INTRODUCTION

The best, if not only, option for cure and long-term survival with malignancy in hepatic surgery has always been surgical resection with negative margins. Patients who are unresectable and undergo chemotherapy and/or interventional procedures have substantially worse survival than those who can be resected. Although interpretation of available data has inherent bias that is included in the selection of patients for surgery, it is clear that there remains some truth in the adage that a chance to cut is a chance to cure.

In the past many surgeons have considered liver tumors with vascular invasion or involvement to be unresectable or at least that the risk involved with the surgery outweighs the benefit. Over the last several years there has been an evolution in surgical...
thought. Many surgeons now consider vascular resection in order to achieve negative margins for resection of hepatic malignancies, including hilar cholangiocarcinoma, as well as other primary or secondary liver malignancies. Resections may include resection of the portal vein (PV), hepatic artery, inferior vena cava (IVC), or hepatic veins and may require conduits for vessel reconstruction. Techniques to control hepatic vascular inflow and outflow must be used; adequate preoperative imaging needs to be obtained to ensure appropriate uninvolved vasculature can be found for clamp placement, anastomosis, and subsequent reestablishment of flow. Improving outcomes has made vascular resection in hepatic malignancy more frequent and successful at centers with experience in these techniques.

General guidelines for liver resections suggest a future liver remnant (FLR) of greater than 20% be obtained to avoid complications of postoperative liver dysfunction. Volumetric assessment of the FLR by preoperative imaging is a key component in planning resections that include vascular reconstruction. With vascular resection and the potential increased ischemic injury to the remnant liver, an FLR of 40% is preferred, though not always obtainable. Preoperative PV embolization (PVE) is an important adjunct to improve outcomes. In cases with borderline FLR or when extremely complex vascular reconstructions may be required, PVE of the side of the liver ipsilateral to the tumor should be performed 4 to 6 weeks before resection to allow hypertrophy of the remaining liver. In many cases that require vascular reconstruction, PVE is not necessary, however, because the involvement of vessels by tumor may create an atrophy/hypertrophy complex that favors resection. The role of preoperative biliary drainage of the FLR in cases with biliary obstruction is controversial. The authors’ own practice in cases of biliary obstruction is to drain the FLR until bilirubin is less than 2 mg/dL before proceeding with resection; however, this practice may increase the risk of perioperative infectious complications and is not uniform across centers.

PORTAL VEIN RESECTION

- It was first described in the West in 1990 by Blumgart for hilar cholangiocarcinoma. Variations in anatomy of the PV can make reconstruction challenging, so thorough assessment with preoperative imaging is necessary.
- Vein grafts can come from the left renal vein, gonadal vein, saphenous vein panel grafts, or resected hepatic veins from the side of the liver removed.

PV resection with hepatectomy was first described in the West in 1990 as a method to achieve negative margins and complete tumor resection for hilar cholangiocarcinoma by Blumgart. This method was met with skepticism at that time as surgeons thought that the risk of such a procedure did not justify the outcome. Over time, more centers published successful results with combined hepatectomy with PV resection; the technique was used to obtain complete resection and increase the number of resectable patients with cholangiocarcinoma or gallbladder adenocarcinoma. In 1997 Klempnauer and colleagues reported the first combined right trisectionectomy and PV resection in the West, and later in 1999 Neuhaus and colleagues described a no-touch en bloc resection technique for hilar cholangiocarcinoma including PV resection with excellent outcomes. PV resection is now the most common vascular resection performed for hilar cholangiocarcinoma and has become an accepted if not uniformly applied technique.

