Chapter 13
Laparoscopic Hepatectomy

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13.1 Introduction

Since the 2008 First International Laparoscopic Liver Consensus Conference, there has been a dramatic increase in minimally invasive liver resections reported worldwide [1]. As the field has evolved, laparoscopic major hepatectomies are also becoming more commonly reported and account for approximately 25% of reported minimally invasive liver resections. Overall, laparoscopic liver surgery has been demonstrated to be safe with a low postoperative mortality (0.3%) and rate of major complications (11%) [2]. The 2014 Second International Laparoscopic Liver Consensus Conference reviewed several studies which consistently reported that minimally invasive hepatectomy is associated with a decrease in hospitalization length of stay, improved postoperative pain, lower wound related complications, and reduced intraoperative blood loss compared to open hepatectomy [3]. Furthermore, minimally invasive techniques do not compromise oncologic outcomes and are associated with an improvement in time to return to intended oncologic therapy in patients with colorectal liver metastasis [4]. In the reported literature there has been no difference in margin status, recurrence rate, or overall survival following hepatectomy for primary or metastatic malignancies.

Several variations of the laparoscopic approach to hepatic resection have been described, including purely laparoscopic, hand assisted laparoscopic surgery (HALS), and the hybrid technique, in which the liver is mobilized laparoscopically

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and delivered through a small incision to complete the hilar dissection and parenchymal transection. Pure laparoscopic liver resection is the most commonly utilized approach (75%), followed by HALS (17%), with the hybrid technique being relatively uncommon (2%). A propensity score matched analysis from two high-volume centers found the HALS or hybrid techniques were not inferior with regards to morbidity or pain medication requirements compared to the pure laparoscopic approach for major hepatectomies [5]. While some surgeons advocate starting with a purely laparoscopic approach and converting to HALS or a hybrid technique when required, the authors prefer HALS as the initial procedure for planned laparoscopic hemi-hepatectomy as it facilitates mobilization, affords direct palpation of the liver parenchyma, and expediates ability to obtain vascular control if hemorrhage is encountered. The hand port may additionally be used to place and additional one to two trocars when not in use to facilitate progression laparoscopically [6].

13.2 Preoperative Assessment

At time of initial evaluation, it is paramount to remember that the indications for hepatectomy remain the same for both open and minimally invasive liver resection. For laparoscopic hepatectomy it is important to consider the patients overall health, comorbidities, ability to tolerate abdominal insufflation, risk of dense adhesions from prior surgery, and liver functional status.

Postoperative liver failure is a concern following both open and laparoscopic hepatectomy, particularly in patients with cirrhosis or liver damage secondary to chemotherapy. General recommendations to prevent postoperative liver failure from the INSTALL study reported that most experienced hepatobiliary surgeons require a functional liver remnant $\geq$40% [7]. INSTALL also found that most surgeons use a serum bilirubin cutoff of 2.0 mg/dL for minor ($\leq$3 segments) and an upper limit of 1.5 mg/dL for major (>3 segments) resections to avoid postoperative liver failure. For malignant lesions, the ability to adhere to sound oncologic principles must also be considered. Tumors abutting major vascular structures, perihilar cholangiocarcinoma, and bulky tumors that may be difficult to manipulate laparoscopically are best reserved for open surgery. Additional anatomic considerations including replaced or accessory hepatic arteries and location of the target lesion within the liver are important to consider, with superficial lesions in right lobe (segments V, VI, & VIII) and left lateral (segments II & III) locations most amenable to the laparoscopic surgical approach.

13.3 Laparoscopic Right Hepatectomy

13.3.1 Patient Positioning

The patient is placed in the supine position with both arms out. Alternatively, some surgeons prefer the French lithotomy position. Like an open major hepatectomy, an orogastric tube and Foley catheter are placed, as well as a central and arterial line for intraoperative monitoring. To accommodate for the steep rotation required during the laparoscopic approach, the patient should be secured to the table using a safety strap and footboard.

