Contemporary techniques commonly adopted for performing laparoscopic liver resection

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It has been nearly three decades since the first laparoscopic liver resection (LLR) was performed (1). Initial concerns about its technical complexity, bleeding control and oncologic margins have been overcome by improvements in surgical technique and advances in surgical technology over last few the years. Several of these have been highlighted in Chanwat's recent article on useful manoeuvres for precise laparoscopic liver resection (2). In our institution we have performed close to 500 LLR since 2006, of which approximately 95% have been performed from 2012 onwards (3-8). We have recently reported our experience with our first 400 consecutive minimally invasive hepatectomies (3,4) demonstrating that with increasing experience; complex procedures such as major resections, tumours in posterosuperior segments and recurrent hepatocellular carcinomas can be performed with a low morbidity and open conversion rate. In this article, we discuss the techniques adopted by Chanwat while sharing our own manoeuvres highlighting the similarities and differences between our techniques.

Patient position

It is important to remember that the final positioning, decision on where the surgeon should stand and placement of trocars should be individualised to the location of the lesion and the patient body habitus (5). One of the most difficult regions to visualise in LLR using the caudal approach is the suprahepatic inferior vena cava (IVC) and hepatocaval confluence at the cranioventral aspect of the liver (9). In our unit, we either adopt a supine position for most resections including major hepatectomies or a partial or full left lateral position for limited resections of tumors located in segments VI/VII/VIII. These 2 positions are similar to that reported by Chanwat *et al.* All patients are placed in the reverse Trendelenburg position with foot pads for support. This offers the additional advantages of lowering the central venous pressure and allows better visualization of the suprahepatic region especially with the use of a flexible tip endoscope. Other authors have also proposed a near prone position for tumours located in the right posterosuperior segments instead of the lateral position (10).

Port placement

Care must be taken to avoid injuring vessels during port insertion, particularly in cirrhotic patients who tend to have thrombocytopenia, recannulated umbilical veins or large collateral veins that develop in the anterior abdominal wall (11). For this reason, we favour the Hasson's open technique for the initial port insertion over the Veress needle technique. This is normally inserted in the sub-umbilical region unless the patient had previous surgery such as a midline laparotomy, in which case a location distant from the previous surgical incision site is selected.

The surgical working ports are usually placed in the right subcostal region in a gentle curve from right anterior axillary line to the midline, leaving adequate distance from each other and from the camera port site to reduce intracorporeal interference. Similar to Chanwat, we usually utilise about 4 to 5 trocars for most LLR (2).

In our practice, we usually place an additional short profile 5 mm port for application of the extracorporeal Pringles manoeuvre, in which a nylon tape encircling the hepatoduodenal ligament is pulled through the port and a cardiac snare is applied. Some authors including Chanwat (2) have proposed using the laparoscopic bull-dog or a cable band for an intracorporeal Pringles manoeuvre in order to reduce the need for additional ports. In our opinion, the intracorporeal application and removal of the bulldog is more cumbersome and inconvenient compared to the external Pringles manoeuvre.

For tumours high up in the dome of segments VII and VIII of the right lobe, we occasionally utilize intercostal or even transthoracic ports for these lesions, to allow better visualization and access (12). Balloon-tipped 5mm or 12mm ports are used for this to prevent pneumoperitoneum from entering the pleural cavity. When the ports are removed at the end of surgery, the defects in the diaphragm should be sutured close to prevent diaphragmatic hernia.

Retraction and exposure

Proper exposure and visualisation of structures is key to performing any laparoscopic surgery safely. In our experience, we have found that the 3D flexible laparoscope (HD EndoEYE, Olympus, Japan) is extremely effective for looking over the dome of the liver and around corners. We begin our mobilisation of the liver by dividing the round ligament and falciform ligament up to the level of the hepatocaval venous confluence, then proceed laterally. To aid in visualisation of the hilar structures during the caudal approach, the assistant can manually retract the round ligament and/or the gallbladder in the cephalad direction. A ‘marionette technique’ has been described whereby a 2-0 nylon needle is inserted through the abdominal wall and traverses the liver edge twice before being pushed out of the abdominal wall and clamped externally for traction (13). This reduces the number of ports required as well as frees up the assistant to allow him to focus on other tasks during surgery. Other similar suspension methods have been reported such as the Arantius ligament approach for isolated laparoscopic caudate lobectomy (14).

