REVIEW ARTICLE

Techniques for Liver Resection

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Abstract

In 1952, Jean Louis Lortat-Jacob undertook the first successful extended right hepatectomy.It was pioneering surgery. Improvement in liver resection has been achieved in the past decade. Among other factors, a gradual change of technology, platforms and refinement of surgical techniques have played significant roles. In this review, the various surgical approaches, operative techniques, operative instruments and adjunctive measures as applied in liver resection are described, along with discussion of the pros and cons of each of these attributes. A brief description of laparoscopic liver resection is also included to address this important and emerging area in liver surgery.

Keywords: Liver resection; surgical techniques, Laparoscopic liver resection.

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Introduction

Liver resection consists of the removal of a lobe or segment of a liver, followed by subsequent regeneration of the residual parenchyma within a few weeks.

Liver resection has long been regarded as one of the most difficult and challenging operations in general surgery. Traditionally, major hepatectomy was associated with a substantial mortality and morbidity[1]. Haemorrhage, liver failure, bile leakage and related sepsis remain the main problems for a successful liver resection. With refinements of surgical techniques, appropriate patient selection, optimal anaesthesia and proper post-operative care, we have witnessed a significant improvement in outcome of liver resection in the last decade. Nowadays, the mortality rate of most liver resections has been brought down to below 5% and blood transfusion rates to between 6.2% and 49% [2-4]. Furthermore, the use of minimal access surgery techniques to reduce access trauma, instead of the conventional big surgery, big wound open hepatectomy, has been successful. In this review, we will discuss and assess the various techniques commonly employed for liver resection, bearing in mind that a successful surgical outcome depends on many other factors.

Anatomical Versus Non-Anatomical Resection

Tumours in the liver can either be excised by anatomical resection or non-anatomical resection. Anatomical resection is based on our understanding of the segmental anatomy of the liver, where each segment has its own hepatic artery, portal vein and biliary drainage [5,6] Resection of liver lesions can thus be planned and carried out according to the segmental distribution . This carries the advantage of less bleeding as it avoids major vessels and also reduces the likelihood of leaving ischaemic liver tissues behind, since the blood supply to the remnants is preserved. Non-anatomical or wedge resection has a place for peripheral or superficial lesions, or when the lesion crosses the boundary of multiple segments, or in situations where the preservation of liver substance is of paramount importance.

Classification of The Extent of Liver Resection

Obviously the risks involved in major liver resection are much higher than those with simple wedge excisions. This is due to a larger transection plane and corresponding increase in blood loss, and a higher risk of liver function derangement. In general, a resection of less than three liver segments is regarded as a minor hepatectomy while resection of three or more liver segments is termed major hepatectomy. Resections involving five or more liver segments are regarded as extended hepatectomy. In fact, a unified nomenclature for liver resection such as the Brisbane 2000 system is desirable to allow comparison from different centres [7]. Although the extent of liver resection correlates well with the magnitude of surgery most of the time, there are occasional exceptions. For example, an isolated segmentectomy I is technically more demanding than a straight-forward right hepatectomy. Similarly, resection of the middle segments (segments IV,

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V, VIII) or right posterior segments (segments VI, VII) may be technically more difficult than a right or left hepatectomy, as the transection area involved is larger. Hence, minor hepatectomy should not be routinely regarded as a procedure of lesser magnitude.

Operative Approaches for Liver Resection

The traditional approach for open liver resection is a bilateral subcostal incision with or without upward midline extension. A thoracic extension may be necessary for bulky right lobe tumours. A J-incision is another way to gain good exposure to the whole liver with the advantage of extension into the thoracic cavity, if needed [8]. Occasionally, an upper midline incision is sufficient for a minor hepatic resection such as a left lateral segmentectomy.