13.3.2 Trocar Insertion

The authors prefer to use hand assisted laparoscopic surgery (HALS) to approach a formal right hepatectomy. First, a small (6–8 cm) upper midline incision is made, and a hand port placed, such as the GelPort laparoscopic system (Applied Biomedical). Pneumoperitoneum established (≤15 mmHg) utilizing a trocar placed through the hand port. Under direct visualization two additional 12 mm and two 5 mm ports are placed using the configuration illustrated in Fig. 13.1a.

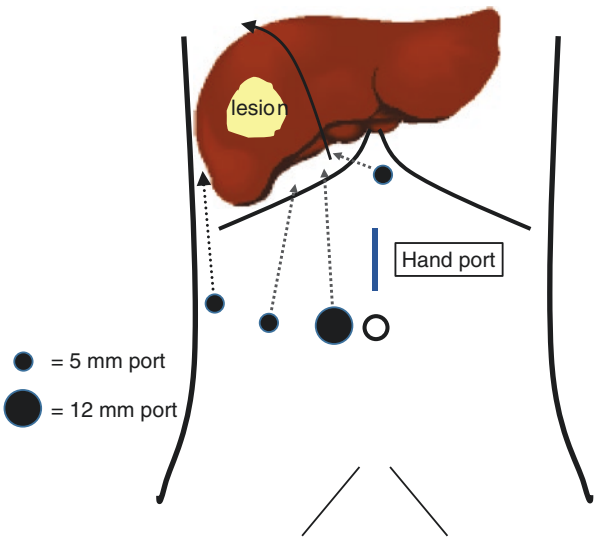

Fig. 13.1 (**a**) Port placement for laparoscopic hand assisted right hepatectomy

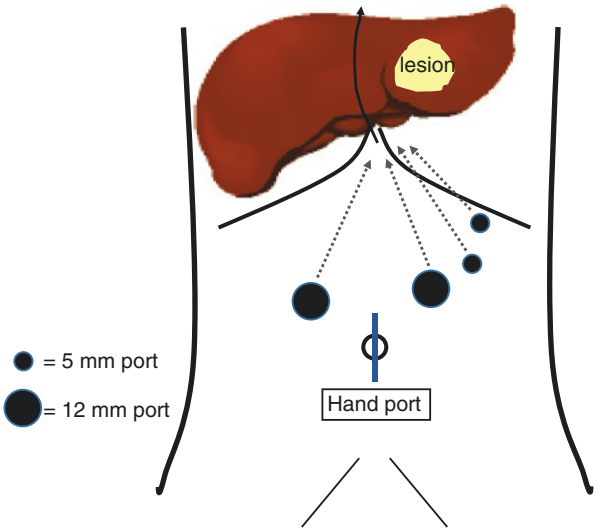

Fig. 13.1 (**b**) Port placement for laparoscopic hand assisted left hepatectomy

Troubleshooting: In the cirrhotic patient, care must be taken to avoid injury to periumbilical varices resulting from recanalization of the umbilical vein. If present, preferred trocar placement is infra-umbilical or lateral to the linea alba if supra-umbilical access is required. In the case of a petite patient (<68 inches) the hand port incision may also be moved to an infra-umbilical location. This hand port incision can also be rapidly extended if conversion to an open operation becomes required.

13.3.3 Liver Mobilization and Intraoperative Anatomical Assessment

First, the falciform is divided at the abdominal wall, leaving sufficient length to aid in retraction, and the round ligament is transected with a surgical energy device or laparoscopic stapler. Next, the right coronary and triangular ligaments are divided. Intraoperative ultrasound is used to assess the hilar structures and hepatic vein anatomy. The hepatic parenchyma should be assessed for any additional lesions and the precise location of the target lesion and its relationship to major vascular structures confirmed using color flow Doppler prior to proceeding with transection. For a right hepatectomy, the middle hepatic vein is used a landmark with the parenchymal transection plane marked with electro cautery lateral to the middle hepatic vein. For oncologic cases, wide margins should also be obtained. Following a complete laparoscopic ultrasound assessment, the plane of transection is scored along the liver capsule using electro cautery. The liver is further mobilized from the retroperitoneum by gently rotating the liver medially away from the inferior vena cava (IVC). The laparoscopic approach affords improved magnification and