Outcomes with PV resection in current studies are similar to hepatic resection without PV resection with comparable morbidity and mortality. The most recent reports have shown improvements in perioperative mortality from 8% to 33% in early
studies in the 1990s and early 2000s to reports of mortality of 0% to 2% more recently.15,17–27 The reasons for improvement in outcome are multifactorial and include not only improved surgical planning and technique but also improved perioperative management, including the use of PVE. The primary goal in obtaining a successful oncologic outcome is the achievement of an R0 resection with or without PV resection. It is clear that survival in patients resected, even should they require PV reconstruction, is longer than those who are deemed unresectable. The use of vascular resection has increased the number of resectable and, therefore, curable patients, both by virtue of patients undergoing resection of the PV as well as those patients who are initially thought to require PV resection but are found at surgery to be resectable without vascular reconstruction. Without the surgeon being at least prepared to perform the vascular resection, those patients would not have been offered surgery. Long-term survival when using PV resection depends entirely on the ability to achieve negative margins. Earlier studies comparing PV resection to resection alone showed a decrease in long-term survival, but these results seemed more related to the ability to achieve negative margins than the issue of PV resection alone.19 Several studies demonstrate patients undergoing combined hepatectomy and PV resection with negative margins have similar outcomes to patients with negative margins undergoing hepatic resection alone.11,13,16,28 However, the presence of intraluminal tumor or positive margins does have a negative effect on survival.26

The potential for resection must be assessed preoperatively with imaging, including either a triphasic computed tomography (CT) or MRI to assess the extent of vessel involvement and confirm that there is an accessible PV segment above and below the tumor for anastomosis. Intraoperatively the distal PV on the liver remnant side must be free of tumor before anastomosis. In general, a minimum of 0.8 to 1.0 cm of PV before segmental branching of the left PV is required after right hepatectomy or trisectionectomy in order to have room for clamp placement and anastomosis. For left-sided resections, the right PV may be the target for anastomosis; but often the resection requires extension, and the right posterior sectoral branch becomes the target for anastomosis. Portal venous anatomy as well as the position of the hepatic artery segmental branches in relation to the PV branches is more variable on the right, and the surgeon must be very aware of the relative positions or risk catastrophe.29–31 Preoperative imaging along with intraoperative identification of vessel position is a key part of the procedure.

Primary end-to-end PV anastomosis is preferred rather than the use of grafts if possible. Complete mobilization of the proximal main PV down to the level of the pancreas during the lymphadenectomy facilitates later resection and anastomosis. Anastomosis of the main to left PV can almost always be performed without the use of a graft (Figs. 1 and 2), frequently before liver transection because the course of the left PV is accessible before liver division. However, if there is likely to be undue tension or there is difficulty with access, the vein resection and anastomosis can be performed after the liver is transected. After transection and specimen removal, the access is excellent and the liver can be rotated down to take tension off of the anastomosis. On a left-sided resection with reconstruction of the right PV or right posterior sectoral branch of the PV, it has been the authors’ experience that the liver requires transection before the portal venous resection and reconstruction. If primary anastomosis is not possible, many potential autologous conduits are available, including left renal vein, superficial femoral vein, hepatic vein (from resected liver), jugular veins, or saphenous vein modified to a spiral graft.17–21,32,33 If the native vein is unable to be used, synthetic or cryopreserved grafts can be used but, if possible, are avoided because of the risk of thrombosis and infection.
HEPATIC ARTERY RESSECTION

- This method is growing in frequency with improved techniques in arterial reconstruction from live-donor liver experience as well as utilization of arterial reconstruction in pancreaticoduodenectomy (PD) for malignancy.
- Similar to early reports of portal venous resection, there is increased morbidity with the procedure with no proven survival benefit.
- Increasing experience and improved techniques with the addition of microsurgery have improved short-term outcomes and may make arterial resection a valuable part of achieving long-term survival.

Although not yet considered mainstream, improving options for chemotherapy have increased the interest in hepatic arterial resection and reconstruction for malignancy in PD, whereby technical issues of reconstruction of the proximal hepatic artery at the level of the gastroduodenal artery are less challenging but the biological behavior of the tumor has remained dismal. In the pancreas setting, technical success of arterial

Fig. 1. In hilar cholangiocarcinoma, the left PV can be dissected out above the tumor with the main PV dissected out and mobilized to the pancreas. Duct, common bile duct; LHA, left hepatic artery; LPV, left PV; PV, main PV.

