How I do it

A technique for safely teaching major hepatectomy to surgical residents

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Abstract

In this era of combination chemotherapy and biologic treatment, the ability to downsize tumors that were previously unresectable will increase the need for major hepatic resections. This makes teaching consistent surgical approaches to these difficult cases imperative. Herein we outline a standardized surgical approach to right hepatectomy, which allows the procedure to be divided into a series of well-defined technical maneuvers. Preoperative preparation and communication with anesthesia to ensure a low central venous pressure is emphasized. A right hepatectomy is described by dividing the procedure into 5 steps: (1) initial mobilization and intraoperative ultrasound, (2) cholecystectomy and extrahepatic inflow occlusion and, (3) posterior mobilization and extrahepatic venous outflow ligation, (4) parenchymal transection, and (5) hemostasis and closure. Such techniques, once adopted by the surgeon, will allow for controlled parenchymal transection, minimal need for inflow occlusion to the liver remnant, and safe and efficient hepatectomy. © 2008 Elsevier Inc. All rights reserved.

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The ability to teach advanced surgical techniques remains a challenge wherein developing consistent approaches to difficult cases is imperative. We outline a standardized surgical approach to right hepatectomy, which allows the procedure to be divided into a series of well-defined technical maneuvers. Each of these maneuvers is relatively simple to accomplish, which allows for independent surgical education of surgical trainees. Intraoperative indecision is minimized, conserving surgical time, blood loss, and subsequent patient morbidity. Our technique of right hepatectomy builds on the work of previous investigators \cite{1,2}. As in previous descriptions of complex surgical procedures such as pancreatoduodenectomy and extended hepatectomy \cite{2,3}, we have divided the resection portion of the procedure into 5 steps, each of which is relatively simple, yet when performed in series enables the completion of a difficult surgery. Clearly, in the new era of systemic chemotherapy for metastatic colorectal adenocarcinoma, dramatically reducing tumor volume \cite{4–6}, an understanding of liver anatomy, and techniques for safe surgical resection will become increasingly more important. Although multiple studies have shown the safety and effectiveness of hepatic resection \cite{2,5,7–11}. It is our belief that an emphasis on safety, appropriate preoperative preparation, and attention to specific intraoperative maneuvers will allow the new generation of surgeons to be able to perform major hepatic resections safely and expeditiously.

Preoperative Preparation

Safe performance of hepatic resection requires a consistent team approach. In particular, explicit and clear communication between the anesthesiologist and the surgeon is a must. A constant team approach—using the same anesthesiologist and nurses as much as possible for each hepatectomy—helps to minimize errors. In particular, preoperative communication with the anesthesiologist the night before surgery is helpful. It is critical that a combination of patient positioning (15° Trendelenburg) and judicious fluid management (1 mL/kg/h), targeting a low central venous pressure (CVP) ($\leq 8$ cmH\textsubscript{2}O and preferably closer to 1 cmH\textsubscript{2}O), be maintained at the start of general anesthesia and through the initial portions of the dissection. Maintaining a low CVP allows for Trendelenburg position during the parenchymal transection portion of the case, which can prevent venous air embolism \cite{12}. Often the patient receives voluminous fluid in the preoperative holding area, needlessly increasing the CVP to provide a buffer for the presumed risk of massive blood loss that may occur with major hepatectomy; however, distension of the hepatic veins and
vena cava as a result of euvolemia or even hypervolemia puts the patient at significant risk for bleeding [13]. Although outside the scope of this article, subsequent anesthetic induction techniques can be altered appropriately to prevent the patient from experiencing an unnecessary decrease in their blood pressure and requiring a fluid bolus. Judicious management of fluid and an epidural catheter allows for maintenance of an adequate mean arterial pressure without compromising the low CVP.

**Procedure**

The patient is placed supine, with a single roll under the costal region. The abdomen may be opened via multiple approaches; we prefer a bilateral subcostal incision, with a vertical extension if needed. The Thompson-Farley retractor (Thompson Surgical Instruments, Traverse City, MI, USA) works very well for this procedure because it provides adequate traction to elevate the costal margin away from the liver, and it is not limited by a rigid and minimally adjustable framework of a ring. The incision and retraction must be appropriate to allow adequate exposure and manipulation of the hepatic parenchyma as well as exposure of the hepatic veins to prevent disastrous bleeding. Clear communication with anesthesia to ensure a low CVP is essential. Attention toward resection can begin after necessary adhesiolysis and adequate exploration has been completed to ensure that no extrahepatic disease is present.

