Radical Resection and Its Limits

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18.1 Introduction

It has been difficult to make an accurate diagnosis of tumor extent and strategy for curative resection of hilar cholangiocarcinoma (HCCa) [1] even in this era of sophisticated imaging diagnostic modalities such as multidetector row computed tomography (MDCT) [2]. An increasing resection rate of HCCa has been achieved and the surgical procedures for HCCa are changing from hilar local resection or limited hepatectomy [3] to major or extensive hepatobiliary resection including caudate lobectomy [1], which remains technically demanding and calls for a high level of skill in biliary and hepatic surgeries. Although the histological curative resection with negative surgical margins (R0) offers the only chance for cure in patients with HCCa, the gold standard for the treatment strategy for HCCa has not yet been determined. To achieve a R0 resection, an extensive hepatectomy (hepatic trisectionectomy) with vascular resection and reconstruction [4, 5], or pancreatoduodenectomy (HPD) [6, 7] is essential in some patients with advanced or extensive disease. Since the majority of patients with HCCa have cholestatic liver damage due to bile duct obstruction, major hepatobiliary resection carries a considerable risk of serious postoperative morbidity and mortality [8]. The limitations for radical resection for HCCa are mainly determined in terms of two factors: whether R0 resection is possible or not against the local tumor extension and whether the functional reserve of the future remnant liver is adequate or not to tolerate the surgical stress. We have a dilemma as to whether extensive hepatobiliary resection is advisable to achieve a R0 resection, or whether less extensive resection is a prerequisite for patients with impaired functional reserve of the liver. Currently, we have adopted a management strategy for patients with HCCa, including preoperative biliary drainage, portal vein embolization (PVE) [9–12] and major hepatobiliary resection [13, 14].

In this chapter, we introduced our current standard approach and surgical techniques in radical resection of HCCa referring to the limits.

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18.1.1 Fundamental Principles of HCCa Surgery in Terms of Limits

Glisson's capsule includes hepatic artery, portal vein, and segmental bile duct, and their detachment from each other is impossible in the liver parenchyma. Detachment of the hepatic artery and portal vein from the segmental bile duct prior to cutting the segmental bile duct at the expected line is essential to preserve the affected liver parenchyma. Hence, if it is impossible to dissociate from the feeding vasculatures and the segmental bile duct upstream of the expected resection line, the affected liver segment must be included in the resected liver segments to achieve a R0 resection (Fig. 18.1). The limitation of the detachment of the segmental bile duct and vasculature is usually determined by the individual anatomical relationship between the vasculature and bile duct system. On the other hand, not only the cancer-free proximal and distal bile duct margins but also the cancer-free dissection margin around the hepatoduodenal ligament is also an important issue in accomplishing a R0 resection [15].

18.1.2 Proximal Limit of Bile Duct Resection Line During HCCa Surgery

The proximal limit of resection of intrahepatic segmental and/or segmental bile ducts is differentially dependent upon

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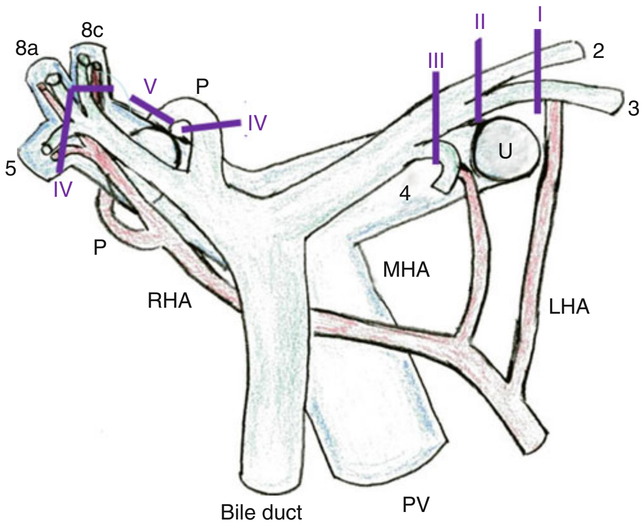

Fig. 18.1 The proximal limit of the resection intrahepatic segmental ducts is schematically illustrated in terms of type of hepatectomy. Numerals indicate Couinauld's segment of the liver. *U* umbilical portion of the left portal vein, *P* right posterior section, *8a* a ventral branch of the right anterosuperior segmental glisson, *8c* a dorsal branch of the right anterosuperior segmental glisson, *PV* portal vein, *LHA* left hepatic artery, *MHA* middle hepatic artery, *RHA* right hepatic artery, *I* right trisectionectomy (anatomical), *II* right trisectionectomy (classical), *III* right hemihepatectomy, *IV* left hemihepatectomy, *V* left trisectionectomy

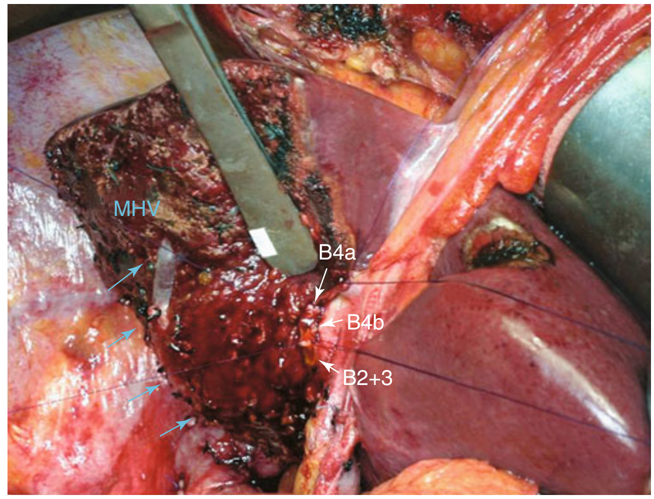

Fig. 18.2 Intraoperative photograph after right hepatectomy with caudate lobectomy shows openings of the left intrahepatic segmental ducts, and completed hepaticoplasty. Middle hepatic vein (*MHV*) indicated with *blue arrows* is clearly exposed on the raw surface of the liver. *B2* left lateral inferior segmental duct, *B3* left lateral superior segmental duct, *B4a* left medial inferior subsegmental duct, *B4b* left medial superior subsegmental duct. The *white arrows* point to B2+3, B4b and B4a

the type of hepatectomy (Fig. 18.1). In a right-sided hepatobiliary resection, the positive cancer involvement of the left medial segmental duct usually does not indicate a right hemihepatectomy but a right trisectionectomy to obtain the proximal tumor-free resection margin. The tumor involvement extends around the confluence of the left lateral anterior and posterior segmental ducts, in which case the limitation of the resecting line of the bile duct must correspond to the left side border of the umbilical portion of the left portal vein. Anatomic right trisectionectomy [16] is a potential option for such patients with right-side predominant extensive disease. This procedure is the ultimate for patients with the right-side predominant HCCa to obtain the proximal tumor-free resection margin. In a right hemihepatectomy, the left hepatic duct should be finally divided in the ventral to dorsal direction. Usually, the orifices of the left medial sectional (B4), the left lateral superior segmental (B3), and the left lateral inferior segmental (B2) bile ducts can be identified in order (Fig. 18.2). The limit of the resection line is the right-side border of the umbilical portion of the left portal vein. This line is somewhat oblique from the point at which the middle hepatic artery runs into the liver parenchyma.

In a left-sided hepatobiliary resection, the cancer involvement extends over the confluence of the right posterosuperior (B7) and posteroinferior segmental ducts (B6). It is usually difficult to secure the cancer-free resection margin even though a left trisectionectomy is performed. With a left hemihepatectomy, three to four proximal bile duct stumps appearing on the raw surface of the right liver is the limit. The orifices of the anteroinferior segmental duct (B5) and/or ventral branch of the anterosuperior segmental duct (B8a), dorsal branch of the anterosuperior segmental duct (B8c), and the posterior sectional duct are arranged in order from the ventral to dorsal direction. The orifice of the transected posterior sectional duct is located cranially to the right portal vein and at the right side border of the inferior vena cava (IVC) (Fig. 18.3).

18.1.3 Distal Limit of Bile Duct Resection Line During HCCa Surgery

As for distal tumor extension along the bile duct, it is theoretically possible to secure a cancer-free margin through concomitant pancreatoduodenectomy (HPD) [6, 7]. HPD usually involves concomitant pancreatoduodenectomy in a hemihepatectomy or more extended hepatobiliary resection in surgery for HCCa (Fig. 18.4). Right-sided hepatectomy is more often involved in HPD than left-sided hepatectomy according to the tumor extent; there is a risk of potential invasion of the right hepatic artery. This procedure is one of the most delicate operations in terms of the degree of invasiveness, and often carries high morbidity and mortality rates. With improved perioperative management and surgical techniques, the short-term outcome for patients undergoing HPD has improved, but the current results are still unsatisfactory [7, 17]. Thus, the selection criteria for HPD should be strict in selected patients with extensive disease.

