total inflow occlusion during the dissection [22]. This technique allows preservation of blood flow to the remaining liver. During the dissection between the right anterior and the left medial sections, the left portal pedicle is clamped instead of Pringle maneuver. During the dissection between the right anterior and posterior sections, the right main portal pedicle is clamped instead of the Pringle maneuver.

During parenchymal transection between the right anterior and the left medial sections, the draining vein from segment 5 is ligated and divided (Fig. 4). While parenchymal dissection is performed cranially leaving the middle hepatic vein trunk intact, the ventral branch of the draining vein from segment 8 is ligated and divided (Fig. 5). The anterior fissure vein close to the origin of the middle hepatic vein is ligated and divided on the completion of dissection along the Rex–Cantlie's line (Fig. 6).

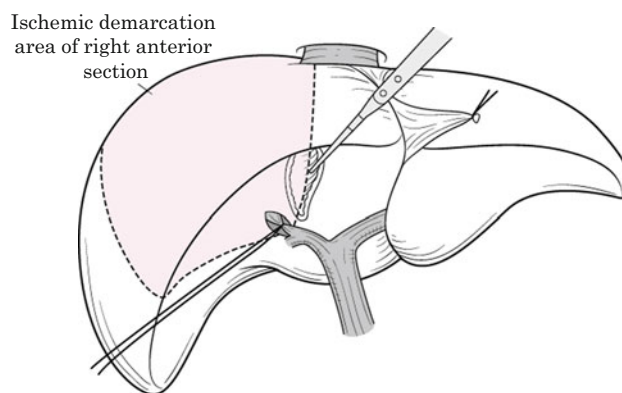


Fig. 3 Ligation of the anterior portal pedicle and marking of the ischemic demarcation area. The distribution of color change in the right anterior section can be confirmed by temporary occlusion of the right anterior pedicle and marked by diathermy. The right anterior pedicle is then ligated

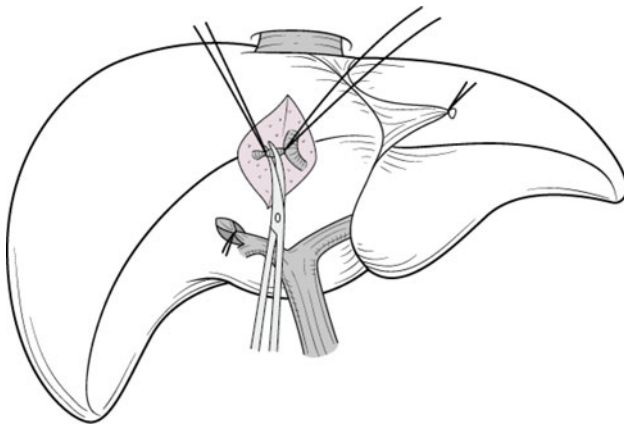


Fig. 4 Division of the draining vein from segment 5 (V5) during parenchymal transection between the right anterior and the left medial sections. When the transection reaches the middle hepatic vein along the principal plane, the draining vein from segment 5 is ligated and divided

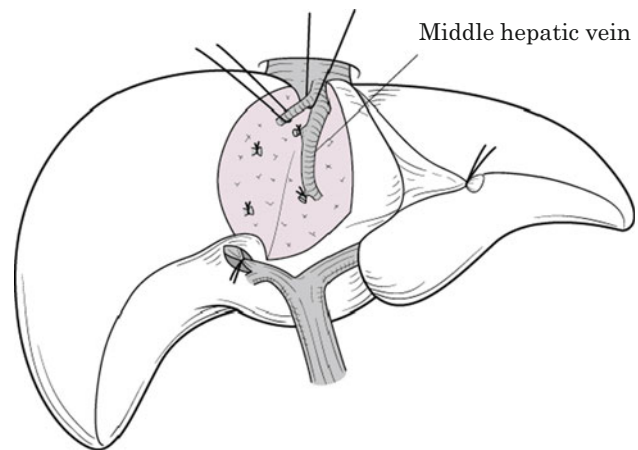


Fig. 6 Division of the anterior fissure vein and completion of dissection between the right anterior and the left medial sections. The anterior fissure vein close to the origin of the middle hepatic vein is ligated and divided

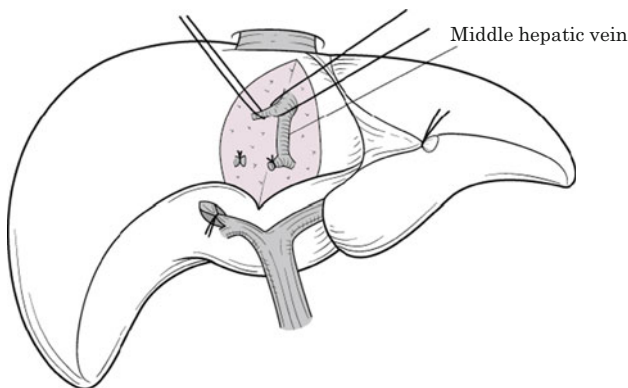


Fig. 5 Preservation of the middle hepatic vein trunk and division of the ventral branch of the draining vein from segment 8 (V8v). While parenchymal dissection is performed cranially leaving the middle hepatic vein trunk intact, V8v is ligated and divided

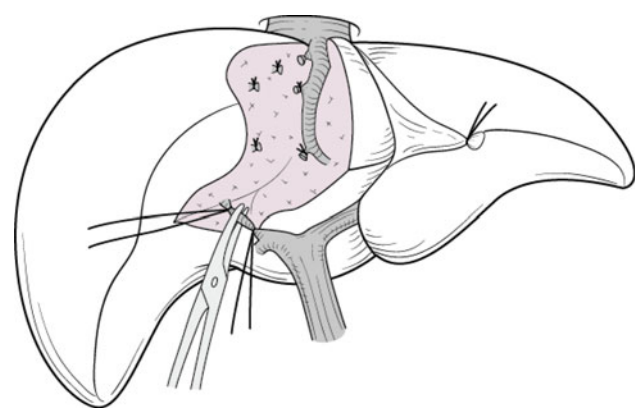


Fig. 7 Division of the right anterior portal pedicle. The previously ligated right anterior portal pedicle at the hilum is divided

When the hepatic hilum is opened, the right anterior sectional pedicle is divided safely (Fig. 7). The application of a straight-bladed vascular clamp is the safest method of transecting the right anterior pedicle. The proximal stump of the right anterior pedicle is oversewn with continuous non-absorbable suture material. Alternatively, curved forceps are gently passed around the right anterior pedicle under direct vision, followed by transfixing double ligation and division of the pedicle. It is worth emphasizing not to simply ligate and transect the pedicle, because the pedicle stump is short and tends to slip unless transfixed. While the right anterior section is lifted up, the right intersectional plane is dissected along the right intersectional line of demarcation (Fig. 8). While parenchymal dissection is performed cranially leaving the right hepatic vein trunk intact, the dorsal branch of the draining vein from segment 8 is ligated and divided (Fig. 9).