In the conventional approach, hepatectomy starts by mobilising the liver lobe to be resected. This consists of division of the falciform ligament, the right or left triangular ligament. In a right hepatectomy, by rotating the right lobe of the liver to the left, the dorsal ligament covering the inferior vena cava (IVC) can be divided to fully expose the right hepatic veins. However, if the right lobe is occupied by a bulky tumour, making dissection difficult, an alternate anterior approach has been advocated.. It starts with hilar dissection, ligation and division of the right hepatic artery and portal vein. Liver transection then begins over the anterior surface of the liver, towards the IVC along the principal plane . The right hepatic vein and inferior hepatic veins are then ligated and divided and, finally, the triangular ligament is divided before the specimen is delivered. Belghiti et al further modified the anterior approach by the liver hanging manoeuvre where a tape is passed between the anterior surface of the IVC and the liver parenchyma to hang up the liver[9-10]. The upper traction of the tape allows better exposure, slightly smaller transection surface, easier haemostasis and better protection of the IVC. However, the technique involves blind dissection of the tissue plane in front of the IVC which is not totally avascular due to the presence of small hepatic veins draining the caudate lobe directly into the anterior surface of the IVC [11]. Bleeding may occur if these small veins are torn but they are usually controllable by parenchymal compression [10] A modified technique using an endoscope to dissect the plane in front of the IVC under direct vision has been shown to be very safe and useful [12]

Vascular Control to Reduce Haemorrhage

Bleeding remains the major problem associated with liver resection. Bleeding and the subsequent blood transfusion have been shown to increase post-operative morbidity and mortality [13-15]. Thus, reducing blood loss and avoidance of transfusion are the primary objectives of most liver surgeons. Hepatic vascular control is an effective way to achieve these goals. Although various forms and modified techniques of vascular control have been practiced, there are basically two main strategies; inflow vascular occlusion and total vascular exclusion [16,17]

Inflow vascular occlusion or Pringle manoeuvre (PM) is the oldest and simplest way to reduce blood loss during hepatectomy [18]. The hepatoduodenal ligament is encircled with a tape, and then a vascular clamp or tourniquet is applied until the pulse in the hepatic artery disappears distally [19]. The PM has relatively little general haemodynamic effect and no specific anaesthetic management is required. However, bleeding can still occur from the backflow from the hepatic veins and from the liver transection plane during unclamping. The other concern is the ischaemic-reperfusion injury to the liver parenchyma, especially in patients with underlying liver diseases [20]. The continuous Pringle manoeuvre (CPM) can be safely applied to the normal liver under normothermic conditions for up to 60 minutes and up to 30 minutes in pathological (fatty or cirrhotic) livers, although much longer durations of continuous clamping 127 minutes in normal livers and 100 minutes in pathological livers have been reported to be safe [21-24]. One way to extend the duration of clamping and to reduce ischaemia to the remnant liver is by the intermittent Pringle manoeuvre (IPM). It involves periods of inflow clamping that last for 15-20 minutes followed by periods of unclamping for five minutes (mode 15/5 or 20/5), or five minutes clamping followed by one minute unclamping (mode 5/1) [25-29] IPM permits a doubling of the ischaemia time, when compared with CPM and the total clamping time can be extended to 120 minutes in normal livers and 60 minutes in pathological livers. The disadvantage of IPM is that bleeding occurs from the liver transection surface during the unclamping period and, thus, the overall transection time is prolonged as more time is spent in achieving haemostasis. Belghiti et al (1999) revealed that there was no significant difference in total blood loss or volume of blood transfusion between CPM and IPM (mode 15/5) [26]. However, they noticed that pathological livers tolerated CPM poorly.

A newer perspective on inflow occlusion comes from the concept of ischaemic preconditioning (IP). It refers to an endogenous self-protective mechanism by which a short period of ischaemia followed by a brief period of reperfusion produces a state of protection against subsequent sustained ischaemia-reperfusion injury[27-30]. The IP is performed with ten minutes of ischaemia followed by ten minutes of reperfusion before livertransectionwith CPM[30,31] .

Hemihepatic clamping (half-Pringle manoeuvre) interrupts the arterial and portal inflow selectively to the right or left liver lobe that is to be resected [34,35]. It can be performed with or without prior hilar dissection. It can also be combined with simultaneous occlusion of the ipsilateral major hepatic vein. The advantage of this technique is that it avoids ischaemia in the remnant liver, avoids splanchic congestion and allows clear demarcation of the resection margin. The disadvantage is that bleeding from the parenchymal cut surface can occur from the non-occluded liver lobe.