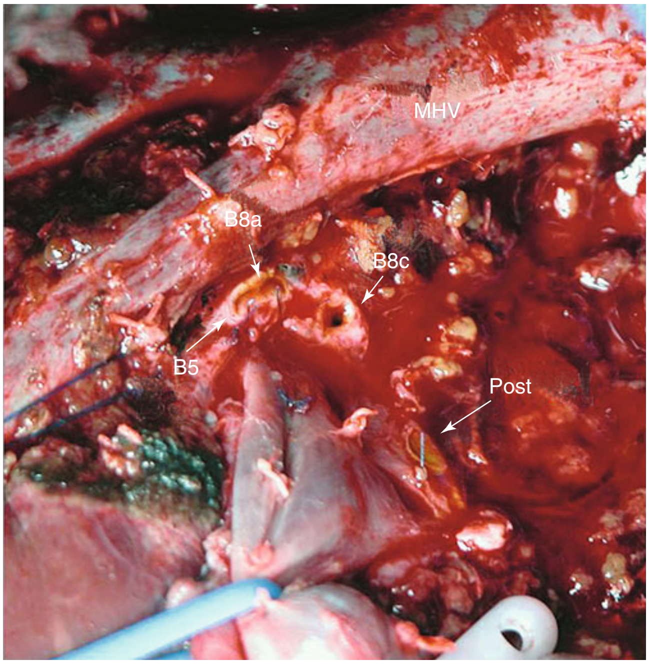

Fig. 18.3 The representative case of left hemihepatectomy with caudate lobectomy depicts bile duct stumps around the right portal vein and the right hepatic arterial branches on the raw surface of the liver. *MHV* middle hepatic vein, *B5* right anteroinferior segmental duct, *B8a* ventral branch of the right anterosuperior segmental duct, *B8c* dorsal branch of the right anterosuperior segmental duct, *Post* right posterior sectional duct

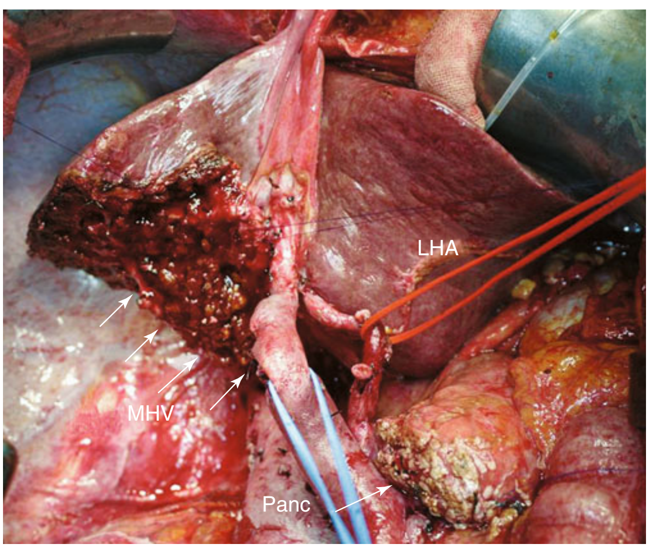

Fig. 18.4 This is an intraoperative photograph after the right hepatopancreatoduodenectomy (right hemihepatectomy with pancreatoduodenectomy) with caudate lobectomy. *LHA* left hepatic artery, *MHV* middle hepatic vein, *Panc* stump of the pancreas

Several predictive factors affecting postoperative survival after surgery for HCCa are reported in the literature. Although in situ cancer at the proximal bile duct margin does not have a strong impact on survival compared with a positive bile duct margin with invasive cancer [18, 19], needless to say, a R0 resection is the ideal option for cure. Resected cases of biliary malignancies by HPD still remain few, so the future accumulation and analyses of HPD cases will delineate the patient profile with large benefit from this invasive operation [3, 19, 20].

18.1.4 Preoperative Staging of HCCa

Preoperative staging is an important issue to estimate the possibility of radical surgery. The first step for staging of HCCa is now ultrasonography (US) followed by multidetector row computed tomography (MDCT) [2, 21] and it should be undertaken prior to biliary drainage for preventing modifications of the bile duct wall by a drainage catheter. The side of the liver resection can be determined by MDCT, and endoscopic naso-biliary drainage (ENBD) for the future remnant liver is performed to relieve cholestasis of the future remnant liver. Recently, ENBD is the first choice and percutaneous transhepatic biliary drainage (PTBD) is the second. Patients with endoscopic retrograde biliary drainage (ERBD) after developing clogging and/or segmental cholangitis, eventually require PTBD to recover from those serious complications. In an actual case of Bismuth type III and IV [22], multiple biliary drainages are often required. Only an endoscopic approach for biliary drainage using three or more stents is usually difficult, so additional PTBD is eventually indicated. We minimize PTBD sessions or the number of PTBD catheters which potentially causes seeding or implantation metastasis along the sinus tract of the PTBD [23]. PTBD still has a strong therapeutic impact on segmental cholangitis, which is a significant risk factor for postoperative morbidity and mortality [24]. Magnetic resonance cholangiopancreatography (MRCP) is insufficient to diagnose the difficult local anatomy of the separated intrahepatic segmental ducts and to design an appropriate operative procedure in patients with Bismuth type III or IV tumor [22]. Both proximal and distal cancer extension along the bile duct is evaluated by the combined use of percutaneous selective cholangiography and endoscopic retrograde cholangiography (ERC) or MRCP, and the resection lines of the separated intrahepatic segmental ducts in the future remnant liver are determined. Mapping biopsy under fluoroscopic guidance, peroral or percutaneous transhepatic cholangioscopy is also useful, especially in cases suspected of superficially spreading cholangiocarcinoma, to define the expected resection line of the proximal or distal bile duct [25].

Thanks to recent advances in imaging techniques, MDCT and three-dimensional CT angiography have replaced conventional angiography to assess the degree of vascular involvement and to delineate the vascular anatomy in each individual HCCa case [2, 21].

18.1.5 Limit of Liver Resection Volume for HCCa

The limit of the liver resection rate is critical to the strategy or decision regarding a radical resection in patients with HCCa. Currently, there is no definitive answer to the question: how much liver volume should be preserved to assure a feasible, safe resection? We routinely examine the indocyanine green (ICG) 15-min retention rate (R15), and the ICG clearance (K-value) is calculated when the serum total bilirubin level has decreased below 3 mg/dl. CT-volumetry is used to estimate the volume of the entire liver and the future remnant liver. PVE for the liver segment to be resected, has been advocated as a useful option to induce compensatory hypertrophy of the future remnant liver [10, 11]. If the estimated resection volume exceeds 55–60%of the whole liver, one must take into consideration the hepatic functional reserve or invasiveness of the additional procedure with concomitant vascular resection and/or pancreatic head resection. We can calculate ICG-K of the future remnant liver (ICG-Krem) according to CT-volumetric analysis by multiplying the ICG-K value by the ratio of future remnant liver volume. The guiding value of ICG-Krem for a safe operation is 0.06, and a 0.05 is considered as the minimal requirement to tolerate major hepatobiliary resection in our current treatment strategy. The actual future remnant liver volume and resection rate are another prime concern; the present ceiling is considered to be 250 mm [3] and 75 %, respectively. In CT-volumetry 2 weeks after PVE, there is an approximately 10 % volume gain in the future remnant liver, whereas there is a 10 % volume loss in the embolized liver to be resected [10, 11]. Although clinical utility and feasibility have been reported, the indication of preoperative PVE has still not been established. Cherqui et al. [26] reported the surgical results of major hepatobiliary resection without preoperative biliary drainage in 20 biliary cancer patients; the postoperative morbidity was significantly higher in the patients with jaundice, while the postoperative liver failure rate was 5 %, and mortality was documented in the same cases. The limit of the preoperative serum total bilirubin level for performing major hepatobiliary resection is also controversial. We usually perform resectional surgery 2–4 weeks after PVE, and when the serum total bilirubin level decreases below 2 mg/dl.