Significant bleeding may occur from branches of the right hepatic vein. Dissection carried out under low central venous pressure allows bleeding from the transected branches of the right hepatic vein to be visualized and controlled. Extrahepatic outflow control of the right hepatic vein is useful for a large tumor adjacent to the right hepatic vein or vena cava, to avoid major hemorrhage due to accidental laceration of the vein. The right hepatic vein can be clamped temporarily in combination with inflow clamping, resulting in right liver vascular exclusion [23].

The dissection along the line of the right intersectional plane is eventually united with the initial hepatotomy along the Rex–Cantlie's line. After complete resection of the right anterior section, the right and middle hepatic veins are left intact and visible (Fig. 10). The ligated branches of the right and middle hepatic veins are also visible, as well as the divided right anterior sectional pedicle, which arises from the right portal pedicle.

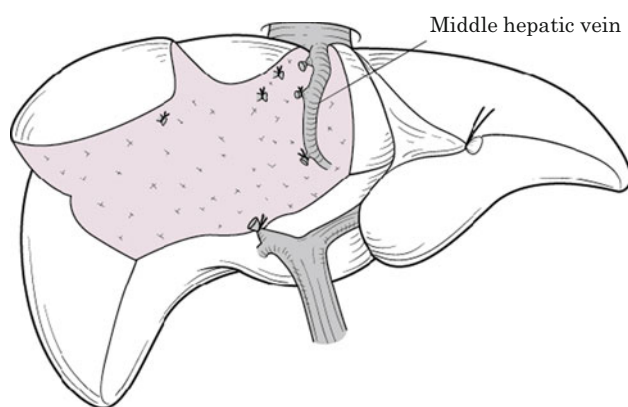


Fig. 8 Dissection between the right anterior and posterior sections. While the right anterior section is lifted up, the right intersectional plane is dissected along the right intersectional line of demarcation

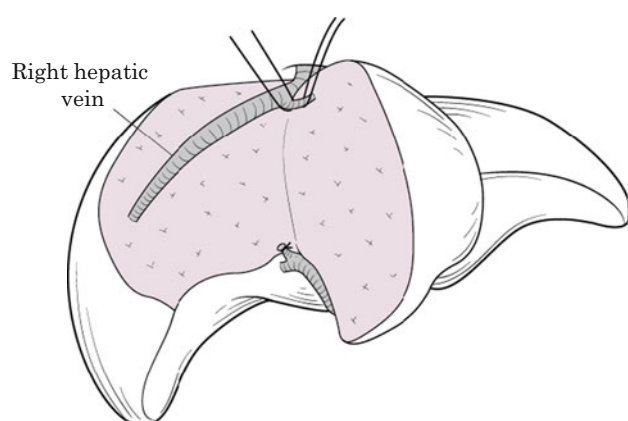


Fig. 9 Preservation of the right hepatic vein trunk and division of the dorsal branch of the draining vein from segment 8 (V8d). While parenchymal dissection is performed cranially leaving the right hepatic vein trunk intact, V8d is ligated and divided

Right posterior sectionectomy

Resection of the right posterior section (segments 6 and 7) requires complete mobilization of the right liver and division of the retrohepatic veins that enter the IVC. Inflow control is obtained by securing the right posterior sectional pedicle (Fig. 11). After cholecystectomy, connective tissue covering the right portal pedicle is removed from the gallbladder bed to expose the hepatic hilum. The right posterior sectional pedicle lies within the base of Rouviere's sulcus, which is a groove at the inferior surface of the liver near the gallbladder bed. To isolate the sectional pedicles, liver tissue at the base of segments 5 and 6 is lifted off by blunt dissection or with an ultrasonic dissector [24]. Although it may be possible to isolate the right posterior sectional pedicle by passing a clamp between the sectional pedicles, this may sometimes result in the isolation of only the pedicle of segment 6. The reason is that the

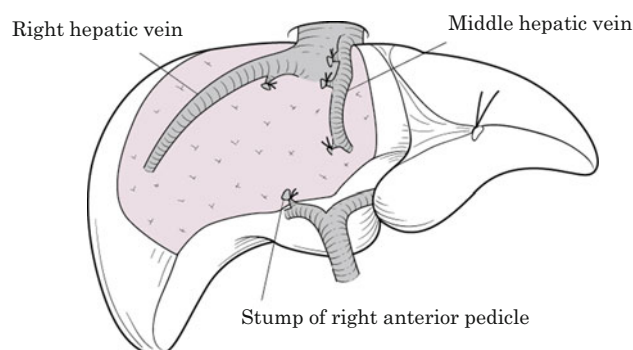


Fig. 10 Cut surface on completion of right anterior sectionectomy. The liver cut surface shows the stump of the right anterior portal pedicle, and the preserved right and middle hepatic veins

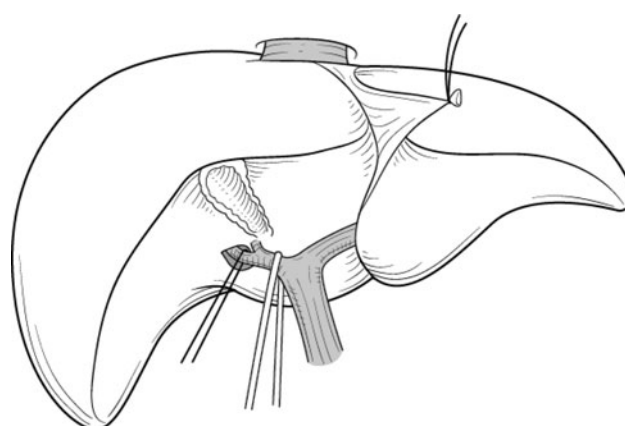


Fig. 11 Taping of the right main and the right posterior portal pedicles. The posterior portal pedicle is encircled en masse, avoiding injury to the right posterior bile duct. The liver parenchyma may be dissected along Rouviere's sulcus to expose the origin of the right posterior pedicle

pedicle to segment 7 may come off very early and posteriorly from the right main pedicle, and be missed. Alternatively, a tape is passed around the right anterior sectional pedicle first (Fig. 12). The upper end of the tape around the right main pedicle is then passed behind the right anterior pedicle. The two ends of the tape are pulled to encircle the right posterior sectional pedicle. Using this 'Glissonean pedicle transection method', the right main and sectional pedicles may be isolated without any inflow occlusion or hepatotomies [20]. The distribution of color change in the right posterior section can be confirmed by temporary occlusion of the right posterior pedicle (Fig. 13). The right posterior sectional pedicle is then divided (Fig. 14).