Fig. 2. The tumor in Fig. 1 has been resected with a right trisectionectomy with bile duct resection and PV resection. The main PV has been anastomosed to the left PV. The segment (Seg) 2 and segment 3 ducts will later be implanted into a Roux-en-Y limb. LHA, left hepatic artery; LPV, left PV; PV, main PV; R Hep Vein, right hepatic vein.
reconstruction is less of an issue because of the size of the vessels reconstructed and also because there is a lesser physiologic insult that occurs more with PD than occurs with extensive liver resection. Improvement in chemotherapeutic options for hilar cholangiocarcinoma has not been as robust, but now hepatic artery resection is slowly being integrated into aggressive resection options for hepatic malignancies to try an increase negative margins during resection.28,34 Most commonly, cases of combined liver and hepatic arterial resection are performed for involvement of the hepatic artery at its bifurcation and are often performed in combination with PV resection with or with PD.

Preoperative imaging assessment is essential for planning both the need and options for reconstruction. Planned arterial resection with reconstruction of either the right or left hepatic artery or posterior branch of the right hepatic artery requires assessment of potential proximal and distal control sites and assessment of options for obtaining suitable grafts or swinging alternative inflow to the liver. If end-to-end primary anastomosis is attempted, the artery must be fully mobilized to avoid tension on the anastomosis. Alternative inflow, such as the gastroduodenal or left hepatic artery, are options; however, careful attention to anatomic variation and preservation of length of those vessels is required during the initial portal dissection. Interposition grafts, including radial artery, splenic artery, or the saphenous vein, can be used (Fig. 3). Microsurgical techniques may be used when dealing with small sectoral (1–2 mm) arteries. Arterial reconstruction should follow PV reconstruction and typically is easier when done after liver transection and specimen removal has been completed.

When hepatic artery resection is required for tumor clearance, but technically reconstruction is simply not feasible, PV arterialization has been described as a final option. Direct end-to-side anastomosis of the hepatic artery to the PV or inferior mesenteric artery to the inferior mesenteric vein anastomosis can be performed. This method is not uncomplicated, however, and is associated with an increased risk of biliary complications, including biliary abscesses and portal hypertension. It has been advocated that if PV arterialization is used, later selective transcatheter embolization of the hepatic artery several weeks after the surgery should be done to prevent long-term issues of portal hypertension and future biliary complications.5

![Fig. 3. An extended left hepatectomy for hilar cholangiocarcinoma has been done. The hepatic artery has been resected with a saphenous vein graft placed from the proper hepatic artery to the right hepatic artery several millimeters before its division into anterior and posterior divisions. PV, main PV; RHD, right hepatic duct; SVG, saphenous vein graft.](image-url)
Because of the increased risk of complications, PV arterialization is only performed when no other options are available. The initial studies involving arterial resection did not demonstrate improved long-term survival: in contradistinction, long-term survival was worse, with a high mortality secondary to the operation itself and no survivors after 3 years. Reports of operative mortality ranged from 33.3% to 55.6%, with 1-year survival of only 17%. These outcomes were confirmed in a recent meta-analysis of 24 articles involving vascular resection for hilar cholangiocarcinoma that concluded with an increased morbidity and no proven survival benefit for arterial resection. However, centers with experience continue to push the boundaries of the possible and have now shown acceptable outcomes when combining arterial resection even with the addition of PV resection. In the largest current reported series Nagino and colleagues reported a cohort of 50 patients who underwent combined PV and arterial resections. Negative margins were obtained in 66% of these patients, with only one perioperative mortality. The 1-, 3-, and 5-year survival rates were 78.9%, 36.3%, and 30.3%, respectively. Microsurgical techniques for anastomosis were used, including 32 end-to-end anastomoses, 11 greater saphenous vein or radial artery interpositions, and 2 using the left or right gastric artery. Three patients were unable to be reconstructed.

Improved surgical techniques and experience, particularly with microsurgery, seem to have potential to improve these short-term outcomes, however improvement in long-term survival awaits improvements in adjuvant therapies. In the authors’ own practice, they will consider arterial resection and reconstruction in very select patients with hilar cholangiocarcinoma or gallbladder carcinoma. The authors’ unpublished results to date, in a mixed cohort of patients with hilar cholangiocarcinoma and gallbladder adenocarcinoma, demonstrate that the procedure can be done with technical success with an acceptable 4% operative mortality but that long-term survival remains elusive with a 5-year survival of only 21% (Alan Hemming, MD, unpublished data). Arterial resection in the setting of hepatic malignancy should likely be considered in only select patients at experienced centers. Widespread utilization of this approach awaits improvements in adjuvant therapy.