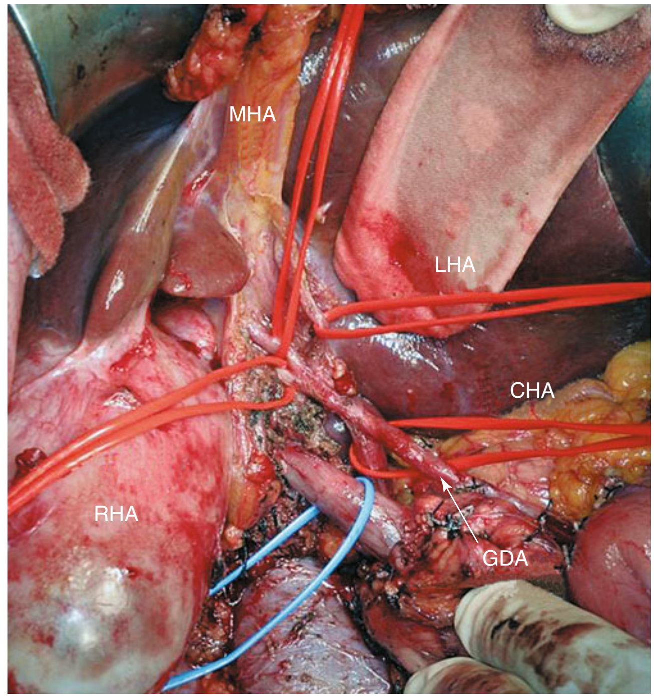

Fig. 18.5 An intraoperative photograph shows skeletonization of the hepatoduodenal ligament prior to right hemihepatectomy with caudate lobectomy. Various arteries and portal vein are isolated with a silicon rubber tape. *CHA* common hepatic artery, *GDA* gastroduodenal artery, *LHA* left hepatic artery, *MHA* middle hepatic artery, *RHA* right hepatic artery

18.2 Surgery

18.2.1 Extent of Lymph Node and Nerve Plexus Dissection During HCCa Surgery

Although lymph node metastasis is known as one of the poor prognostic factors, there is no golden standard with regard to the extent of lymph node dissection. En-bloc dissection of the regional (cystic duct, pericholedochal, periportal, periduodenal, peripancreatic head, celiac) nodes is routine for radical resection for HCCa (Figs. 18.5, 18.6, 18.7, and 18.8). Inspection and sampling dissection of the paraaortic lymph node followed by intraoperative frozen section examination are often included. In a case with definitive paraaortic lymph node metastasis, the long-term outcome is usually disappointing [27], so the indications for aggressive surgery such as HPD [6] or extended hepatobiliary resection with complex vascular reconstruction [5] may require careful reconsideration.

On the other hand, we consider not only lymph nodes but also connective tissue clearance, especially the autonomic nerve plexus around the common hepatic, proper hepatic, and right or left hepatic arteries, is crucial for radical resection. Although the clinical impact or efficacy of nerve plexus dissection has not been established, biliary cancer is often associated with perineural invasion which is identified as a significant prognostic factor in bile duct [28] and gallbladder cancers [29]. Thus, we perform complete skeletonization of the hepatoduodenal ligament to achieve cancer-free dissection margins in radical resection for HCCa (Figs. 18.5, 18.6, 18.7, and 18.8). It is advisable to use topical application of

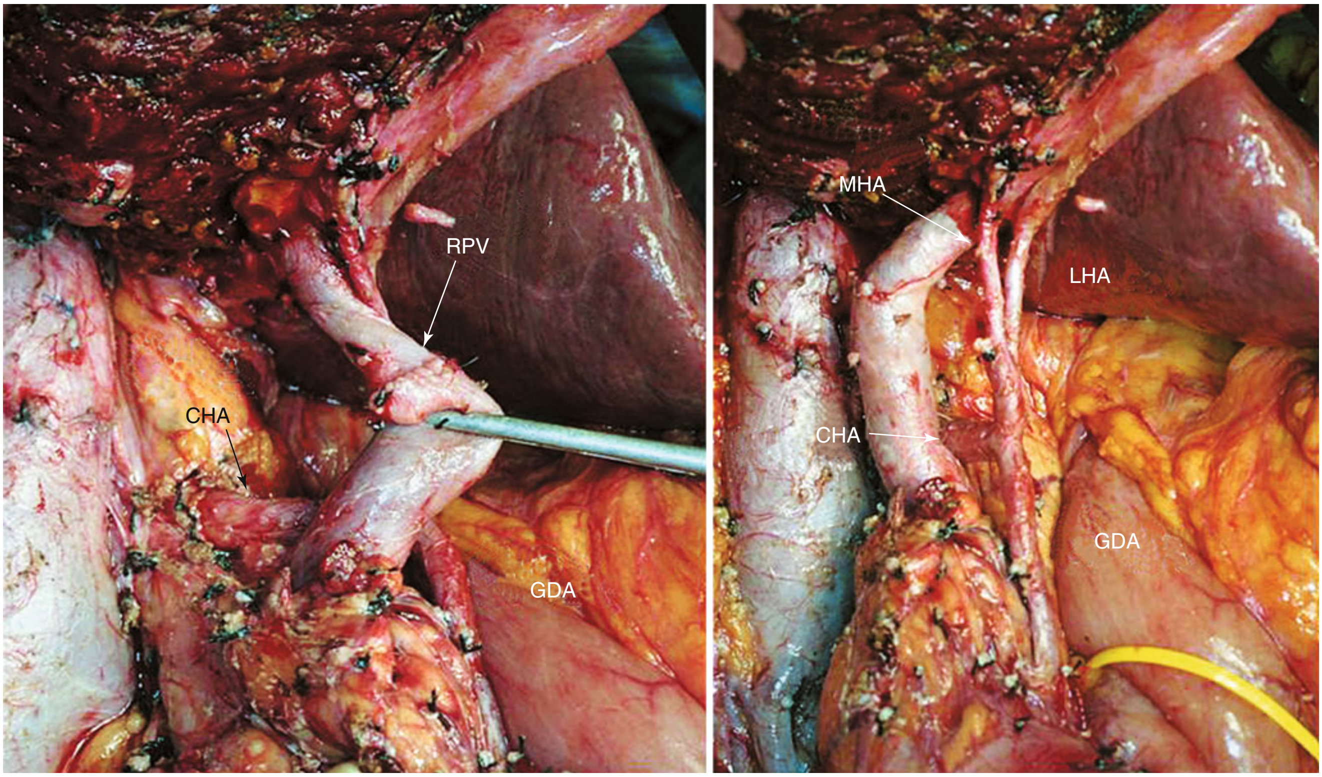

Fig. 18.6 Intraoperative photographs after a right hemihepatectomy with caudate lobectomy show complete skeletonization of the hepatoduodenal ligament and clearance of retropancreatic, celiac, and common hepatic lymph nodes.*CHA* common hepatic artery, *GDA* gastroduodenal artery, *LHA* left hepatic artery, *MHA* middle hepatic artery, *RPV* stump of the right portal vein

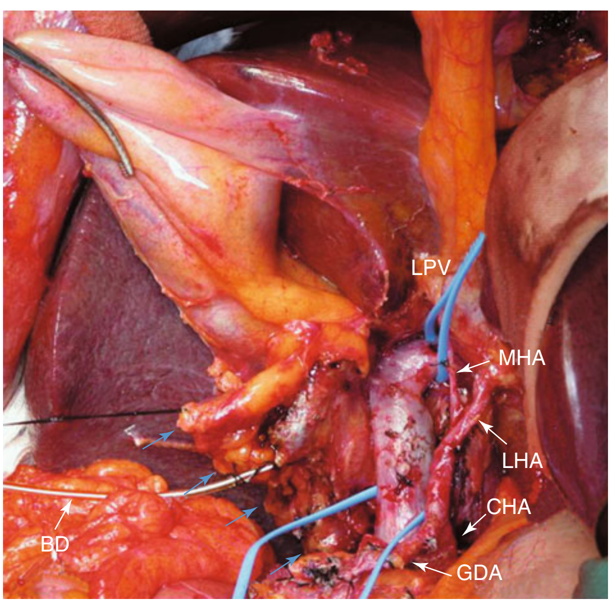

Fig. 18.7 An intraoperative photograph just prior to transecting the right portal vein depicts *en bloc* skeletonized connective tissue and lymph nodes surrounding the bile duct (*blue arrows*). The left portal vein (*LPV*) and portal vein are encircled with a silicon rubber tape. *BD* a tube for intraoperative biliary drainage, *CHA* common hepatic artery, *GDA* gastroduodenal artery, *LHA* left hepatic artery, *MHA* middle hepatic artery, *LPV* left portal vein

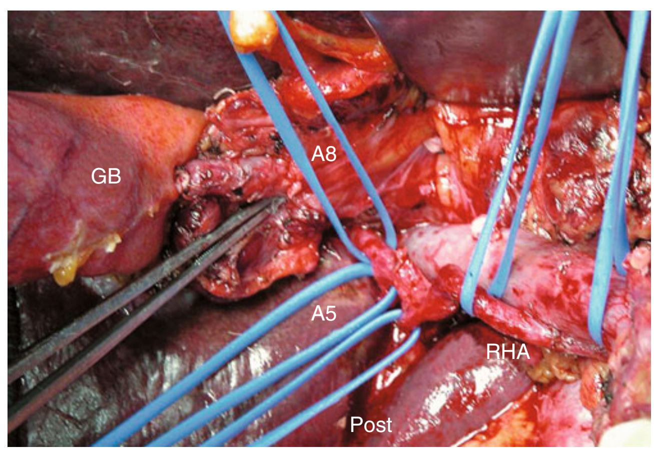

Fig. 18.8 An intraoperative photograph shows skeletonization of the hepatoduodenal ligament during the left hemihepatectomy with caudate lobectomy. Branches of the replaced right hepatic artery are isolated with silicon rubber tape. *GB* gallbladder, *A5* anteroinferior segmental branch of the right hepatic artery, *A8* anterosuperior segmental branch of the right hepatic artery, *Post* posterior sectional branch of the right hepatic artery, *RHA* replaced right hepatic artery from superior mesenteric artery

1 % procaine solution for the skeletonized hepatic artery to prevent spastic reaction of the artery followed by unexpected thrombosis.