The resultant demarcation of liver parenchyma provides an accurate guide for parenchymal transection. This plane of dissection is just posterior to the right intersectional plane. Transection is performed using right portal pedicle clamping or portal triad clamping. After the peripheral

Fig. 12 ‘Glissonean pedicle transection method’ for taping of the right posterior pedicle. **a** After the right anterior pedicle is taped, curved forceps are passed behind the right main portal pedicle. **b** The right main pedicle is taped. **c** The curved forceps are passed behind the right anterior pedicle to hold the upper end of the tape around the right main pedicle. **d** The tape is pulled out to encircle the right posterior pedicle

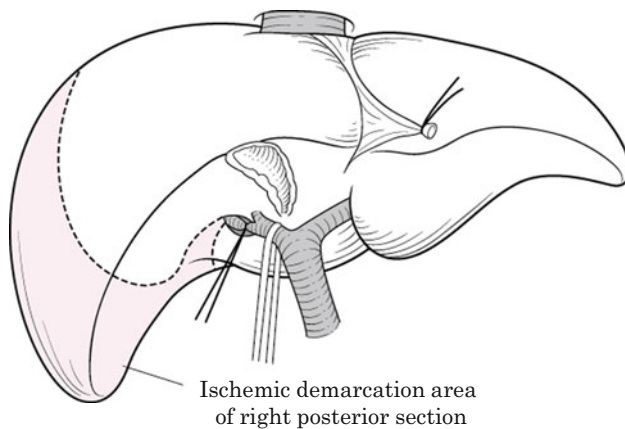
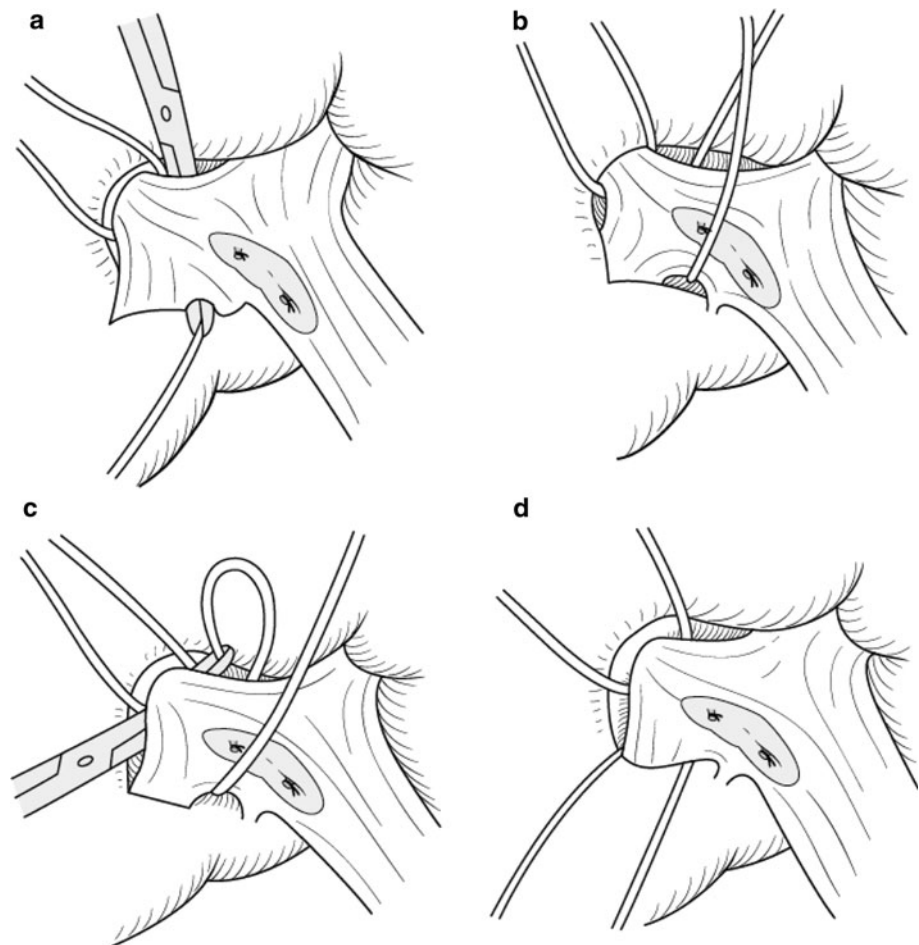


Fig. 13 Ligation of the right posterior pedicle and marking of the ischemic demarcation area. The distribution of color change in the right posterior section can be confirmed by clamping of the right posterior pedicle and marked by diathermy

draining vein from segment 6 is ligated and divided during parenchymal dissection along the right intersectional plane, the right hepatic vein trunk is identified and exposed (Fig. 15). Parenchymal dissection is continued cranially

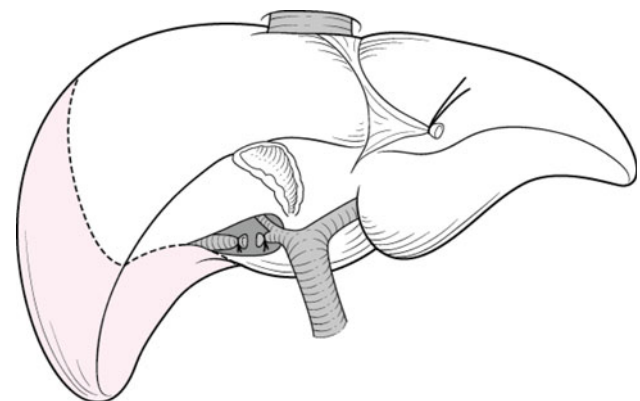


Fig. 14 Division of the right posterior pedicle. The right posterior pedicle is ligated and divided

along the right hepatic vein trunk, which is left intact (Fig. 16). Temporary clamping of the right hepatic vein adjacent to the vena cava permits swift repair of any venous laceration that has been caused during parenchymal transection.