HEPATIC VEIN/INFERIOR VENA CAVA RESECTION

- IVC and high hepatic vein involvement have traditionally been contraindications to resection.
- Resection with vascular reconstruction has improved outcomes over chemotherapy.
- Techniques for complex resection include in situ cold perfusion, ante situm, and ex vivo resection.

Patients with tumors involving the IVC or hepatic veins have limited options for treatment with chemotherapy or interventional radiology. Survival without surgical treatment is typically less than 1 year. However, with techniques ported from liver transplant along with improved techniques for liver resection and perioperative management, tumors involving the IVC and hepatic veins are now considered resectable in select patients with acceptable morbidity and mortality. Including venous resection/reconstruction with liver resection is now accepted for most liver tumors, including hepatocellular carcinoma, cholangiocarcinoma, and colorectal metastasis, although the extent of vascular reconstruction and need for cold perfusion techniques remain open for discussion.

The technique for resection depends on the extent of involvement of the IVC or hepatic veins and location of the tumor. Options for vena caval involvement alone include primary resection, patch reconstruction, or complete replacement of the
vena cava with a synthetic or biological graft. If there is minimal IVC involvement, a side-biting clamp can be used to preserve caval flow and reconstruction can be done primarily or with a patch.44–47 For larger degrees of involvement, that is, not involving the hepatic veins or IVC at the hepatic vein confluence, the vena cava can be clamped below the level of the hepatic veins to occlude flow through the retrohepatic IVC, while preserving portal inflow and hepatic venous outflow. In this technique, most of the liver parenchymal transection can be completed and the hepatic veins of the planned resection side of the liver segment divided, exposing the IVC below. Once the IVC above and below the tumor involvement is exposed, clamps are placed and the liver resection completed along with caval resection, leaving the IVC ready for reconstruction. Resection of portions of the IVC up to approximately 3 to 4 cm can be resected with primary end-to-end repair still possible. Larger defects can be reconstructed using 20-mm Gore-Tex (W.L. Gore & Associates, Inc, Newark, DE) graft, autologous peritoneum,14 or bovine pericardium if needed (Fig. 4).48

Tumors that involve the IVC at the hepatic confluence require total vascular exclusion (TVE) with occlusion of both portal venous and hepatic arterial inflow as well as occluding the IVC above and below the hepatic veins. TVE is considered to be more damaging to the liver than simply portal inflow clamping, given the lack of hepatic venous backflow from the IVC and hepatic veins.49 In order to avoid ischemic damage to the liver, as much of the liver resection and exposure of the IVC that can be done should be done before placing the clamps for TVE. The clamp placement sequence for TVE is in the sequence of infrahepatic cava, then PV and hepatic artery,

---

**Fig. 4.** (A) CT demonstrating tumor extending to the IVC at the hepatic vein confluence. RA, right atrium; T, tumor. (B) Intraoperative picture of the patient shown in (A). The liver has been divided exposing the tumor around the IVC. Control of the suprahepatic IVC required sternotomy with intrapericardial control. Left lobe, left hepatic lobe; T, tumor. (C) The case in (B) with 20-mm ringed Gore-Tex graft used to reconstruct the IVC. Left lobe, left lobe of liver; RA, right atrium. (From [B] Hemming AW, Mekeel KL, Zendejas I, et al. Resection of the liver and inferior vena cava for hepatic malignancy. J Am Coll Surg 2013;217(1):117, with permission; and [C] Hemming AW, Mekeel KL, Zendejas I, et al. Resection of the liver and inferior vena cava for hepatic malignancy. J Am Coll Surg 2013;217(1):118, with permission.)
and lastly suprahepatic IVC. Clamps can be repositioned as needed on the IVC to isolate only hepatic veins if only hepatic veins require reconstruction.