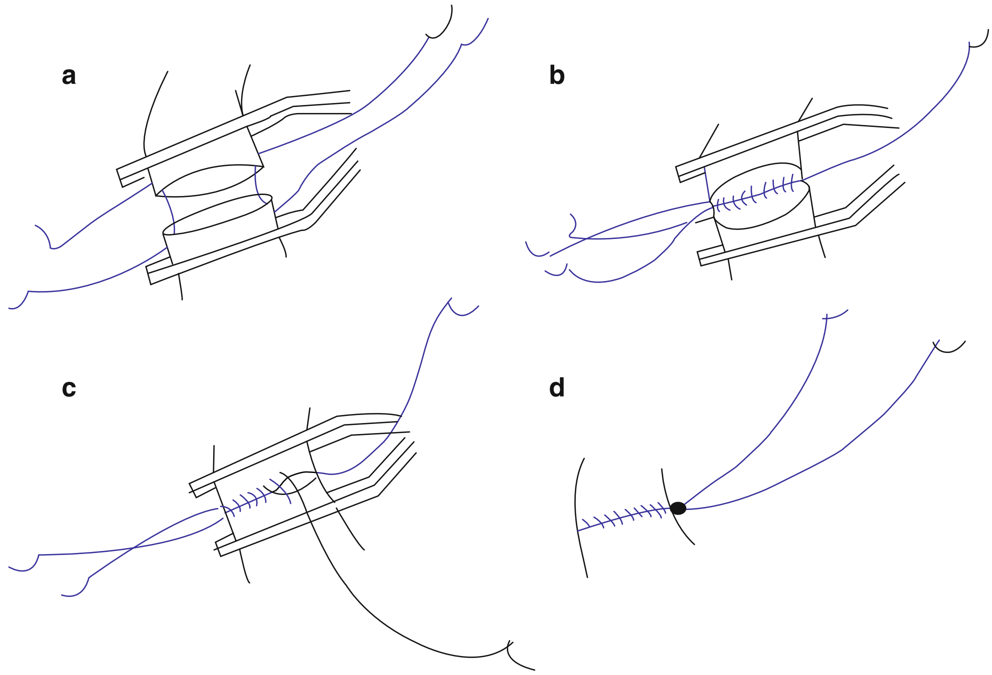

Fig. 18.9 Schematic drawing of the portal vein resection and reconstruction. At first, stay suture is placed bilaterally (**a**), and intraluminal technique is used for the posterior wall suture (**b**). Next, anterior wall anastomosis is performed using the same string (**c**), then single string continuous suture is completed (**d**)

18.2.2 Limit of Portal Vein Resection and Reconstruction

In right-sided hepatectomies, portal vein resection and reconstruction prior to liver parenchymal transection are feasible [30]. The wedge resection or segmental resection with end-to-end anastomosis is possible in many cases (Fig. 18.9), and segmental resection with an autologous vein grafting is uncommon in a right-sided hepatectomy. If the length of the portal vein resection exceeds 5 or 6 cm, an interposition graft must be required (Figs. 18.10 and 18.11). An external iliac vein is usually harvested through an extraperitoneal approach as an autologous graft for portal vein reconstruction, because the diameter of the external iliac vein is similar to that of the portal veins for reconstruction. Roughly one-fourth of the external iliac veins have a valve, so normograde reconstruction of the portal vein using an external iliac vein is essential to prevent portal thrombosis. In portal vein reconstruction using an interposition graft, the proximal anastomosis precedes the distal anastomosis. After releasing of the proximal clamp to expand the anastomotic side, the distal anastomosis is then performed. In left sided-hepatectomies, portal vein resection and reconstruction prior to liver resection are difficult and rare, and segmental autologous vein grafting is often required for reconstruction. Depending upon the defect of the resected portal vein to be reconstructed, a direct transverse suture, patch graft repair, or segmental vein grafting are selected for portal vein reconstruction. The limit of the portal vein resection and reconstruction during right-sided hepatectomies is the feasibility of cross-clamping of the root of the umbilical portion of the left portal vein. There is an exceptional case in which the left lateral inferior and umbilical portion of the left portal vein are isolated and separately clamped for the portal vein reconstruction during right hepatectomy. In left-sided hepatectomies, isolation and clamping of the right posterior sectional and/or the right anterior sectional portal vein are the critical procedure. For the end-to-end portal vein anastomosis, a stay stitch is placed on both sides and an intraluminal technique is usually used for the posterior wall suture, followed by anterior wall anastomosis using the over and over suture technique with 6-0 prolene.

In most cases undergoing portal vein resection and reconstruction, anticoagulant therapy is not employed. Color Doppler ultrasonography is used to examine the perioperative portal blood flow for patients undergoing portal vein resection and reconstruction [31]. We consider that the portal vein resection and reconstruction per se does not increase the operative risk during hepatobiliary resection; moreover, long-term survival is actually expected after this aggressive surgery [32]. Thus, the hepatobiliary surgeon should not hesitate to perform portal vein resection and reconstruction during hepatobiliary resection in case of a promising R0 resection for a locally advanced HCCa.

18.2.3 Hepatic Arterial Resection and Reconstruction During HCCa Surgery

Concomitant left hepatic arterial resection and reconstruction during right-sided hepatobiliary resection is uncommon and an extremely rare. The left hepatic artery usually runs along

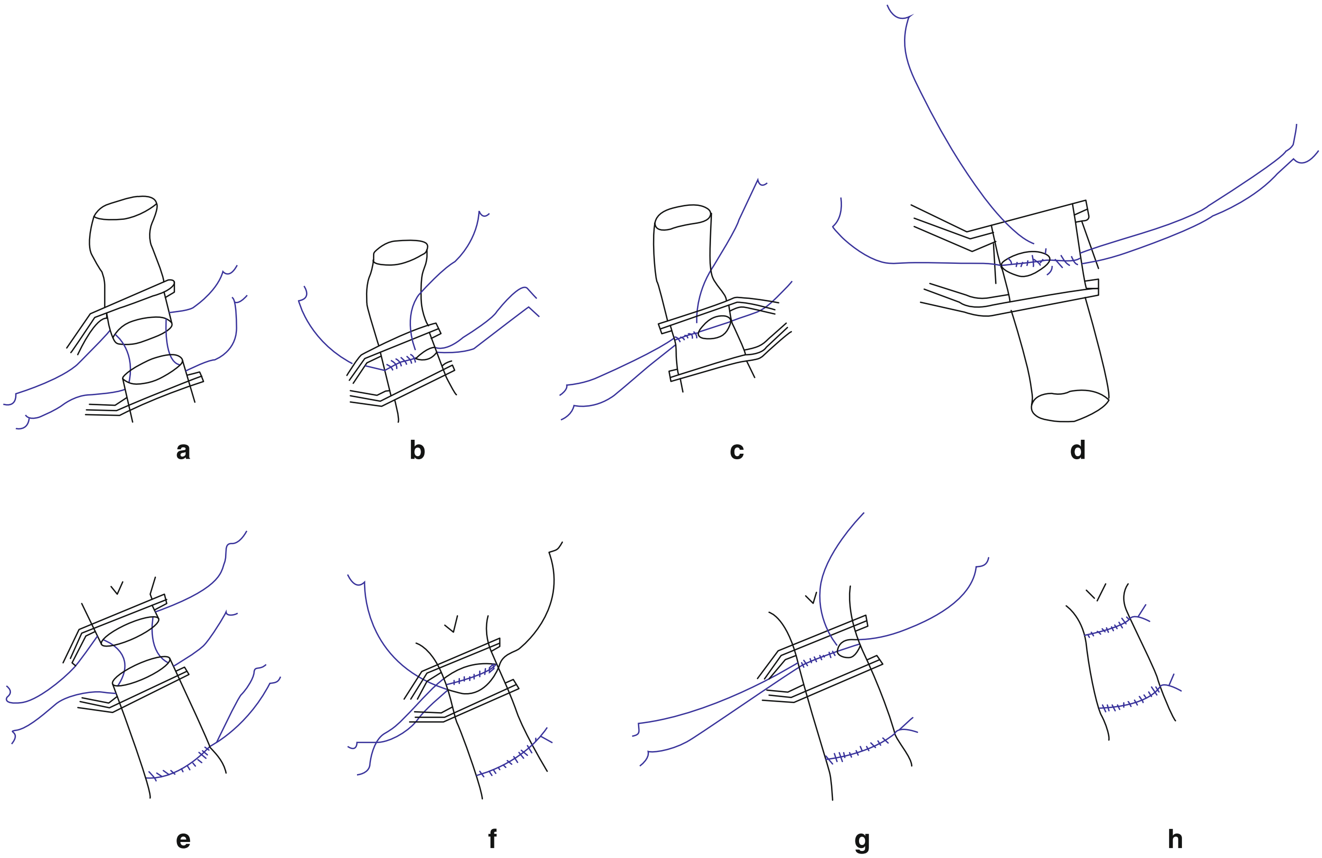

Fig. 18.10 Scheme of the interposition grafting for the portal vein reconstruction is illustrated. The proximal single-string continuous suture is performed (**a–d**), followed by the distal anastomosis (**e–h**). In case of the proximal anastomosis, over and over suture for both anterior and posterior wall is capable in terms of inversion of the graft (d)