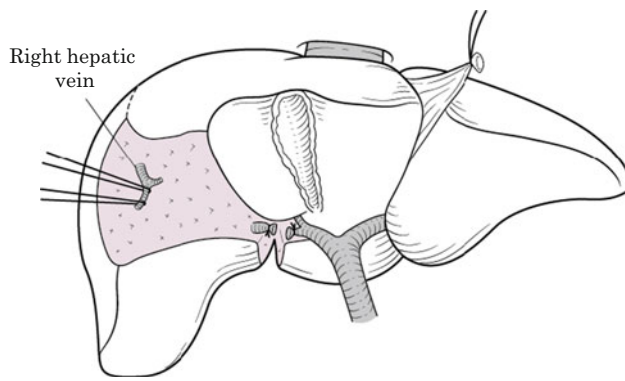


Fig. 15 Identification of the peripheral branch and main trunk of the right hepatic vein. After the peripheral draining vein from segment 6 is ligated and divided during parenchymal dissection along the right intersectional plane, the right hepatic vein trunk is identified and exposed

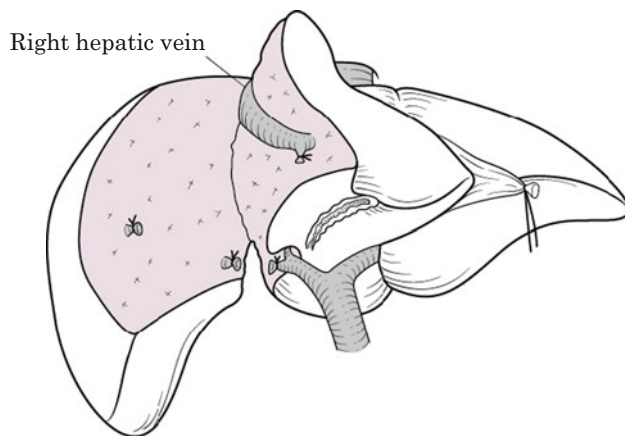


Fig. 16 Preservation of the right hepatic vein trunk during dissection between the right anterior and posterior sections. Parenchymal dissection is continued cranially along the right hepatic vein trunk, which is left intact

After complete resection of the right posterior section, the right hepatic vein is left intact and visible. The ligated branches of the right hepatic vein and the divided right posterior sectional pedicle are also visible (Fig. 17).

Left medial sectionectomy

A bilateral subcostal incision with upper midline extension is used for left medial sectionectomy. The beginning of the left medial sectionectomy involves dissection of the ligamentum teres and the falciform ligament. After cholecystectomy, the portal triad is encircled with umbilical tape and clamping is applied with a tourniquet. Mobilization of the liver is carried out by division of the bilateral triangular and coronary ligaments. The bridge of liver tissue that joins segments 3 and 4 at the base of the umbilical fissure is divided using electrocautery. The hilar plate is lowered using sharp dissection at the base of segment 4. This

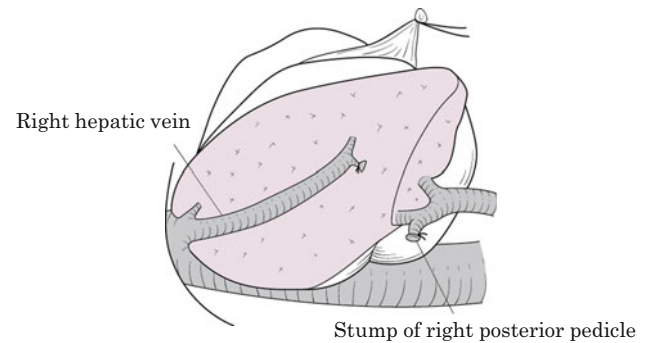


Fig. 17 Cut surface of the liver after right posterior sectionectomy. The right hepatic vein is exposed when parenchymal transection between the right anterior and posterior sections is completed

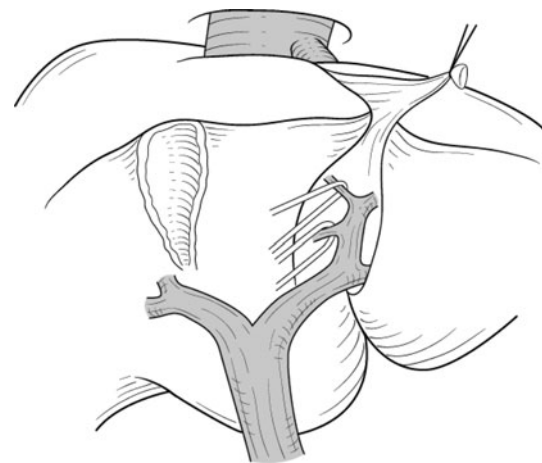


Fig. 18 Exposure of the umbilical fissure, and taping of the cranial and caudal segment 4 pedicles. The cranial and caudal segment 4 pedicles are encircled by opening the liver parenchyma to the right side of the umbilical fissure

maneuver exposes the left portal vessels, which reside within the umbilical fissure. Dissection of the hilar plate at the base of segment 4 results in exposure of the cranial and caudal segment 4 portal pedicles (Fig. 18). When the segment 4 pedicles are clamped temporarily, 2 lines of demarcation along the falciform ligament and the Rex–Cantlie’s line develop, showing the ischemic demarcation area of segment 4. Then the segment 4 pedicles are divided, taking care to preserve the left main portal pedicle (Fig. 19). To avoid injury to the left main hepatic duct, it is important that the hilar plate is detached and lowered from the undersurface of segment 4, especially in the case of a large tumor displacing the left hepatic duct.

Inflow control is obtained with the Pringle maneuver. In patients with liver cirrhosis, alternative selective clamping of the left and right portal pedicles may be performed to reduce ischemic liver damage during the dissection. During the dissection between the left medial and lateral sections,

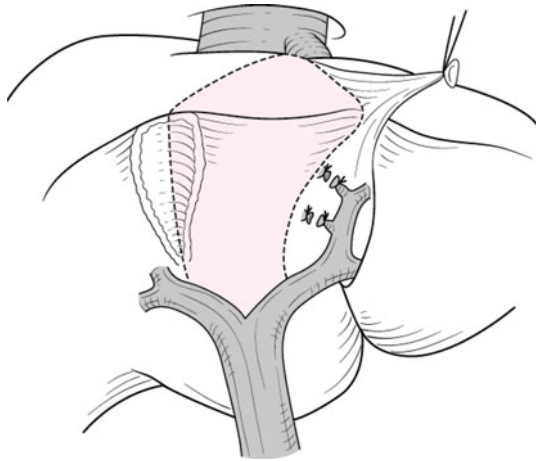


Fig. 19 Inflow control and demarcation area of segment 4. After the cranial and caudal segment 4 pedicles are ligated and divided, the ischemic demarcation area is marked by diathermy