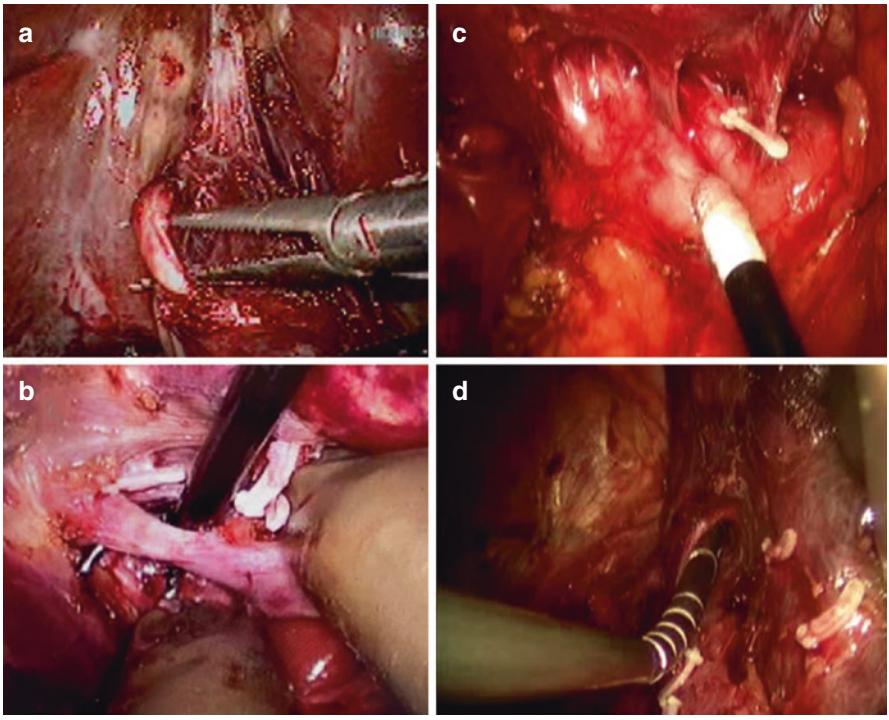

Fig. 13.2 (**a**) Right hepatic artery. (**b**) Right portal vein. (**c**) Short hepatic veins. (**d**) Inferior vena cava and right hepatic vein

exposure around the right adrenal gland and vena cava to facilitate identification of the Laennec capsule and Glissonian pedicle at the hilar plate. Using a caudal to cranial approach, the caval ligament is opened on the right, exposing the short hepatic veins arising from the IVC. These may be clipped with 5 mm hem-o-lock clips (Weck Closure System) or if small (<7 mm) can be taken using the LigaSure device (Medtronic). (Fig. 13.2c).

13.3.4 Hepatic Outflow Control

Following adequate mobilization of the liver the right hepatic vein is safely identified as it enters the retro-hepatic IVC. A window between the right and middle hepatic veins is carefully dissected. The right hepatic vein is encircled with umbilical tape (and eventually divided) at its confluence with the IVC using a laparoscopic stapler with a vascular load (Fig. 13.2d).

Troubleshooting: If exposure of the right hepatic vein is not optimal, division may be considered from an intraparenchymal approach following completion of parenchymal dissection.

13.3.5 Hilar Dissection

The round ligament remnant is used to retract the liver anteriorly toward the abdominal wall to facilitate exposure to the porta hepatis and the pars flaccida of the gastrohepatic ligament is opened, with care to avoid injuring an accessory or replaced right hepatic artery. An umbilical tape or vessel loop is placed through the foramen of Winslow to encircle the porta hepatis and may be used to perform a Pringle maneuver if required. Dissection of the right portal hilar structures begins with a standard laparoscopic cholecystectomy. After confirming a critical view of safety, the cystic artery and cystic duct are doubly clipped and divided. The cystic artery serves as a handle to expose the right hepatic artery. The right hepatic artery is secured and transected between two locking clips on the proximal aspect and a single clip distally (Fig. 13.1a). Next, the right portal vein is meticulously dissected circumferentially and transected with a laparoscopic stapler using a vascular load (Fig. 13.2b).