**Initial mobilization and ultrasonography**

The falciform ligament is identified and the umbilical vessels are ligated adjacent to the hepatic parenchyma with a 0 silk tie, the umbilical ligament then is resected. The avascular attachment to the anterior abdominal wall is divided from caudad to cephalad at the midpoint between the hepatic parenchyma and the abdominal wall. At this point, intraoperative ultrasonography should be performed to assess the anatomic relationships of the lesion(s) and to ensure that no previously unsuspected findings on cross-sectional imaging would contraindicate hepatectomy. By using a 7.5-MHz probe (small t-probe or finger probe), the surgeon first should identify and examine the caudate lobe. The junction of the right, middle, and left hepatic veins with the inferior vena cava is identified next. After this, a thorough counterclockwise parenchymal examination from segment 8 to segment 2 is conducted. The probe then is brought back to the junction of the hepatic veins and drawn inferiorly until the pars umbilicularis of the portal vein is identified. The presence of a right lobe mass(es) is noted as well as their relationship to the anterior and posterior branches of the right portal vein, and the right and middle hepatic veins. After completing ultrasonography, the left triangular ligament should be taken down as necessary to prevent traction injury to the spleen. At this point the inferior portion of the right triangular ligament should be mobilized from the inferior portion of segment 7 around segment 6 and to the level of the inferior vena cava.

**Cholecystectomy and extrahepatic inflow occlusion**

At this point a finger may be passed through the foramen of Winslow into the lesser sac. The avascular portion of the lesser omentum is opened with electrocautery just medial to the hepatoduodenal ligament. An umbilical tape then is passed around the porta hepatis and a Rummell clamp is prepared in the event that a Pringle maneuver is necessary. The mesentery over the common bile duct is scored and the cystic duct is dissected free. A 2-0 tie is passed about the cystic duct and left in place with a mosquito clamp. The cystic artery is identified and ligated with a 3-0 silk tie. The gallbladder then is taken down from the fundus to the cystic duct. On confirmation that the tie is on the cystic duct, this structure is ligated and the gallbladder is removed from the field. If necessary, hemostasis in the gallbladder fossa may be achieved with the argon-beam coagulator. After this the porta hepatis is dissected appropriately. The cystic artery often easily is traced to its origin on the right hepatic artery. Once the right branch of the hepatic artery is identified a bulldog clamp is placed on this vessel briefly and Doppler flow is confirmed in the left hepatic artery at the hilar plate at the junction of segment 4b and segment 3. If flow is normal within the left hepatic artery, then the right hepatic artery is ligated proximally with a 4-0 Prolene suture (Ethicon Products, Summerville, NJ, USA) and a small titanium clip. Distally, the artery may be tied with a 3-0 silk that is secured further with a clip placed distal to the tie. At this point the portal vein is dissected free. The bifurcation is identified and the right branch may be ligated by using an articulated stapling device with a vascular load if the portal vein is mobilized easily. If this is not possible the right portal vein should be divided between vascular clamps and oversewn with 4-0 Prolene. (The use of a simple tie or clips on the portal vein should be avoided because dislodgement will produce bothersome bleeding.) At this point a very clear demarcation of the right lobe should appear. If demarcation does not occur, further exploration in the porta hepatis for an accessory right hepatic artery should be undertaken. It also is prudent to look for an accessory posterior branch from the portal vein to the right lobe of the liver. After this the common hepatic duct is dissected to the level of the right and left bifurcation. The main branch of the right hepatic duct then may be divided with a 3-0 Prolene suture ligature.