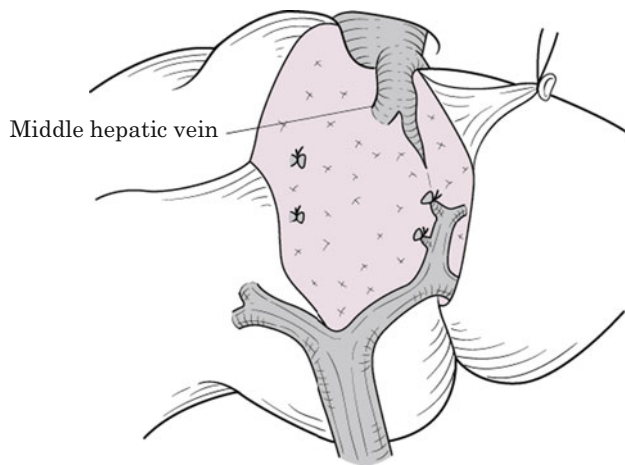


Fig. 20 Exposure of the origin of the middle hepatic vein during dissection between the left medial and lateral sections. Parenchymal dissection is continued cranially along the falciform ligament until the origin of the middle hepatic vein is exposed

the left main pedicle is clamped instead of the Pringle maneuver. During the dissection between the left medial and right anterior sections, the right main pedicle is clamped instead of the Pringle maneuver.

The parenchymal transection is performed along the two demarcated planes. Dissection is initiated anteriorly along the demarcation line just to the right of the falciform ligament and continued until the origin of the middle hepatic vein is exposed (Fig. 20). The parenchymal dissection proceeds down to the base of the umbilical fissure. The second line of parenchymal division is developed along the Rex–Cantlie’s line towards the vena cava dorsally. After the peripheral draining vein from segment 4 is ligated and divided, the middle hepatic vein is identified (Fig. 21). Parenchymal dissection is continued cranially along the

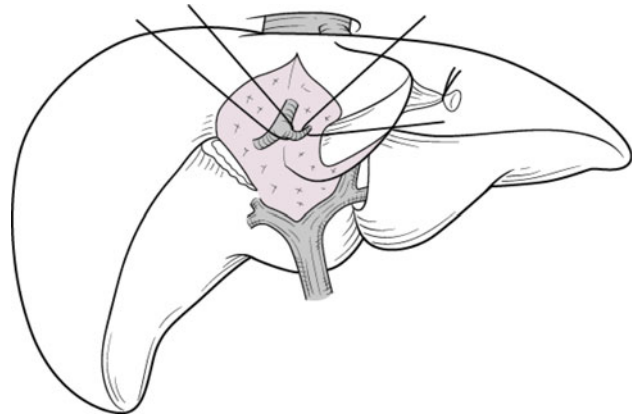


Fig. 21 Identification of the peripheral branch and main trunk of the middle hepatic vein. After the peripheral draining vein from segment 4 is ligated and divided during parenchymal dissection along the Rex–Cantlie’s line, the middle hepatic vein trunk is identified and exposed

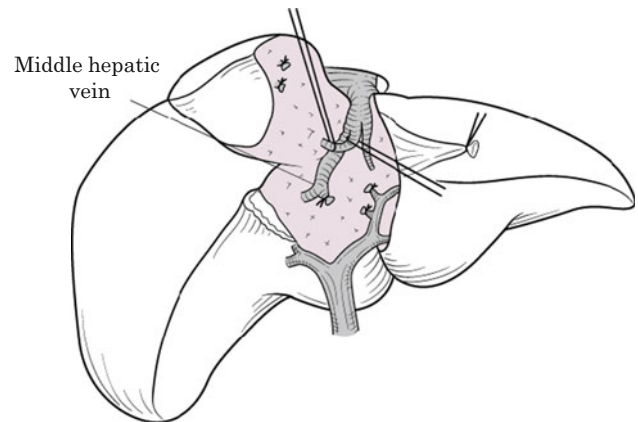


Fig. 22 Preservation of the middle hepatic vein trunk and division of the cranial draining vein from segment 4. Parenchymal dissection is continued cranially along the middle hepatic vein trunk, which is left intact. The cranial branch of the middle hepatic vein is ligated and divided. The origin of the left hepatic vein is also exposed and preserved

middle hepatic vein trunk, which is left intact (Fig. 22). The cranial branch of the middle hepatic vein is ligated and divided. Caution must be exercised to preserve the trunk of the left hepatic vein. After the two initial parenchymal divisions are performed, a transverse dissection is made along the ventral aspect of segment 1 to join the posterior ends of the previous parenchymal divisions. If the tumor is located deep in segment 4, the transverse dissection should be carried out along the ventral surface of the IVC. The middle and left hepatic veins are exposed when the left medial sectionectomy is completed (Fig. 23).

Left lateral sectionectomy

Segments 2 and 3, comprising the left lateral section of the liver, are resected by approaching the portal triads to

segments 2 and 3 in the umbilical fissure. If present, the bridge of tissue between segments 3 and 4 is divided by diathermy. The left lateral section is mobilized by division of the left triangular and coronary ligaments. Care must be taken not to damage the spleen close to the left of the triangular ligament.

Inflow control is achieved by isolation of the pedicles to segments 2 and 3 within the umbilical fissure to the left of the portal triad. Individual ligation of the segmental pedicles allows demarcation of the relevant parenchyma and guides resection. This approach is important in allowing tumor clearance for lesions close to the umbilical fissure. It should be noted that Spiegel lobe branches arise from the posterolateral aspect of the left portal pedicle. Failure to preserve these branches will devascularize the Spiegel lobe.

The parenchymal transection proceeds towards the duct of Alantius, thus separating the left lateral section from the

anterior surface of the Spiegel lobe. As the liver tissue is opened, the origin of the left hepatic vein is exposed cranially and can be controlled. The left hepatic vein can be secured using a vascular clamp within the liver substance, divided, and oversewn with a continuous suture. The middle hepatic vein must be preserved to avoid congestion of segment 4 when the left hepatic vein is transected at its origin.

If the tumor is located close to the junction of the left and middle hepatic veins, extrahepatic dissection and control of the vein should be performed. After the left hepatic vein and suprahepatic vena cava are exposed, the gastrohepatic ligament is divided and the ligamentum venosum is identified (Fig. 24). Division of the ligamentum venosum close to its entry into the left hepatic vein opens up a triangular tunnel, the sides of which are the left hepatic vein anteriorly, the anterior surface of the vena cava posteriorly, and the upper surface of segment 2 inferiorly. This tunnel is carefully dissected and the left hepatic vein is taped. Securing the left hepatic vein is of great importance in controlling hemorrhage during the resection of large left-sided tumors.