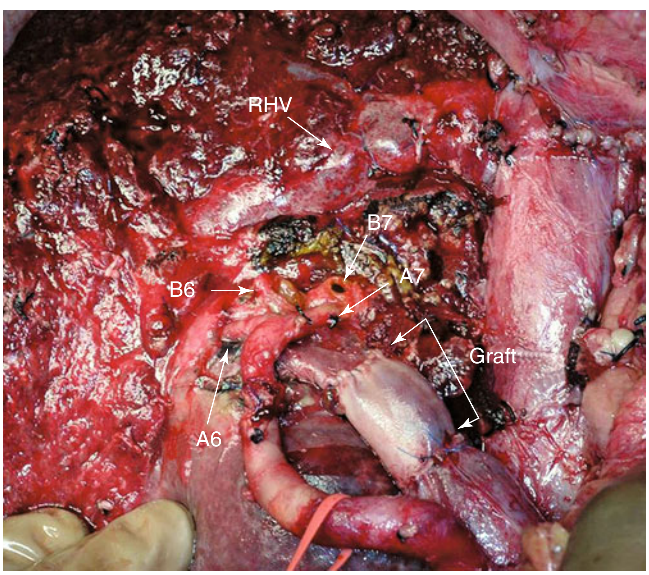

Fig. 18.11 Left trisectionectomy with caudate lobectomy with portal vein resection and reconstruction using an external iliac vein graft. There is no obvious caliber change in the reconstructed portal vein. *RHV* right hepatic vein, *A6* posteroinferior branch of the right hepatic artery, *A7* posterosuperior branch of the right hepatic artery, *B6* right posteroinferior segmental duct, *B7* right posterosuperior segmental duct

the left edge of the hepatoduodenal ligament, so a right-side predominant HCCa involving the left hepatic artery implies almost entire invasion of the hepatoduodenal ligament. In this event, it is virtually impossible to obtain tumor-free resection margins even after hepatoduodenal ligamentectomy, major hepatectomy with *en bloc* resection of the hepatic artery, portal vein, and pancreas head. In patients with a replaced left hepatic artery arising from the left gastric artery, hepatic arterial reconstruction is unnecessary for hepatoduodenal ligamentectomy, and the success of R0 resection might be further assured by preserving the replaced arterial blood supply [20].

In case of Bismuth type I or II [22] with definitive or suspected right hepatic arterial invasion, a right hemihepatectomy is ideal to achieve a R0 resection, but a left hemihepatectomy with right hepatic arterial resection and reconstruction is one of the alternative strategies for patients with poor liver functional reserve. Recently, a more aggressive approach to patients with more advanced left-side predominant HCCa has been applied through a left trisectionectomy using right hepatic arterial resection and reconstruction with or without simultaneous portal vein resection and reconstruction [5]. Most of the right hepatic

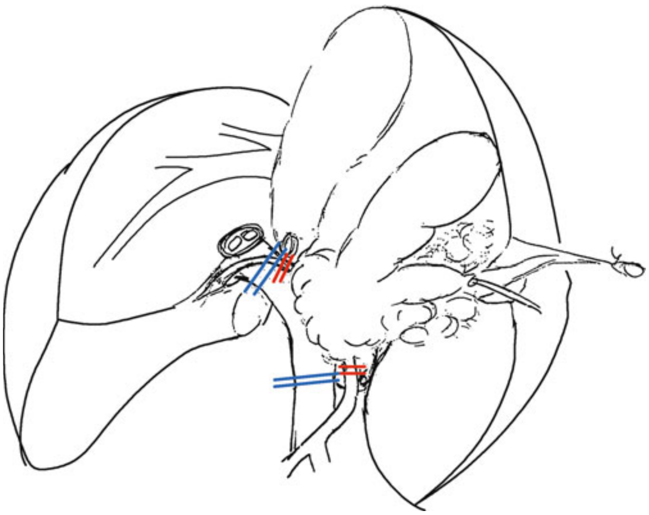

Fig. 18.12 Left trisectionectomy with portal vein and hepatic arterial resection and reconstruction. Portal vein and hepatic arterial resection lines are depicted with *double lines*

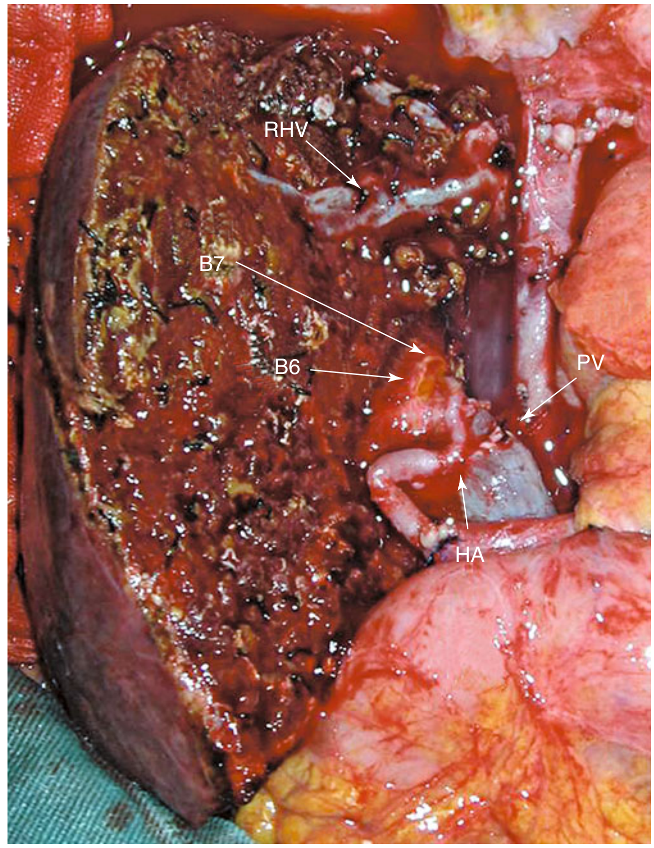

Fig. 18.13 Left trisectionectomy with caudate lobectomy plus portal vein and hepatic arterial resection and reconstruction. Portal vein is reconstructed in end-to-end fashion, and the right hepatic artery is reconstructed by end-to-end anastomosis between the right posterior branch and the proper hepatic artery. There is no obvious caliber change in the reconstructed portal vein. *RHV* right hepatic vein, *B6* right posteroinferior segmental duct, *B7* right posterosuperior segmental duct, *PV* anastomosis of the portal vein, *HA* anastomosis of the hepatic artery

arterial resection and reconstruction is done in left-sided hepatectomy, and reconstruction of the right hepatic artery with an end-to-end anastomosis is a common microsurgical technique (Figs. 18.12 and 18.13). The right gastroepiploic artery [33] or radial artery graft [5] is sometimes selected as a recipient artery. The posterior branch of the right hepatic artery often runs on the caudal side of the posterior branch of the right portal vein in the Rouviere's sulcus, making it easy to assess and ensure the cancer negative dissection of the posterior branch of the right hepatic artery prior to liver parenchymal transaction. On the other hand, the posterior branch of the right hepatic artery occasionally runs on the cranial side of the right portal vein, and it is difficult to assess the capability of securing the distal portion of the posterior branch of the right hepatic artery for reconstructing before proceeding in hepatectomy. This anatomical variation of the posterior branch of the right hepatic artery is a key issue to assess or decide the indication of the right hepatic arterial resection and reconstruction in case of a left-sided hepatectomy.

When arterial reconstruction is impossible, one possible countermeasure is arterialization of the portal vein using arterioportal shunting [34]. Oblique-to-side anastomosis is performed between the common hepatic artery and the main portal vein. Approximately 3 weeks after surgery, transcatheter arterial embolization of the common hepatic artery is carried out to prevent further portal hypertension. This procedure possibly prevents liver infarction or liver abscess in the remnant liver leading to postoperative liver failure. Preoperative left trisectional portal vein embolization is beneficial to enhance not only the compensatory hypertrophy of the future remnant liver, but also easy detection of the right portal fissure as the demarcation line on the liver surface just after clamping of the right hepatic artery in a case of left trisectionactomy.