In order to fully mobilise the right lobe off the lateral abdominal wall, after dividing the right triangular and coronary ligaments, we retract the right lobe medially by a number of methods. These include postural changes such as turning the patient full left lateral to allow gravity to pull the liver away from the abdominal wall, as well as using the laparoscopic liver retractor or the fan retractor. Others have described the use of a sterile glove filled with saline placed as a padded spacer behind the right liver (15), or using a ribbon gauze held between two graspers to ‘hug’ and retract the liver edge (16). It is imperative to add that in cases with a bulky right lobe or if there is a very large tumour in the right liver, we employ a medial-to-lateral approach where the right lobe is only fully mobilised at the end of surgery, after parenchymal transection is completed.

Intra-operative ultrasonography

Intra-operative ultrasonography (IOUS) is particularly important in LLR, and any surgeon embarking on starting a laparoscopic hepatectomy programme should be competent in this.

Deep-seated liver lesions not visible from the liver surface can be manually palpated in OLR to identify them, but this is not possible in LLR. This loss of tactile feedback in laparoscopy can be overcome to a certain extent by locating the culprit lesion and assessing its extent on IOUS. Massive bleeding is significantly more challenging to control laparoscopically, hence every effort should be made to avoid vascular injury (17). In addition to studying the preoperative images carefully, real-time image guidance with Doppler mode is extremely helpful for intra-parenchymal identification of hepatic arteries, portal pedicles, hepatic veins and their branches. In LLR, due to the limitations of the fixed trocar positions and limited working field, a flexible probe is used which can be adjusted 90 degrees in 4 planes. We perform IOUS in a similar systematic manner in both open and LLR. After screening the entire liver, we assess the future liver remnant to ensure that it is truly free of lesions. We then localise the tumour, and mark the resection line with a diathermy hook on either side of the lesion, taking care to leave adequate margins. This resection line is seen on ultrasound as a hyperechoic line casting an acoustic shadow within the liver parenchyma. The hepatic veins running in the intersegmental planes are then identified sonographically and used as landmarks for vein-guided parenchymal transection in anatomic hepatectomies, and vertical (longitudinal) demarcation lines for segmentectomies. The MHV in particular has several branches, such as V4, V5 as well as umbilical fissure veins, which need to be located prior to ligation. For postersuperior lesions, the US probe can be inserted through intercostal trocars to aid in visualisation of the tumour as well as the root of the RHV and the V8 branch. For segmentectomies, the bifurcation of the portal pedicle is identified on IOUS and used as a horizontal demarcation line between segments VI/VII, V/VIII and IVa/b (17). In some cases, the specific tumour-bearing portal pedicle can also be localised by ultrasound.

We perform IOUS intermittently throughout the entire parenchymal transection process to maintain our orientation with respect to the tumour and vasculobiliary structures, and to ensure that we obtain adequate oncologic margins. Once resection has been completed, we assess the remnant liver using Doppler mode to confirm there is adequate perfusion.

Approach to the pedicle for anatomical resection

Couinaud described three approaches to the inflow pedicles, all of which can be performed in both open and laparoscopic surgery (18). In the conventional extrahepatic intrafascial approach, the hepatic artery, portal vein and bile ducts branches are individually dissected out prior to ligation. This may be hazardous if there are anatomical variations and vessels to the remnant liver are inadvertently injured. However, for tumors located close to the hepatic hilum, this technique must be used to ensure adequate oncologic margins.

For most cases, we prefer the extrahepatic Glissonean pedicle approach (GPA), similar to that adopted by Chanwat (2). Recently, Sugioka *et al.* described the presence of 'six gates' indicated by 'four anatomical landmarks' which allow access to the gaps between the Laennec's capsule and the Glissonean pedicles via the extrahepatic approach (19). Machado published his experience of intrahepatic GPA, achieved via a series of small hepatotomies around the hilar plate, used to perform segmentectomies, anatomic hepatectomies and even trisectionectomies and mesohepatectomies over a 7-year period. He showed that in experienced hands, this approach is safer and may be faster than the conventional approach (20).

Liver hanging

In the classical liver hanging manoeuvre, there is a risk of injury to the IVC, short hepatic veins (SHV) or caudate process veins when bluntly dissecting out the retrohepatic tunnel (21). Hence, some authors have suggested modifications of this procedure.

For LLR, Kim *et al.* have described a lateral approach, which starts by performing suprahepatic dissection to create a small opening lateral to the RHV or LHV for the upper end of the tape (22,23). Inferiorly, for right hepatectomies, an avascular plane was created between the right lateral border of the IVC and the right adrenal gland. After division of the caudate branches draining into the IVC, a space was dissected between the lateral side of the suprahepatic IVC and the retrohepatic IVC, and the tape was then passed through. This approach is cited by the authors to be safer than the classical hanging method as the surgeon can avoid blunt retrohepatic IVC dissection altogether (22).