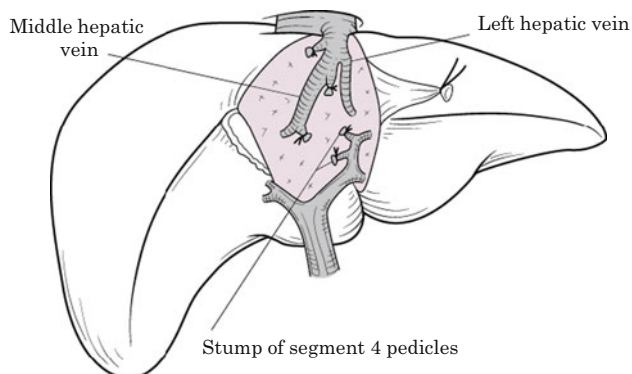


Fig. 23 Liver cut surface after left medial sectionectomy. After the left medial sectionectomy, the middle and left hepatic veins are exposed

Dos and Don'ts

1. When the main and sectional pedicles are taped, care must be taken not to injure the bile duct and caudate branches.
2. Before the sectional portal pedicle is divided, it is important to ensure that damage to the blood supply and biliary drainage of the remaining liver is avoided. The ischemic demarcation area intended for resection should be confirmed by temporary clamping of the corresponding portal pedicle prior to its division.

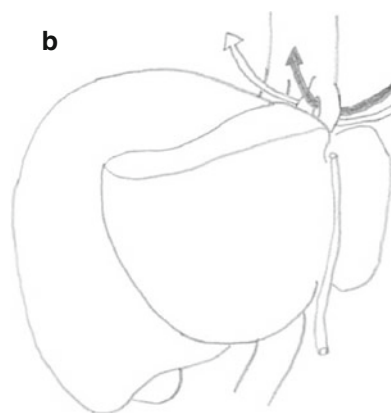
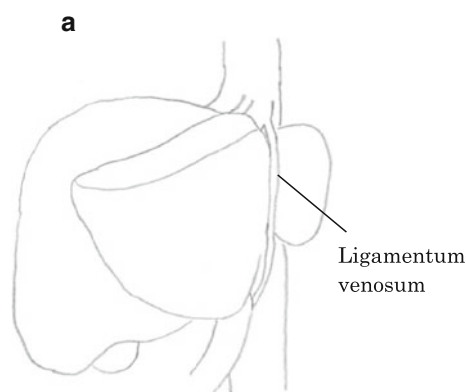


Fig. 24 Approach and dissection of the left hepatic vein. **a** Exposure of the ligamentum venosum. The left lateral section is turned to the right and the ligamentum venosum is exposed. **b** Division of the ligamentum venosum allows exposure of the window between

the vena cava and the left hepatic vein. By dissecting this space, the left hepatic vein can be encircled separately (*black curved arrow*) or together with the middle hepatic vein (*white curved arrow*) at its origin

3. The application of a vascular clamp is a safe method of transecting the sectional portal pedicle. If the pedicle is ligated, it should be transfixed and double ligated.
4. When a bile leak is repaired, caution must be exercised to prevent biliary stenosis, especially after right anterior and left medial sectionectomies. Intraoperative cholangiography is recommended to make sure of the patency of the remaining sectional bile ducts in patients with tumors close to the hepatic hilum.
5. It is important that hemostasis of the preserved hepatic vein on the liver cut surface is checked repeatedly. When the liver is repositioned, bleeding from venous pores that was previously stopped may recur.

Discussion

Anatomic liver resections are based on an understanding of functional hepatic anatomy, particularly the relation between the portal pedicles and the hepatic veins. The use of the Glisson's pedicle transection or ligation technique has assisted surgeons in performing anatomic resections [14, 16]. This approach is safe and enables precise transection of the tumor-bearing portal pedicle, leaving the other pedicles of the remaining liver intact. Pedicle ligation also guides parenchymal transection by indicating demarcation lines on the liver. In recent years, a preoperative simulation system has allowed the stereoscopic identification of the tumor-bearing portal vein and draining vein based on hepatic perfusion data [6, 25].

Anatomic sectionectomies are safe alternatives to extensive liver resections in selected patients. They avoid unnecessary sacrifice of functional parenchyma, prevent postoperative liver failure in patients with underlying liver disease, and enhance the possibility of repeat liver resections. There are benefits of preserving the liver parenchyma both in cirrhotic and non-cirrhotic patients. For the cirrhotic patients, preserving the liver parenchyma makes resection possible in the setting of diminished hepatocellular function. For the non-cirrhotic patients, such preservation enhances postoperative recovery and facilitates the resection of multiple hepatic lesions. Considering the safety, oncologic efficacy, and utility of anatomic resection, hepatic sectionectomy is an appropriate surgical approach for limited neoplasms of the liver.

The advantage of anatomic hepatectomy in terms of tumor clearance is that the entire territory of the feeding portal pedicle is resected. This is of particular importance for patients with HCC, given the well-described propensity of this neoplasm to grow by intraportal extension [26]. Indeed, vascular invasion and intrahepatic metastasis are among the risk factors that most strongly influence the postoperative prognosis

[27, 28]. Therefore, the eradication of intrahepatic metastasis is the most crucial consideration for improving the surgical outcome in HCC. Anatomic resection is theoretically effective for the systemic eradication of intrahepatic metastasis in relevant hepatic sections or segments confined by tumor-bearing tributaries. Anatomic resection has been reported to yield better 5-year overall and disease-free survival rates for a single HCC than non-anatomic resection [29]. Scheele et al. [30] and Hughes et al. [31] reported that anatomic resection was also effective for liver metastasis from colorectal cancer, while non-anatomic resections produced rates of margin positivity as high as 20–30% and resulted in diminished survival.

Liver resection offers a potential cure for a hepatic neoplasm when the surgical margin is clear of tumor. Anatomic sectionectomies may be associated with smaller margins than extensive hepatectomies. However, several studies including large numbers of patients with HCC [32–34], cholangiocellular carcinoma [35], and colorectal metastases [36–38] showed no negative effect on survival of a <10-mm margin. In addition, sectionectomies may increase the opportunity to perform repeat resection, which has been reported to improve survival rates both in HCC [39, 40] and colorectal metastases [41–43].

Glisson described the connective tissue capsule surrounding the liver substance, which bears his name, in 1645, although Valeous had already described connective tissue surrounding the structures at the hilum of the liver in 1640 [44]. Couinaud [45] demonstrated that the structures of the portal triad are contained by a well-formed sheath (Glisson's capsule) and penetrate the liver parenchyma as they repeat ramification. Inflow control can be obtained by a pedicle ligation technique, which encircles sectional portal structures within the sheath and ligates them. Variations of the intrahepatic anatomy are so common that confirmation should always be sought by clamping each pedicle with a vascular clamp, with the main hepatic pedicle remaining unclamped. Color changes in the liver substance then identify the precise boundaries of the section that the pedicle supplies.