For tumors involving the hepatic vein confluence and vena cava where simple resection is not possible, options include in situ cold perfusion, ante situm, and ex vivo techniques. These procedures involve TVE and potentially require the use of venovenous bypass or alternate strategies to maintain cardiac return if patients cannot tolerate clamping of the vena cava after volume resuscitation. In situ cold perfusion may be used if the length of ischemia is expected to extend past 45 minutes to an hour. Cold perfusion may be done in situ or ex vivo and improves the ability of the liver to tolerate ischemia and allows resection to be completed in a bloodless field.43,50–52

For better exposure of the area around the hepatic veins, in situ cold perfusion can be modified to an ante situm technique in which the suprahepatic vena cava is divided and movement and rotation of the liver forward allows better access to the hepatic venous/caval confluence.53 This method can be combined with division of the infrahepatic IVC below for even more rotation of the liver up into the operative field and improved access. Compared with TVE alone, cold perfusion of the liver decreases the ischemic injury.

Ex vivo resection gives the ideal access and can also be performed for tumor involvement of vascular structures requiring complex reconstruction. The ex vivo technique interrupts and transects major inflow and outflow, as well as the bile duct, to remove the liver from the abdomen for cold perfusion on the back table. The resection is completed on the back table before reimplantation of the liver, similar to a partial liver graft transplant.38 In ex vivo cases, the IVC may be reconstructed with a Gore-Tex graft with hepatic vein branches reimplanted into the Gore-Tex.

When venovenous bypass is used during caval clamping to decrease venous pressure and maintain cardiac return, outflow cannulas are placed in the femoral vein and PV and inflow into the right jugular or axillary vein. Cannulas can be placed via the open or percutaneous technique, depending on surgeon preference. An alternative to venovenous bypass to maintain cardiac return and portal venous decompression is to place both an IVC graft and temporary portacaval shunt during the time that the liver is ex vivo. The resected/reconstructed liver can then be implanted into the Gore-Tex graft and the temporary shunt taken down to perform the portal venous anastomosis. In cases when the tumor has no IVC involvement and needs only hepatic vein reconstruction, the hepatic veins are controlled and divided with maintenance of IVC flow. A temporary portacaval shunt is created to decompress the splanchnic circulation and avoid bypass. The use of bypass does increase potential complications, including venous thromboembolic events and increased length of stay, and has the potential for vascular complications or air embolus with increased need for blood transfusions. Bypass does not, however, seem to increase the risk of renal injury or need for dialysis over clamping and may help in more complex cases.54–57

The in situ cold perfusion techniques offer the advantage of keeping the PV and hilum intact as compared with ex vivo perfusion.43 Perfusion is instituted through a small incision in the PV above the portal clamp or via the PV branch on the resection side. During the infusion of the cold perfusate, the effluent is removed via a venotomy in the IVC or hepatic veins that can be repaired after completion of the resection/reconstruction before restoration of flow.

Cold perfusion is given with standard preservations solutions, including University of Wisconsin (UW) solution or histidine-tryptophan-ketoglutarate. UW solution has high potassium content, and should be flushed out of the liver before reperfusion of the liver. At the authors’ institution, they use UW as their perfusion solution and then flush with chilled 5% albumin or Ringers lactate solution.
For tumors that involve more extensive sections of the hepatic veins, or have hepatic confluence and hilar involvement, ex vivo resection is used. Before removal of the liver, the tumor must be assessed for resectability. A sternotomy with opening of the pericardium may be needed for better visualization of the IVC and tumor. Once a tumor is deemed resectable, the hilum is dissected and cholecystectomy performed. The infrahepatic IVC is dissected down to the renal veins, and the liver is mobilized. The suprahepatic IVC is then dissected free, and phrenic veins are divided. Depending on tumor involvement, clamps are placed in sequence: the artery is transected typically at the level of the gastroduodenal artery, PV 1.5 to 2.0 cm below the bifurcation, and the bile duct taken sharply at 1.0 to 1.5 cm below the bifurcation. The suprahepatic IVC may be transected below the diaphragm or clamped in the intrapericardial portion if more distance from the tumor is needed. The IVC is then transected leaving as much length behind as possible, and the liver is taken to the back table.