18.2.4 General Procedures in Resectional Surgery for HCCa

After laparotomy, Kocher's maneuver is performed to mobilize the pancreas head and allow regional lymphadenectomy in the hepatoduodenal ligament and around the retropancreatic, and celiac arteries (Figs. 18.5 and 18.6). Simultaneously, the distal bile duct is isolated and resected at the intrapancreatic portion. The distal margin should be submitted for intraoperative frozen section examination. Once a negative resection margin is confirmed, the bile duct stump is closed with interrupted or continuous sutures of monofilament thread. If the distal bile duct margin is positive for cancer even after additional resection of the intrapancreatic bile

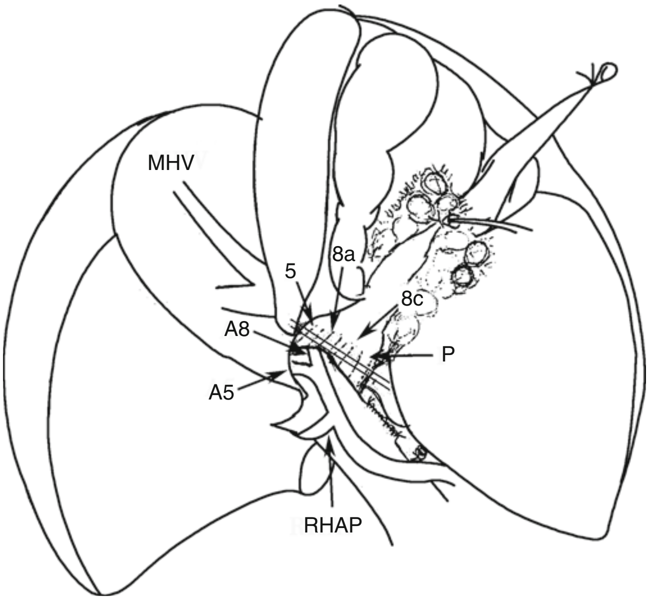

Fig. 18.14 Schematic illustration of left hemihepatectomy just prior to bile duct resection. The resection line is presented with double line. *P* right posterior sectional duct, *8a* ventral branch of the right anterosuperior segmental duct, *8c* dorsal branch of the right anterosuperior segmental duct, *5* right anteroinferior segmental duct, *RHAP* posterior sectional branch of the right hepatic artery, *A5* anteroinferior branch of the right hepatic artery, *A8* anterosuperior branch of the right hepatic artery

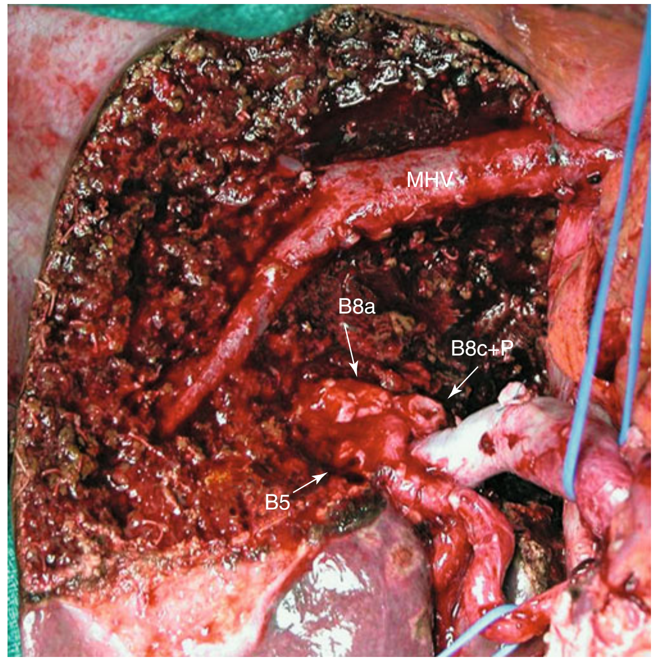

Fig. 18.15 Intraoperative photograph after left hemihepatectomy with caudate lobectomy. Middle hepatic vein (*MHV*) is clearly exposed on the raw surface of the liver and bile duct stumps formed around the right portal vein and the right hepatic arterial branches. *B5* right anteroinferior segmental duct, *B8a* ventral branch of the right anterosuperior segmental duct, *B8c* dorsal branch of the right anterosuperior segmental duct, *P* right posterior sectional duct

duct, indication of concomitant pancreaticoduodenectomy should be decided in terms of the status of the proximal and/or dissected margins. The posterior superior pancreatoduodenal artery should be divided in some cases of more distal intrapancreatic bile duct resection close to the papilla of Vater. Intraoperative biliary drainage through the resected end of the bile duct is advisable for patients with ENBD or ERBD, or without preoperative biliary drainage. Spilled bile contaminated with bacteria or tumor cells may well cause postoperative abdominal sepsis and/or seeding metastasis.

18.2.5 Left Hemihepatectomy with Caudate Lobectomy (Figs. 18.3, 18.8, 18.14, and 18.15)

During skeletonization of the hepatoduodenal ligament, the right gastric artery, then the left hepatic artery is ligated, transfixed, and divided. Next, the middle hepatic artery is divided. The main portal vein is skeletonized and encircled with a vessel loop. Careful division of the several tiny caudate branches around the portal bifurcation makes for easier division of the left portal vein at its origin by ligation with transfixing. Another way to divide the left portal vein is to clamp on the proximal side and the right portal vein, and oversew the venous stump with a transverse running suture of 6-0 prolene. After complete or partial detachment of the gallbladder from the gallbladder bed, the extrahepatic bile duct including lymph nodes and connective tissues is retracted in the cranio-ventral direction and the right hepatic artery is carefully isolated and encircled with a vessel loop; the cystic artery is then ligated and divided at its origin, and the right anterior and posterior branches are isolated. Meticulous manipulation and skeletonization dissection of the nerve plexus around the right hepatic artery is advisable. A demarcation line appearing on the main portal fissure is marked by electrocautery.

For complete mobilization of the left liver, the falciform and coronary ligaments are incised and the triangle ligament is ligated and divided. The root of the left (LHV) and middle hepatic vein (MHV) making a common trunk in many cases should be identified. Next, the distal side of the Arantius canal is ligated and divided, to make it easier to encircle the common trunk of LHV and MHV. The entire caudate lobe is completely mobilized on the right and ventrally and detached from the inferior vena cava (IVC) from the caudal to cranial direction. During this procedure the short hepatic veins (SHV) are carefully ligated and divided step by step. Thick SHV such as the caudate vein [35] often located around one-third of the cranial part of the caudate lobe should be clamped with a vascular forceps, then transected and sutured. Liver parenchymal transection is carried out along the demarcation line using an ultrasonic dissector or the forceps clamp crushing method. Hepatic inflow occlusion is employed for 20 min at 5-min intervals. The MHV appears on the transection plane, the left lateral aspect of the MHV is exposed, and the confluence of the MHV and LHV is identified. The root of the LHV is clamped, divided and closed with running sutures of 4-0 prolene. Then the liver parenchymal transection advances exposing the dorsal wall of the MHV in the direction of the right-side border of the IVC, a critical landmark of the right side margin of the right caudate lobe. Then, the caudate process and posterior section are divided in the cranial direction. Careful dissection of the branches of the right hepatic artery and the right portal vein is critical prior to transection of the right hepatic duct beneath the MHV at the expected point determined preoperatively. Bile duct transection starts from the ventral to the dorsal wall, and usually the orifices of the anteroinferior segmental duct (B5), ventral branch of the anterosuperior segmental duct (B8a), dorsal branch of the anterosuperior segmental duct (B8c), and the posterior sectional duct are observed in that order. These bile duct orifices are noticed around the right portal vein and the right hepatic arterial branches. Frozen sections of the proximal bile duct margins should be submitted to check the negative margins.

After completing hemostasis, hepaticoplasty prior to bilio-enterostomy using a Roux-en-Y jejunal limb is advisable to reduce the number of anastomoses and simplify the procedure. The external biliary stents are usually placed across the bilio-enteric anastomosis. Interrupted or continuous sutures of 5-0 monofilament absorbable thread are used. The enteral feeding tube is sometimes placed through the proximal jejunal limb for replacement of externally drained bile. A retrocolic and retrogastric route [36] is often selected to elevate the jejunal limb.