Troubleshooting: During the portal vein dissection, caution must be used to avoid tearing small branches draining from the caudate lobe. If the angle required for transection of the right portal vein cannot be safely obtained at this stage, an alternative approach is to use a laparoscopic vascular clamp, such as a Satinsky or bulldog, to control portal inflow and defer transecting the right portal vein until later in the parenchymal transection phase of the procedure.

13.3.6 Parenchymal Transection

As opposed to the anterior approach utilized in open hepatectomy, the laparoscopic major liver resection proceeds in a caudal to cranial fashion. This meticulous approachutilizes the improved laparoscopic magnification to optimally identify intraparenchymal structures for optimal division of the liver parenchyma. The superficial transection is started using an ultrasonic dissector and/or energy device such as the Harmonic scalpel (Ethicon), LigaSure (Medtronic), or Thunderbeat (Olympus) along the previously scored plane (Fig. 13.3c). The right hepatic duct is identified inside the liver parenchyma and transected using a laparoscopic surgical stapler. Deeper parenchymal dissection proceeds and bridging veins from the middle hepatic vein to segments V & VIII are encountered and divided with a vascular stapler load. Alternatively, some surgeons prefer the bipolar pinching forceps alone or in combination with a Cavitron ultrasonic surgical aspirator (CUSA). Like in an open hepatectomy, the central venous pressure (CVP) should be kept low (<5 mmHg) by judicious fluid management prior to initiating parenchymal transection to minimize blood loss. This can be further accomplished by placing the patient in steep Trendelenburg position to further reduce the CVP during liver parenchymal transection. Hemostasis from the cut edge of the liver surface is obtained using

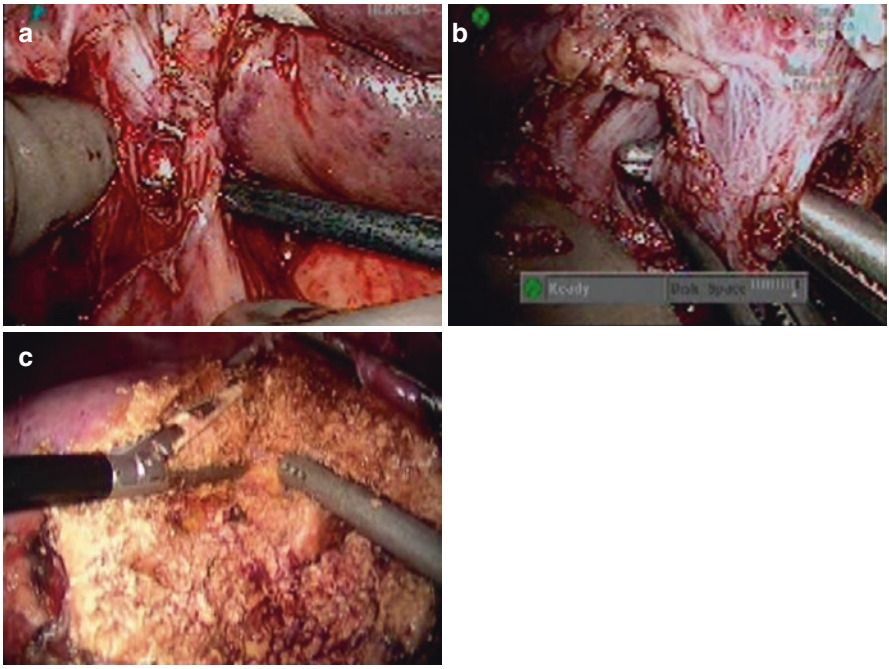

Fig. 13.3 (**a**) Left hepatic artery. (**b**) Left portal vein. (**c**) Liver parenchymal transection

electrocautery, or the laparoscopic Aquamantys system (Medtronic) combing bipolar cautery using radiofrequency in conjunction with saline to achieve hemostasis and tissue sealing. The right hepatic vein is divided last under direct vision. Note that some surgeons prefer to divide the right hepatic vein prior to mobilizing the right triangular ligament. All visible bile leaks are oversewn using a 4–0 absorbable suture. The resected right lobe is delivered through the handport for extraction. After hemostasis is confirmed, the authors place a closed suction drain terminating at the cut liver remnant edge that is brought out through a 5 mm trocar site at the completion of the case.