Biliary injury is an 'Achilles heel' in hepatic resection and occurs most commonly when tumors are located close to the liver hilum, or as a result of variations in biliary anatomy. The pedicle ligation approach has an advantage because it obviates hilar dissection and minimizes the risk of biliary injury to the remaining liver. The left bile duct has a long extrahepatic course and can be identified beneath segment 4 behind the portal vein. In left medial sectionectomy, lowering the hilar plate is important to drop the portal structures off the base of segment 4 and expose the left hepatic duct. When a right sectional pedicle ligation cannot be performed in case of a tumor close to the hilum, extrahepatic dissection is performed with individual isolation of the sectional portal vein and hepatic artery.

However, the biliary tree can be divided within the liver at the final stage of parenchymal dissection to prevent injury to the remaining sectional bile ducts.

The complexity and variability of the hepatic vasculature increases the technical difficulty of anatomic hepatectomy procedures. Moreover, impaired hepatic function in HCC patients restricts the volume of liver tissue that can be resected [4, 5]. Therefore, accurate preoperative assessment of the anatomy, resection volume, and surgical margin is crucial for performing safe and curative anatomic hepatectomy. We have reported the accuracy and usefulness of simulation based on multidetector computed tomography scanning for the planning of anatomic liver resection, liver transplantation, and laparoscopic hepatectomy [6, 7, 25, 46]. The 3D simulation system allowed stereoscopic identification of the tumor-bearing portal vein and draining vein based on hepatic perfusion data. Simulation provided detailed preoperative planning for hepatectomy, including accurate prediction of the liver resection volume and surgical resection margin. The surgical resection margin could not be estimated previously. Thus this accurate prediction assisted in the curative resection of neoplastic lesions. The simulation system can be used not only to facilitate intraoperative procedures, but also to rehearse maneuvers preoperatively [47]. Based on the results of the simulation, surgeons can obtain precise knowledge about the position of crucial anatomic landmarks that formerly could not be visualized.

In conclusion, anatomic sectionectomies can achieve curative resection, preserving the liver parenchyma. Therefore, anatomic sectionectomy could be performed as a safe alternative to extensive hepatectomies, both in cirrhotic and non-cirrhotic patients with tumors located centrally or in the vicinity of major intrahepatic vessels. Preoperative planning with this simulation system is useful for anatomic hepatectomies, including sectionectomies.

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

References

1. Bosch FX, Ribes J, Diaz M, Cleries R. Primary liver cancer: worldwide incidence and trends. *Gastroenterology*. 2004;127:S5–16.
2. El-Serag HB, Mason AC. Rising incidence of hepatocellular carcinoma in the United States. *N Engl J Med*. 1999;340:745–50.
3. Kiyosawa K, Umemura T, Ichijo T, Matsumoto A, Yoshizawa K, Gad A, et al. Hepatocellular carcinoma: recent trends in Japan. *Gastroenterology*. 2004;127:S17–26.
4. Yamanaka N, Okamoto E, Oriyama T, Fujimoto J, Furukawa K, Kawamura E, et al. A prediction scoring system to select the surgical treatment of liver cancer. Further refinement based on 10 years of use. *Ann Surg*. 1994;219:342–6.
5. Wu CC, Ho WL, Yeh DC, Huang CR, Liu TJ, P'eng FK. Hepatic resection of hepatocellular carcinoma in cirrhotic livers: is it unjustified in impaired liver function? *Surgery*. 1996;120:34–9.
6. Saito S, Yamanaka J, Miura K, Nakao N, Nagao T, Sugimoto T, et al. A novel 3D hepatectomy simulation based on liver circulation: application to liver resection and transplantation. *Hepatology*. 2005;41:1297–304.
7. Yamanaka J, Saito S, Fujimoto J. Impact of preoperative planning using virtual segmental volumetry on liver resection for hepatocellular carcinoma. *World J Surg*. 2007;31:1249–55.
8. Strasberg SM. Nomenclature of hepatic anatomy and resections: a review of the Brisbane 2000 system. *J Hepatobiliary Pancreat Surg*. 2005;12:351–5.
9. Marescaux J, Clement J, Tasseti V, Koehl C, Cotin S, Russier Y, et al. Virtual reality applied to hepatic surgery simulation: the next revolution. *Ann Surg*. 1998;228:627–34.
10. Rau HG, Schauer R, Helmberger T, Holzknecht N, von Ruckmann B, Meyer L, et al. Impact of virtual reality imaging on hepatic liver tumor resection: calculation of risk. *Langenbeck's Arch Surg*. 2000;385:162–70.
11. Wigmore SJ, Redhead DN, Yan XJ, Casey J, Madhavan K, De-jong CH, et al. Virtual hepatic resection using three-dimensional reconstruction of helical computed tomography angioprotograms. *Ann Surg*. 2000;233:221–6.
12. Lamade W, Glombitza G, Fischer L, Chiu P, Cardenas CE Sr, Thorn M, et al. The impact of 3-dimensional reconstructions on operation planning in liver surgery. *Arch Surg*. 2000;135:1256–61.
13. Makuuchi M, Hasegawa H, Yamazaki S. Ultrasonically guided subsegmentectomy. *Surg Gynecol Obstet*. 1985;161:346–50.
14. Launois B, Jamieson GG. The posterior intrahepatic approach for hepatectomy or removal of segments of the liver. *Surg Gynecol Obstet*. 1992;174:155–8.
15. Makuuchi M, Hashikura Y, Kawasaki S, Tan D, Kosuge T, Takayama T. Personal experience of right anterior segmentectomy (segments V and VIII) for hepatic malignancies. *Surgery*. 1993;114:52–8.
16. Takasaki K, Kobayashi S, Tanaka S, Saito A, Yamamoto M, Hanyu F. Highly anatomically systematized hepatic resection with Glissonian sheath code transection at the hepatic hilus. *Int Surg*. 1990;75:73–7.
17. Batignani G. Hilar plate detachment and extraglissonian extrahepatic anterior approach to the right portal pedicle for right liver resections. *J Am Coll Surg*. 2000;190:631–4.
18. Belghiti J, Noun R, Zante E, Ballet T, Sauvanet A. Portal triad clamping or hepatic vascular exclusion for major liver resection. A controlled study. *Ann Surg*. 1996;224:155–61.
19. Bismuth HCL. Surgical anatomy and anatomical surgery of the liver. In: Blumgart LH, editor. *Surgery of the liver and biliary tract*. 2nd ed. Edinburgh: Churchill-Livingstone; 1994. p. 3–9.
20. Takasaki K. Glissonian pedicle transection method for hepatic resection. Tokyo: Springer; 2007.
21. Yamamoto M, Takasaki K, Ohtsubo T, Katsuragawa H, Fukuda C, Katagiri S. Effectiveness of systematized hepatectomy with Glisson's pedicle transection at the hepatic hilus for small nodular hepatocellular carcinoma: retrospective analysis. *Surgery*. 2001;130:443–8.
22. Takayama T, Makuuchi M, Inoue K, Sakamoto Y, Kubota K, Harihara Y. Selective and unselective clamping in cirrhotic liver. *Hepatogastroenterology*. 1998;45:376–80.
23. Cherqui D, Malassagne B, Colau PI, Brunetti F, Rotman N, Fagniez PL. Hepatic vascular exclusion with preservation of the caval flow for liver resections. *Ann Surg*. 1999;230:24–30.
24. Strasberg SM, Linehan DC, Hawkins WG. Isolation of right main and right sectional portal pedicles for liver resection without hepatotomy or inflow occlusion. *J Am Coll Surg*. 2008;206:390–6.