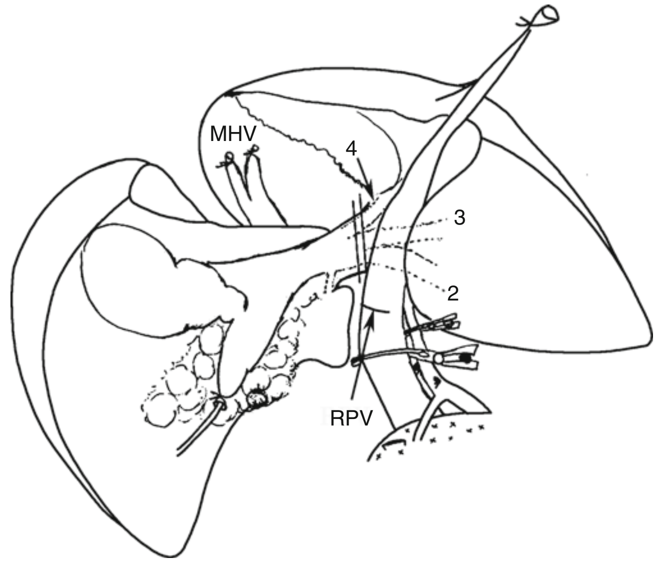

Fig. 18.16 Final step of the right hemihepatectomy. Bile duct resection is indicated by double lines. *2* left lateral inferior segmental duct, *3* left lateral superior segmental duct, *4* left medial sectional duct, *MHV* middle hepatic vein, *RPV* stump of the right portal vein

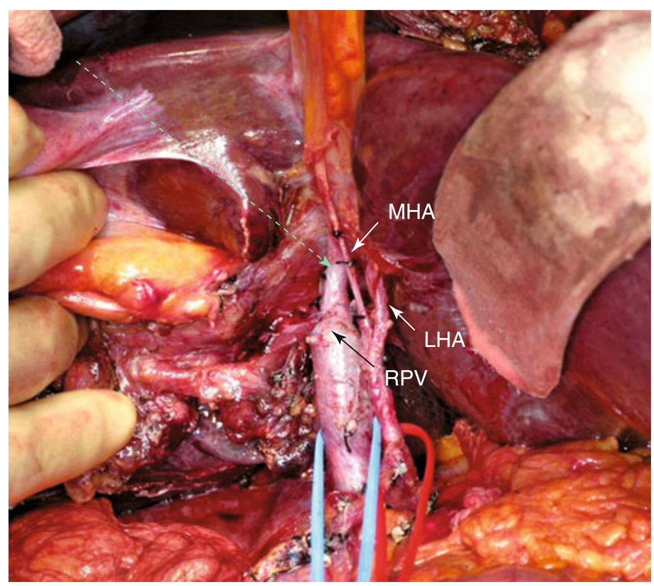

Fig. 18.17 *Dotted line* shows the liver transection line of the ventral part of the left medial section and the solid line depicts expected resection line of the bile duct during right hemihepatectomy with caudate lobectomy. *LHA* left hepatic artery, *MHA* middle hepatic artery, *RPV* stump of the right portal vein

18.2.6 Right Hemihepatectomy with Caudate Lobectomy (Figs. 18.2, 18.7, 18.16, 18.17, and 18.18)

After retropancreatic lymph node dissection, the distal bile duct is dissected similarly to the *left hemihepatectomy*. Next, skeletonization of the hepatoduodenal ligament is follows, and then the common hepatic, gastroduodenal, and proper hepatic arteries are isolated with the vessel loops. The right gastric artery is ligated and divided, then the middle hepatic and the left hepatic arteries is identified, and the right hepatic artery is ligated, transfixed, and divided at its origin. Next, the portal vein is taped and skeletonized up to the portal bifurcation. After division of the caudate and the quadrate lobe branches, the main, left and right portal veins are encircled with the vessel loops. The right portal vein is transected after ligation with a transfixing suture. In patients who have undergone PVE, the main and the left portal vein are clamped with vascular forceps and the origin of the right portal vein is transversely incised to inspect the unexpected embolic material migration in the portal bifurcation. Any embolic materials, if detected, should be removed and washed out from the orifice of the right portal vein with heparinized saline. This

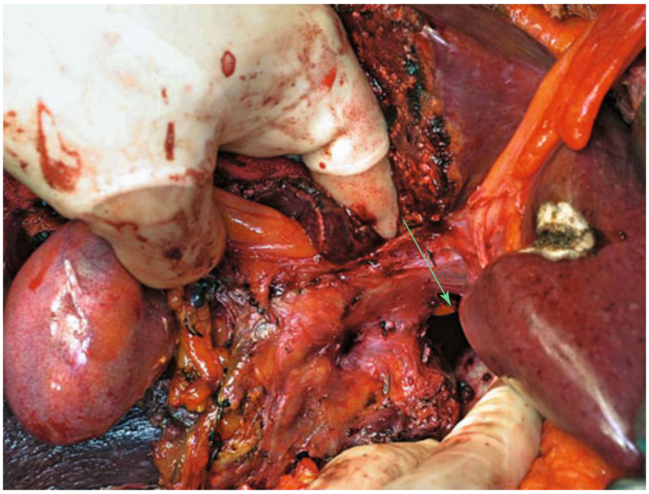

Fig. 18.18 Bile duct transection on the *solid line* is the final step during right hemihepatectomy with caudate lobectomy. The *green line* with an *arrow* indicate the line of bile duct transection as the final step during right hemihepatectomy with caudate lobectomy. The arrow points to the direction of transection from the surgeon's left to right

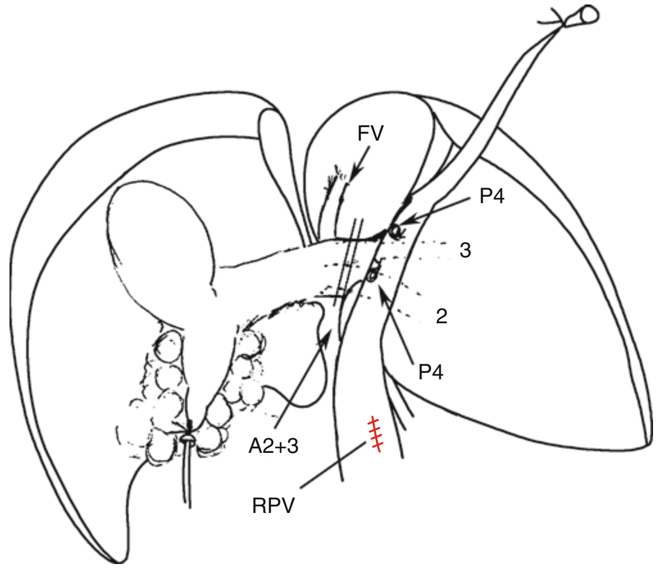

Fig. 18.19 Schematic illustration of anatomical right trisectionectomy just prior to bile duct resection (*double line*) depicts dissection along the cranial aspect of the umbilical portion of the left portal vein and exposure of the umbilical plate. *2* left lateral inferior segmental duct, *3* left lateral superior segmental duct, *FV* fissural vein, *A2+3* left hepatic artery, *RPV* stump of the right portal vein, *P4* stump of the medial sectional portal vein

orifice should be closed with transverse suture to prevent stenosis of the portal vein. On the other hand, in a case with apparent or suspected cancer invasion around the portal bifurcation, combined portal vein resection and reconstruction should be performed to obtain cancer-free dissection margins [4].

Next, the proximal origin of the Arantius canal is ligated and divided, and the Rex's recess is dissected to expose the visceral part of the umbilical portion of the left portal vein. At that time one can identify the left hepatic artery running into the liver from the left side of the umbilical portion of the portal vein. The middle hepatic artery (MHA) usually runs into the liver from the right side of umbilical portion of the left portal vein. Occasionally, the MHA arises from the left hepatic artery in the umbilical plate. On the other hand, MHA sometimes branches from RHA close to the left-side border of the common hepatic duct and may be potentially involved by the tumor. In such cases, combined resection of MHA is advisable to achieve R0 resection. If backflow bleeding from the hepatic-side stump of resected MHA is documented, we consider there is no indication for the reconstruction but simple ligation of MHA is thereby validated [37].

When a demarcation line appears along the main portal fissure, it is marked by electrocautery. On the inferior aspect of the left medial section, the liver transection line should be delimited transversely approximately 1 cm above (ventral to) the hilar plate to secure the negative surgical margin.

During mobilization of the right liver, detachment of the right adrenal gland is carefully carried out because dense adhesion between the right liver and the right adrenal gland is encountered in some patients. The right hepatic vein (RHV) is encircled, divided and closed with manual running sutures or a stapler device. The RHV is usually divided behind the liver before liver transaction which makes complete detachment of the entire caudate lobe from the IVC easier. The managements of SHV are similar to those for the left hemihepatectomy.

Liver parenchymal transection starts along the demarcation line during intermittent inflow occlusion similar to the left hemihepatectomy. The MHV appears on the transection plane, and the tributaries from the right liver should be carefully ligated and divided. From the confluence of the IVC, the dorsal aspect of the MHV is exposed and the operator at the same time pulls and turns the left caudate lobe right dorsally with the left fingers. Finally, the right and the left livers are connected with the left hepatic duct. The right liver with entire caudate lobe is held in the left hand of the operator, and the left hepatic duct is incised in the ventral to dorsal direction. Usually, we can identify orifices of B4, B3, and B2 in order, hepaticoplasty follows, and a bilioenterostomy is created.