After the liver is removed, it is placed in an ice bath and cold perfusion initiated via the PV. The hepatic artery and bile duct are also hand flushed with preservation solution. The resection is then performed using standard liver resection techniques or can be done sharply with a knife. Flushing the liver after resection helps identify potential leaks that are repaired before reimplantation. Complex reconstructions can be performed in multiple methods depending on what remains after resection (Fig. 5).

![Fig. 5. (A) Centrally placed cholangiocarcinoma involving IVC and all hepatic veins. Note that tumor extends to branches of right hepatic vein (RHV) that will need reconstruction. The 2 arrows show the tumor extending to branch point of RHV; 3 arrows show the tumor involvement of IVC. (B) Bovine pericardial fence placed to plastied branches of RHV during ex vivo procedure. BP, bovine pericardium. (C) Bovine pericardial fence implanted into Gore-Tex IVC graft that will subsequently be reimplanted in the patient. Three arrows show branches of RHV. (From [A] Hemming AW, Mekeel KL, Zendejas I, et al. Resection of the liver and inferior vena cava for hepatic malignancy. J Am Coll Surg 2013;217(1):117, with permission; and [B] Hemming AW, Mekeel KL, Zendejas I, et al. Resection of the liver and inferior vena cava for hepatic malignancy. J Am Coll Surg 2013;217(1):119, with permission.)](image-url)
Hepatic veins are reimplanted into the IVC, reconstructed with multiple vein grafts, or plastied together in groups for reconstruction.\textsuperscript{58} If needed, the IVC is typically replaced using a 20-mm Gore-Tex tube graft.

After completion of resection and reconstruction, the resultant liver segment is reimplanted. The anastomoses are performed in a similar fashion to a standard partial liver transplant. The suprahepatic caval anastomosis is completed first, followed by the infrahepatic anastomosis. Before completion of the infrahepatic anastomosis, the liver is flushed free of UW solution if used. The portal venous anastomosis is completed next; the liver is reperfused sequentially starting first with the suprahepatic clamp removal and then the infrahepatic clamp removal; then the portal flow is reestablished. The arterial anastomosis is performed typically after the liver has been reperfused with portal flow and hemostasis has been obtained. The last anastomosis completed is the biliary anastomosis, done either duct to duct or with a Roux-en-Y choledochojejunostomy if the duct ends do not come together without tension.

It is clear in multiple studies that caval and hepatic vein resection, particularly with ex vivo resection and subsequent auto transplantation of the liver, has definite increased morbidity and mortality.\textsuperscript{38,52,58–64} However, for these patients resection is the only possibility for cure. Additionally, those patients who are resected have longer median survival than those who are not resected. Successful long-term survival in a small number of patients is possible,\textsuperscript{52,60} although patient selection is important to minimize postoperative mortality.\textsuperscript{65–68} The largest series to date of combined liver and IVC resection for hepatic malignancy includes 60 patients over a 16-year period.\textsuperscript{38} In that series, 8 patients underwent primary reconstruction, including 3 with hepatic vein reimplantation, one of which required an ex vivo approach to reimplant the hepatic veins, though the IVC was reconstructed primarily. Fourteen patients had defects greater than 5 cm that were repaired with a patch of autologous vein, bovine pericardium, or Gore-Tex. Thirty-eight patients required full reconstruction of the IVC with a Gore-Tex graft, including 5 ex vivo resections and 8 with cold perfusion. Perioperative mortality was 8\% and 3-year survival 35\%.\textsuperscript{38} In another similar series published by Malde and colleagues,\textsuperscript{58} 35 patients underwent combined liver and IVC resection over 15 years. Thirty-four of these required total vascular isolation, with 13 using cold perfusion, 3 ante situm, and 6 ex vivo techniques. Among these, 23 had primary or patch repair of the cava and 12 had reconstruction with an interposition graft. The perioperative mortality in this series was 11.4\% and morbidity 40.0\% with an actuarial 5-year survival of 37.7\%. Another recent study by Azoulay and colleagues\textsuperscript{51} published a series of 391 patients who underwent TVE with venovenous bypass for complex liver resections. Seventy-seven of these had in situ cold perfusion, and 35 had hepatic vein or IVC reconstructions. The 90-day mortality was 19.5\% (15 patients) and seemed to be significantly related to a maximum tumor size of greater than 10 cm, Charlson Comorbidity Index of 3 or more, and postoperative liver insufficiency on multivariate analysis. The 5-year survival rate in this group was 30.4\%.