For left-sided lesions, after creating the superior opening, the lesser omentum and ligamentum venosum were divided and the tape was passed between the caudate lobe and left lateral sector in alignment with the ligamentum venosum. This manoeuvre makes it unnecessary to dissect in the space between the MHV and LHV, which is often difficult and dangerous especially when there is a common trunk located deep within the liver parenchyma (23).

Hepatic vein-guided transection

Certain surface landmarks are useful for exposing the hepatic veins in order to perform vein-guided transection as mentioned by Chanwat. For left-sided resections, the Arantius ligament can be identified after division of the lesser omentum. This is a fibrous remnant of the fetal ductus venosus located between the caudate and left lateral lobe. The caudal end is attached to the left portal vein, and the cranial end serves as a guide leading to the root of the LHV draining into the IVC (24).

The peripheral part of the MHV can be identified by transecting the parenchyma 1cm above the hilar plate, along Cantlie's line (25). The root of the drainage vein of segment 5 (V5) runs very closely behind the hepatic hilum and is typically encountered before the MHV is seen. This must be carefully dissected and divided. V8 is another important branch of the MHV near the IVC, which must be identified and ligated. Honda *et al.* recently advocated a caudodorsal approach for right hemihepatectomy where the MHV is exposed from the root side towards the periphery, in order to avoid the dreaded 'split injury' of the MHV (26).

Parenchymal division

There are certain fundamental differences in laparoscopic parenchymal division which surgeons must be aware of prior to performing LLR (6). In open hepatectomies, the operator views the liver from the ventral aspect and hence has a complete hepatic bird's-eye overview. In LLR, the default view is from the caudal to cranial direction. As a result, parenchymal transection performed using this 'caudal approach' opens up the liver in an antero-posterior direction, akin to opening a door. This is in contrast to OLR where the parenchyma is divided in a cranioventral direction, which has been likened to opening a book. The angle of approach exposes the dorsal wall better, however the ventral wall is not seen as well.

Laparoscopic parenchymal transection can be performed using a variety of devices, according to individual surgeon choice. In our practice, we prefer to use a single energy device for most cases such as the Harmonic Scalpel (Ethicon Endosurgery, Cincinnati, OH, USA) or Thunderbeat (Olympus, Tokyo, Japan) with a bipolar device (Biclamp, Erbe, Tuebingen, Germany). Parenchymal transection is performed using the clamp crush technique under selective inflow control. In selected cases, especially with tumors located close to major vasculature, we use the Cavitron Ultrasonic Surgical Aspirator (CUSA) (Valleylab, Boulder, CO, USA) in combination with an energy device. To date, no studies have proven the superiority of any one device over another in LLR in terms of bleeding control or oncologic outcomes (27,28).

Bleeding control

Bleeding control in liver resections is done by reducing inflow, outflow and by carefully controlling vessels during parenchymal transection. Inflow can be reduced by performing the PM as mentioned above. To reduce outflow, the central venous pressure (CVP) is usually kept low at 4 to 6cm H_2O by keeping patients dry and lowering the airway pressure if required by briefly pausing artificial ventilation. One main advantage of laparoscopy is that a pneumoperitoneum of 10–12 mmHg helps to provide counter pressure which further reduces bleeding. If there is a hepatic vein injury, this can be temporarily increased to 15–18 mmHg in order to tamponade the bleeding. However, the surgeon must be aware of the risk of CO_2 gas embolism with increased pneumoperitoneum pressure, and repair of the lacerated vein must be performed expeditiously.

Once transection is completed, the cut surface of the liver must be carefully inspected for bleeding or bile leaks. Final confirmation of hemostasis should only be done after the patient has been adequately fluid resuscitated and the pneumoperitoneum lowered to 5mmHg. Haemostasis is done by manual compression with gauze, using a combination of monopolar or fenestrated bipolar diathermy, clips, tissue glue and Surgicel SNoW (Johnson & Johnson Wound Management). Large vessel bleeding can be controlled by suturing. Once we are satisfied, we do a final check by reducing the pneumoperitoneum pressure, increasing the CVP to normal physiological values and perform a Valsalva manoeuvre to confirm no residual oozing from the liver surface.

Conclusions

In conclusion, the techniques described in the article by Chanwat and elsewhere in the literature have all contributed to making LLR safe, feasible and reproducible for liver surgeons worldwide. In our opinion, with the advantages of LLR over the conventional open approach, LLR would soon become the standard of care in most expert liver centers for most LLR.

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