18.2.7 Right Trisectionectomy with Caudate Lobectomy (Figs. 18.19, 18.20, and 18.21)

In case of right-sided hepatobiliary resection, especially in the right trisectionectomy, exposure of the umbilical portion of the left portal vein is a fundamental manipulation. We sometimes encounter a bridge in front of the umbilical portion of the left portal vein, so transection of this bridge is the first step to expose the umbilical portion of the left portal

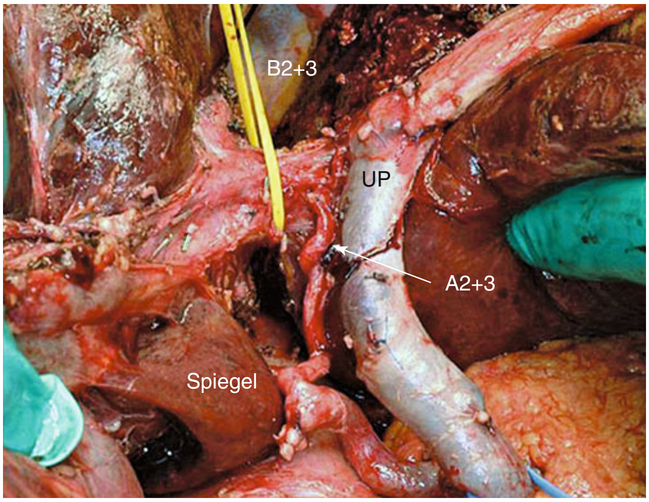

Fig. 18.20 Intraoperative photograph prior to bile duct resection during anatomical right trisectionectomy with caudate lobectomy demonstrates complete mobilization of the umbilical portion of the left portal vein (*UP*) and isolation of the left lateral superior and inferior segmental ducts with silicon rubber tape. The left lateral inferior and superior segmental branches of the hepatic artery is clearly exposed and identified between left lateral segmental ducts and UP. *B2* left lateral inferior segmental duct, *B3* left lateral superior segmental duct, *A2* left lateral inferior segmental branch of the hepatic artery, *A3* left lateral superior segmental branch of the hepatic artery

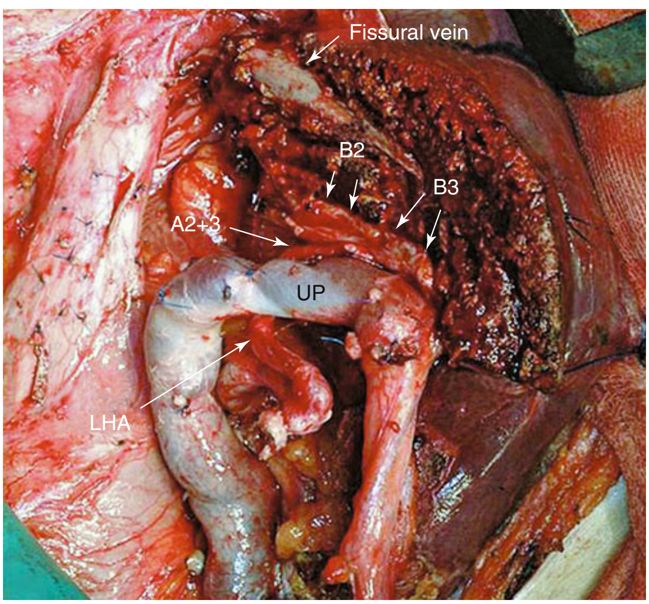

Fig. 18.21 A fissural vein can be identified on the raw surface of the liver after the anatomical right trisectionectomy with caudate lobectomy. Plural left lateral superior and inferior segmental ducts are observed. *B2* left lateral inferior segmental duct, *B3* left lateral superior segmental duct, *A2* left lateral inferior segmental branch of the hepatic artery, *A3* left lateral superior segmental branch of the hepatic artery, *LHA* left hepatic artery, *UP* umbilical portion of the left portal vein

vein. Surgeons must be aware that a thick bridge potentially includes the infra-portal bile duct [38, 39], which should be diagnosed preoperatively by MDCT. If the infra-portal left lateral or left lateral superior bile duct is detected and transected, bilioenteric anastomosis for transected bile duct is mandatory. After division of the middle hepatic artery, the visceral connective tissue of the umbilical portion of the left portal vein is dissected, and portal vein branches for the left medial section are ligated and divided step by step. Simultaneously, the proximal end of the Arantius canal is ligated and divided at the portal elbow.

In case of anatomic (extended) right trisectionectomy, all portal vein branches arising from the dorsal aspect of umbilical portion of the left portal vein should be completely ligated and divided [16]. This procedure provides complete mobilization of the umbilical portion of the left portal vein which can be completely turned out to confirm the root of the left lateral inferior (P2) and the left lateral superior (P3) segmental branches of the portal vein. Also, the left hepatic artery and its branches run through the left side of the umbilical portion of the left portal vein, and can be clearly identified between the bile ducts and the portal veins of the left lateral section. The demarcation line appears not on the right but rather on the left side of the falciform ligament. After complete mobilization of the right liver and caudate lobe similar to the *right hemihepatectomy*, liver parenchymal transection along the demarcation line starts using intermittent inflow occlusion. The fissural vein should be identified by intraoperative ultrasonography and preserved as far as possible. The middle hepatic vein is divided at its root with a stapler or sutured. Finally, the bile ducts are transected in the ventral to dorsal direction, and the left lateral superior segmental duct (B3) and left lateral inferior segmental duct (B2) are identified in order. Separate hepaticojejunostomies for B2 and B3 are required in the case of anatomic right trisectionectomy.

18.2.8 Left Trisectionectomy with Caudate Lobectomy (Figs. 18.11, 18.13, and 18.22)

Similarly to the *left hemihepatectomy*, retropancreatic lymph node dissection, and division of the distal bile duct are the first step. The right gastric, left hepatic, middle hepatic, cystic, and anterior branch of the right hepatic artery are identified, ligated, and divided step by step during the skeletonization of the hepatoduodenal ligament. Tiny branches for the caudate lobe around the portal bifurcation should be carefully ligated and divided, which makes it easier to isolate and encircle the left, right, right anterior, and right posterior portal veins. Preoperative left trisection PVE is indicated for most patients undergoing left trisectionectomy. Therefore, a careful inspection of the embolic material is advisable prior to transecting portal vein branches. If the embolic material migrates to the right or main portal vein, the embolic material must be removed from the right anterior or left portal

Fig. 18.22 Schematic illustration of the left trisectionectomy just prior to bile duct resection. *6* right posteroinferior segmental duct, *7* right posterosuperior segmental duct, *RHV* right hepatic vein

vein. After division of the left and the right anterior portal vein, both the right posterior branch of the portal and hepatic artery should be dissected further up to the predetermined resection line of the posterior sectional bile duct.

After the above-mentioned manipulations, a demarcation line corresponding to the right portal fissure appears and is marked by electrocautery. The distal portion of the Arantius canal is ligated and divided, which makes it easier to encircle the common trunk of the MHV and LHV. Then mobilization of the left liver and caudate lobe is completed similarly to the *left hemihepatectomy*. We prefer to divide the common trunk of the MHV and LHV with manual suture or a stapler technique prior to liver transection.

Liver transection along the demarcation line starts under intermittent inflow occlusion. The right hepatic vein should be exposed on the raw surface of the liver from the periphery to the confluence of the IVC, and the parenchymal transection between the caudate lobe and right posterior section then starts along the right edge of the IVC. Another critical landmark for transection is the root of the right posterior branch of the portal vein. The transection of the dorsal part of the right portal vein proceeds from the caudal side, and the transection plane is connected to the cranial plane. Finally, the left trisection of the liver and the caudate lobe are simply interconnected with the right posterior section through the posterior sectional bile duct. Adequate isolation of the right posterior portal and hepatic artery is confirmed, then the bile duct is divided for completion of the left hepatic trisectionectomy. Eventually, the bile duct orifices of the right posteroinferior branches (B6) and the right posterosuperior (B7) are sometimes identified separately.

18.2.9 Perioperative Management

Preoperative periodic bile culture, at least once a week, for possible positive bacteria for appropriate use of sensitive antibiotics is routine in patients with biliary drainage. Perioperative septic complications considerably influence surgical outcome [24]. To prevent severe septic complications, appropriate use of antibiotics as well as proper biliary drainage is crucial.

External biliary drainage without bile replacement impairs intestinal barrier function in patients with biliary obstruction, primarily due to physical damage to the integrity of the intestinal mucosa. Therefore, externally drained bile should be replaced as perioperative management for patients with HCCa to prevent bacterial translocation [40, 41]. In this connection, perioperative oral synbiotics administration can enhance immune responses and attenuate systemic postoperative inflammatory responses, as well as improve the intestinal microbial environment [42]. These procedures reduce postoperative infectious complications after major hepatobiliary resection, so perioperative synbiotics treatment deserves consideration as a management of choice for patients with HCCa.

Conclusion

We have various limitations for surgical treatment of HCCa, and the R0 resection still remains a difficult challenge for the surgeon. Coordination of the radicality and the safety of surgery for HCCa is the prime concern, and the many issues remaining to be resolved include precise determination of the tumor extent, liver resection volume, and estimation of the functional reserve of the future remnant liver, when the limitation of surgery for HCCa is discussed. Currently only several large surgical series treating HCCa have been published [14, 43–55]. Forthcoming accumulation of cases and evaluation of the surgical outcome will serve to delineate future problems to be addressed.

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