**Posterior mobilization and extrahepatic venous outflow ligation**

After inflow occlusion to the right lobe has been achieved, posterior dissection generally is much easier because the posterior communicating veins from segments 6 and 7 become somewhat flaccid. At this point it generally is easiest to proceed along the anterior surface of the inferior vena cava from caudad to cephalad. These normally small branches, which we refer to as the short hepatics, can be double ligated with titanium clips and transected with a Metzenbaum scissors (V. Mueller, McGraw Park, IL, USA) (Fig. 1). In the majority of cases this dissection is performed easily and quickly to the level of the right hepatic vein, with care taken to elevate the liver gently and transect the right triangular ligament from caudad to cephalad as necessary, however, in some instances a large accessory right hepatic vein may be encountered, which changes the plan of dissection (see section on Right accessory hepatic vein). Once the right hepatic vein is reached posteriorly, attention then is
directed to complete division of the right triangular ligament anteriorly. After all avascular tissue is divided, the ligamentous attachment between the diaphragm and the inferior vena cava should be dissected carefully with a right-angled clamp and electrocautery. Often the junction of the right phrenic vein and the right hepatic vein are encountered and ligation of the right phrenic vein near the right hepatic vein affords significant mobilization. With meticulous dissection the extrahepatic portion of the right hepatic vein can be encircled. The appropriate motion for dissection is straight caudad along the anterior surface of the inferior vena cava. The thin areolar tissue between the vena cava and the space between the right and middle hepatic veins are divided quickly and prior posterior mobilization prevents untoward bleeding. It cannot be overemphasized that careful division of the fibrous structures anterior to the right hepatic vein greatly assist in encircling the vein. Further, appropriate elevation of the right lateral border of the liver toward the midline prevents injury to the vena cava. Once the right hepatic vein has been encircled, gentle enlargement of this space with the right angle clamp is performed such that an articulated vascular stapling device can be placed around the right hepatic vein for ligation and division.

**Right accessory hepatic vein**

Posterior dissection is considerably more difficult if a large accessory right hepatic vein is encountered. The presence of such a vessel generally can be determined from high-quality preoperative axial hepatic imaging (Fig. 2). In this situation, we recommend caudal to cephalad dissection as far as possible because there often are small venous branches caudal to this structure. Attention then is directed to dissection of the extrahepatic portion of the right hepatic vein. The right hepatic vein is encircled in the same method as described earlier; however, cautious dissection and retraction of the liver is imperative because the inability to axially rotate the right lateral portion of the liver to the anterior midline makes the possibility of injury to the inferior vena cava greater. Once the right hepatic vein has been ligated, enough mobilization of the right lobe can be obtained to allow safe dissection of the accessory vein. It then can be encircled with a Kocher-Director clamp (Medsys s.a. Gembloux, Belgium) or a blunt right angle clamp. At this point we recommend staple ligation and division of this branch with an endovascular stapling device. The use of vascular clamps may facilitate safer dissection in this region and an array should be available immediately in case emergent hemostasis if required. Clearly, dissection on the vena cava at this point is assisted greatly by maintaining a low CVP.

**Parenchymal transection**

At this point the liver should be quite mobile, to the point that compression of any vessel to the right lobe can be accomplished between the hands of the surgeon on the left side of the table. It is important to note that torrential bleeding still may be encountered from large branches of the middle hepatic vein. It is warranted to reconfirm a low CVP intermittently throughout the procedure with the anesthesiologist. For additional hemostatic control, we place a Lin clamp (Tanaka Medical Instruments Co., Ltd., Tokyo, Japan) to the left of our transection line after the liver has been mobilized appropriately to prevent cross-flow bleeding from the middle hepatic vein and Glisson’s capsule (Fig. 3). After the Lin clamp is placed, Glisson’s capsule then is scored to a depth of approximately 4 mm (Fig. 4). This scoring will determine the actual line of division and prevent the parenchyma from fracturing in an uncontrolled fashion. Scoring is accomplished easily with a harmonic
scalpel. Before scoring, we place figure-of-eight sutures on either side of the line of demarcation at the anterior inferior portion of the liver along the gallbladder fossa using 0-chromic sutures on blunt needles. This allows for transection of the first 2 to 3 cm of the hepatic parenchyma without bleeding and gentle traction facilitates the process of scoring the liver. At this point major parenchymal transaction is to commence. With formal control of the inflow and outflow achieved as well as the placement of a Lin clamp, a variety of techniques can be used to formally transect the parenchyma. Formal inflow and outflow occlusion as well as the Lin clamp are extremely helpful in teaching residents because this allows for an extremely safe transection with minimal blood loss. We generally have used multiple firings of an endovascular stapler across the parenchymal structures because this is relatively rapid and the mechanistic action prevents dislodgement of the Lin clamp. This is performed in a layer-by-layer fashion and care should be taken not to attempt to staple too much tissue in any one firing (Fig. 5). The 60-mm/2.5-mm vascular load Autosuture stapler (Covidien, Norwalk, CT, USA) generally is turned upside down, with the lower blade used in lieu of a clamp to dissect through the hepatic parenchyma. If the lower blade encounters resistance it should be backed out and redirected gently. Once the blade has been inserted fully into the hepatic parenchyma the stapler may be fired. The firing characteristics of this stapler are well suited to this application because it does not need to close completely before stapling and transection of the hepatic parenchyma. The gentle manner in which this device closes prevents injury to thin-walled structures within the liver. Multiple firings are performed along the previously scored line in Glisson’s capsule. The stapler generally is placed anteriorly, then posteriorly. The right lobe generally can be divided in 10 to 12 firings of the stapler, allowing removal of the lobe with appropriate margins.