25. Yamanaka J, Saito S, Iimuro Y, Hirano T, Okada T, Kuroda N, et al. The impact of 3-D virtual hepatectomy simulation in living-donor liver transplantation. *J Hepatobiliary Pancreat Surg*. 2006;13:363–9.
26. Nakashima T, Kojiro M. Pathologic characteristics of hepatocellular carcinoma. *Semin Liver Dis*. 1986;6:259–66.
27. Shirabe K, Kanematsu T, Matsumata T, Adachi E, Akazawa K, Sugimachi K. Factors linked to early recurrence of small hepatocellular carcinoma after hepatectomy: univariate and multivariate analyses. *Hepatology*. 1991;14:802–5.
28. Takayama T, Makuuchi M, Hirohashi S, Sakamoto M, Yamamoto J, Shimada K. Early hepatocellular carcinoma as an entity with a high rate of surgical cure. *Hepatology*. 1998;28:1141–246.
29. Hasegawa K, Kokudo N, Imamura H, Matsuyama Y, Aoki T, Minagawa M, et al. Prognostic impact of anatomic resection for hepatocellular carcinoma. *Ann Surg*. 2005;242:252–9.
30. Scheele J, Stangl R, Altendorf-Hofmann A, Gall FP. Indicators of prognosis after hepatic resection for colorectal secondaries. *Surgery*. 1991;110:13–29.
31. Hughes K, Scheele J, Sugarbaker PH. Surgery for colorectal cancer metastatic to the liver. Optimizing the results of treatment. *Surg Clin N Am*. 1989;69:339–59.
32. Poon RT, Fan ST, Ng IO, Wong J. Significance of resection margin in hepatectomy for hepatocellular carcinoma: a critical reappraisal. *Ann Surg*. 2000;231:544–51.
33. Ochiai T, Takayama T, Inoue K, Yamamoto J, Shimada K, Kosuge T, et al. Hepatic resection with and without surgical margins for hepatocellular carcinoma in patients with impaired liver function. *Hepatogastroenterology*. 1999;46:1885–9.
34. Bilimoria MM, Lauwers GY, Doherty DA, Nagomey DM, Belghiti J, Do KA, et al. Underlying liver disease, not tumor factors, predicts long-term survival after resection of hepatocellular carcinoma. *Arch Surg*. 2001;136:528–35.
35. Weimann A, Varnholt H, Schlitt HJ, Lang H, Flemming P, Hustedt C, et al. Retrospective analysis of prognostic factors after liver resection and transplantation for cholangiocellular carcinoma. *Br J Surg*. 2000;87:1182–7.
36. Elias D, Cavalcanti A, Sabourin JC, Pignon JP, Ducreux M, Lasser P. Results of 136 curative hepatectomies with a safety margin of less than 10 mm for colorectal metastases. *J Surg Oncol*. 1998;69:88–93.
37. Kokudo N, Miki Y, Sugai S, Yanagisawa A, Kato Y, Sakamoto Y, et al. Genetic and histological assessment of surgical margins in resected liver metastases from colorectal carcinoma. *Arch Surg*. 2002;137:833–40.
38. Minagawa M, Makuuchi M, Torzilli G, Takayama T, Kawasaki S, Kosuge T, et al. Extension of the frontiers of surgical indications in the treatment of liver metastases from colorectal cancer: long-term results. *Ann Surg*. 2000;231:487–99.
39. Nakajima Y, Ko S, Kanamura T, Nagao M, Kanehiro H, Hisanaga M, et al. Repeat liver resection for hepatocellular carcinoma. *J Am Coll Surg*. 2001;192:339–44.
40. Minagawa M, Makuuchi M, Takayama T, Kokudo N. Selection criteria for repeat hepatectomy in patients with recurrent hepatocellular carcinoma. *Ann Surg*. 2003;238:703–10.
41. Scheele J, Altendorf-Hofmann A. Resection of colorectal liver metastases. *Langenbecks Arch Surg*. 1999;384:313–27.
42. DeMatteo RP, Palese C, Jarnagin WR, Sun RL, Blumgart LH, Fong Y. Anatomic segmental hepatic resection is superior to wedge resection as an oncologic operation for colorectal liver metastases. *J Gastrointest Surg*. 2000;4:178–84.
43. Yamada H, Katoh H, Kondo S, Okushiba S, Morikawa T. Repeat hepatectomy for recurrent hepatic metastases from colorectal cancer. *Hepatogastroenterology*. 2001;48:828–30.
44. Launois B. The intrahepatic Glissonian approach to liver resection. In: Blumgart LH, editor. *Surgery of the liver and biliary tract*. 3rd ed. London: W.B. Saunders; 2000. p. 1698–1703.
45. Couinaud C. *Le Foie: Etudes anatomiques et chirurgicales*. Paris: Masson; 1957.
46. Yamanaka J, Okada T, Saito S, Kondo Y, Yoshida Y, Suzumura K, et al. Minimally invasive laparoscopic liver resection: 3D MDCT simulation for preoperative planning. *J Hepatobiliary Pancreat Surg*. 2009;16:808–15.
47. Marescaux J, Rubino F, Arenas M, Mutter D, Soler L. Augmented reality-assisted laparoscopic adrenalectomy. *JAMA*. 2004;291:2214–5.