Troubleshooting: If the right hepatic vein has been ligated, a laparoscopic hanging maneuver may be performed by passing an umbilical tape anterior to the IVC to retract the liver away and facilitate parenchymaltran section. If the right hepatic and/or right portal veins have not been previously transected (as outlined in steps 5 & 6 respectively), this can be performedat their intraparenchymal location using a vascular staple load. If hemorrhage is encountered performing a Pringle maneuver will assist in slowing bleeding originating from a portal vein or hepatic artery. However, injury to a hepatic vein or retrocaval IVC will not be impacted by the Pringle maneuver and alternatively the intra-abdominal pressure may be increase temporarily to 20 mmHg, although this may predispose to an inadvertent air embolus.

13.3.7 Postoperative Considerations

In the immediate postoperative period, the patient should be vigilantly monitored for evidence of hemorrhage and post-operative liver failure. In addition, hypertrophy of the liver remnant will occur, and care should be taken to closely monitor and replete phosphorous levels as required. The closed suction drain should be vigilantly checked for bile to suggest an ongoing leak.

13.4 Laparoscopic Left Hepatectomy

Many of the techniques reviewed above regarding laparoscopic right hepatectomy are applied during a formal left resection. Steps that are unique to performing a laparoscopic left hepatectomy are outlined below.

13.4.1 Patient Positioning

Patient positioning is like that described for laparoscopic right hepatectomy.

13.4.2 Trocar Insertion

The position of trocar placement for a hand assisted laparoscopic left hepatectomy is modified as depicted in Fig. 13.1b.

Troubleshooting: A formal left hepatectomy may be amenable to using a purely laparoscopic approach, reserving the use of HALS for challenging cases.

13.4.3 Liver Mobilization and Intraoperative Anatomical Assessment

During mobilization and take down of the left triangular ligament, caution must be used to avoid injuring the left phrenic and left hepatic veins.

13.4.4 Hilar Dissection

The left hilar dissection starts with exposing the umbilical fissure by dividing the bridge of liver tissue connecting segment III and IVB at the base of the falciform ligament. Identifying the common hepatic duct and retracting laterally allows

identification of the left hepatic artery, is secured with clips and transected (Fig. 13.3a). The hilar plate is lower to reveal the left hepatic duct and portal vein. Dissection of the left portal proceeds to obtain adequate length of the vein for division with using a vascular load (Fig. 13.3b). A hepatotomy in segment IVB is created at the lateral base of the umbilical fissure and the left hepatic duct transected with a laparoscopic stapler.

Troubleshooting: Dividing the left hepatic duct at the lateral base of the umbilical fissure avoids potential injury to a commonly aberrant right posterior sectoral duct arising from the proximal left hepatic duct.

13.4.5 Parenchymal Transection

Liver parenchymal transection using the laparoscopic approach occurs in a caudal to cranial approach along the Cantlie line medial to the middle hepatic vein, with technique similar to description for right hepatectomy (Fig. 13.3c). Use of intraoperative ultrasound greatly assists in staying in the correct transection plane.

13.4.6 Hepatic Outflow Control

In contrast to a laparoscopic right hepatectomy, the left hepatic vein is divided following completion of parenchymal dissection. The confluence of middle and left hepatic veins is identified and the left hepatic vein divided proximally, preserving outflow via the middle hepatic vein. Depending on tumor location, sometimes the middle hepatic vein and/or caudate lobe also need to be divided and removed with the formal anatomic left hepatic lobectomy.

Troubleshooting: Identifying the left hepatic vein trunk laparoscopically is often challenging. If a pure laparoscopic approach is being used, consideration should be given to using a hand port to ensure optimal identification of the left hepatic vein.

13.4.7 Postoperative Considerations

Care in the postoperative period is like that outlined previously following a laparoscopic right hepatectomy.

13.5 Summary

Overall, laparoscopic liver resection is increasingly being performed safely and offers several potential benefits compared to open surgery. Careful patient evaluation and selection, along with increasing laparoscopic liver experience allows

for the application of minimally invasive surgical techniques in major hepatectomies.

Conflict of Interest Statement The authors have no conflicts of interest to declare.

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