**Hemostasis and closure**

At this point bleeding generally is minimal, although some venous bleeding may be encountered that requires suture ligation. We recommend using a 2-0 Vicryl (Ethicon Products) on a large SH needle, and if possible including Glisson’s capsule within the ligation to prevent the stitch from pulling through the hepatic parenchyma. The size of this needle makes it easy to recover for the surgeon. If no surgical bleeding is present at this stage gentle pressure should be held on the raw surface of the liver with a clean laparotomy sponge. At this time the anesthesiologist should be instructed to begin to bolus the patient. This allows the surgeon to evaluate the raw surface of the liver for missed
venous lacerations and unsuspected bile duct injury. It also allows for normalization of the patient's volume status. We recommend a 1-L crystalloid bolus at this stage. After a period of 5 minutes of gentle pressure, the raw edge of the liver as well as the laparotomy pad should be inspected carefully for evidence of a bile leak. If present, the injured duct should be identified and appropriately repaired with fine PDS suture. If no evidence of a bile leak is present, the entire raw edge of the liver should be coagulated with the argon-beam coagulator. Gentle pressure again is held for a period of 5 minutes. After this the laparotomy pad again is removed and inspected carefully for evidence of bile staining. At this point we recommend covering the raw surface of the liver with a large sheet of Surgicel (Johnson & Johnson, Cincinnati, OH, USA). Any areas that stain through the Surgicel should be treated with the argon-beam coagulator. At this point a laparotomy pad is placed over the treated raw edge without pressure. This should be left in place for 10 minutes and checked periodically for evidence of bleeding. At the end of this period, the intravenous bolus should be completed. If the laparotomy pad is dry then closure may commence. If possible, an omental pedicle should be completed. If the laparotomy pad is not dry then a 19F, round, fluted drain near, but not in direct apposition to, the raw surface of the liver. Closure is accomplished in a standard fashion.

Summary

The described technique allows for a timely and safe hepatic resection. In particular, we believe that a low CVP and extrahepatic dissection first of the inflow followed by outflow prevents disastrous complications. After taking formal inflow to the right lobe it is considerably easier to mobilize the right lobe and particularly the short hepatics. This inflow-to-outflow technique also reduces hepatic engorgement from early venous division. The mobilization achieved from below makes formal division of the hepatic vein much easier, particularly for the trainee. The development of appropriate vascular stapling devices also has been of great significance in terms of dividing the hepatic veins. We strongly believe that the addition of the Lin clamp greatly enhances the safety of the parenchymal division because it allows the residents to move through this portion with near impunity. Finally, this technique obviates the need for a Pringle maneuver, leaving the remaining hepatic parenchyma to function normally throughout the period of parenchymal transection. This fact becomes more germane as patients receiving combination chemotherapy experience a reduction in tumor volume at the expense of sequelae of their therapy and the potential for increased postresectional morbidity from steatosis, steatohepatitis, and sinusoidal dilatation. [14].

References