Table 1 shows several series and reports of hepatic and IVC resections involving ex situ liver surgery. The reported 5-year survival for these groups was 20\% to 30\%, if long-term survival was achieved and reported. Several of the patients in early studies did require salvage liver transplantation for liver failure, which carried a high mortality rate; all but one patient reported had tumor recurrence within 1 year after transplant. Salvage liver transplantation is, therefore, not recommended (see Table 1).\textsuperscript{42,60,69–74}
<table>
<thead>
<tr>
<th>Author</th>
<th>Dates</th>
<th>Indications</th>
<th>TVE</th>
<th>In Situ</th>
<th>Ante</th>
<th>Ex Vivo</th>
<th>90-d Mortality</th>
<th>1-y Survival</th>
<th>3-y Survival</th>
<th>5-y Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oldhafer</td>
<td>1988–1998</td>
<td>1° or 2° malignancy, FNH</td>
<td>24</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>23</td>
<td>8</td>
<td>NR, only FNH pts alive at 5 and 9 y</td>
<td></td>
</tr>
<tr>
<td>Lodge</td>
<td>1995–1998</td>
<td>CLM</td>
<td>6</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>NR</td>
<td></td>
</tr>
<tr>
<td>Hemming</td>
<td>1996–2012</td>
<td>CLM, HCC, CHL, GIST, HPBST, SCC</td>
<td>60</td>
<td>8</td>
<td>NR</td>
<td>6</td>
<td>5</td>
<td>89%</td>
<td>NR</td>
<td>35%</td>
</tr>
<tr>
<td>Zhang</td>
<td>1999–2008</td>
<td>Hemangioma, CHL</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>2 pts still alive at publication</td>
<td></td>
</tr>
<tr>
<td>Forni</td>
<td>NR</td>
<td>CLM, RCC</td>
<td>4</td>
<td>—</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>Fourth pt died of recurrence at 16 mo</td>
<td></td>
</tr>
<tr>
<td>Malde</td>
<td>1995–2010</td>
<td>CLM, HCC, CHL</td>
<td>34</td>
<td>35</td>
<td>13</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>75.9%</td>
<td>58.7%</td>
</tr>
<tr>
<td>Gruttandauria</td>
<td>2003–2004</td>
<td>CLM</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>First pt alive at 23 mo, second NR</td>
<td></td>
</tr>
<tr>
<td>Wang</td>
<td>2008–2010</td>
<td>Echinococcal cyst</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>83.3%</td>
<td>NR</td>
</tr>
</tbody>
</table>

Abbreviations: CHL, cholangiocarcinoma; CLM, colorectal liver metastasis; FNH, focal nodular hyperplasia; GIST, gastrointestinal stromal tumor; HCC, hepatocellular carcinoma; HPBST, hepatoblastoma; NR, none reported; pt, patient; RCC, renal cell carcinoma; SCC, squamous cell carcinoma.

Data from Refs.43,48,59,61,69–72
SUMMARY

- Vascular resection is a growing trend in hepatic surgery for malignancy with improved outcomes over time.
- One must be able to achieve adequate margins for success, which may involve PV, hepatic artery, IVC, or hepatic vein resection and reconstruction with multiple techniques.
- In situ cold perfusion, ante situm, and ex vivo resections offer a technically challenging option to tumor resection in select patients.

With current relatively ineffective options for chemotherapy and nonsurgical intervention for patients with vascular involvement of hepatic tumors, vascular resection has become an increasingly used option in combination with hepatic resection to obtain tumor clearance. Preoperative imaging is essential to determine the potential for complete resection and for operative planning for vessel reconstruction. With increasing experience, a small number of centers have significantly improved outcomes and decreased mortality in the last 2 decades. Although vascular reconstruction is associated with an increased morbidity and mortality, it allows a potential curative approach in otherwise incurable patients and should be considered in select patients.

REFERENCES