Segmental vascular clamping entails the occlusion of the ipsilateral hepatic artery branch and balloon occlusion of the portal branch of a particular segment. The portal branch is identified by intra-operative ultrasound and puncture with a cholangiography needle through which a guide wire and balloon catheter is passed[36,37]. Total vascular exclusion (TVE) combines total inflow and outflow vascular occlusion of the liver, isolating it completely from the systemic circulation. It is done with complete mobilisation of the liver, encircling of the suprahepatic and infrahepatic IVC, application of the Pringle manoeuvre, and then clamping the infrahepatic IVC followed by clamping of the suprahepatic IVC. Clamps are removed in reverse order after liver transection, which is almost bloodless[38] TVE is associated with significant haemodynamic changes and warrants close invasive and anaesthetic monitoring. Occlusion of the IVC leads to marked reduction of venous return and cardiac output, with a compensatory 80% increase in systemic vascular resistance and 50% increase in heart rate and, thus, not every patient can tolerate TVE[39]. TVE can be applied to a normal liver for up to 60 minutes and for 30 minutes in a diseased liver. The ischaemic time can be extended when combined with hypothermic perfusion of the liver [39,40]. While haemodynamic intolerance usually necessitates cessation of TVE, alternatives like supracoeliac aortic clamp or venovenous bypass have been suggested[41,42]. Apart from the unpredictable haemodynamic intolerance, post-operative abdominal collections or abscesses and pulmonary complications are more common in TVE, when compared with CPM[43]. Inflow occlusion with extraparenchymal control of hepatic veins is a modified way of performing TVE. The main and any accessory right hepatic vein, the common trunk of the middle and left hepatic veins, or the separate trunks of the middle and left hepatic veins (15% of cases) are first dissected free and looped. It has been reported that the trunks of the major hepatic veins can be safely looped in 90% of patients [44-45]. The loops can then be tightened or the vessels clamped after inflow occlusion is applied, so that the liver lobe is isolated from the systemic circulation without interrupting the caval flow. It can be applied in a continuous or intermittent manner. The maximal ischaemia time is up to 58 minutes under continuous occlusion[24]. This technique is more demanding than TVE, but it can avoid the haemodynamic drawbacks of TVE while at the same time provide almost a bloodless field for liver transection.Studies have also shown that blood loss could be reduced by lowering the CVP below 5cmH [20.29,46-48]. Low CVP can be achieved with a combination of techniques including restriction of fluid, intravenous nitroglycerine and frosemide infusion [48]. This illustrates the importance of collaboration between surgeons and anaesthetists for a

Successful Hepatectomy

Techniques of Parenchymal Transection

Finger-fracture technique (Digitoclasia) or clamp crushing method (Kellyclasia) are the typical ways of blunt transection when the liver parenchyma is crushed between the thumb and one finger or with Kelly clamps so that vessels and bile ducts stand out for proper haemostasis by diathermy, metal clips, or suture ligatures[50]. Unipolar cautery, bipolar cautery and argon beam coagulation are commonly employed for simultaneous haemostasis while transection is carried out.[51]. These methods are commonly practiced in many centres around the world[3,4]

Undoubtedly, nowadays ultrasonic dissectors such as the Cavitron ultrasonic surgical aspirator (CUSA) are increasingly popular for liver transection[2,4]. The CUSA allows meticulous division of the liver parenchyma leaving behind vessels and bile ducts for proper ligature and haemostasis. It needs to work with a haemostatic device like diathermy forceps. Although it has previously been shown to reduce blood loss, a recent randomised controlled trial showed that CUSA offered no reduction in blood loss in liver resection, when compared with the clamp crushing method[52,53] Since these methods of transection involve quite a different set of skills, not only is it difficult to compare, it may well be a simple case of the surgeon’s preference for one technique over another.

Newer bipolar devices such as the Ligasure vessel sealing system has been shown to permanently seal off vessels up to 7mm in diameter. This has been employed for liver transection with proven effectiveness[54,55]. The liver tissue can be crushed between the blades of the device and then coagulation energy is applied to seal the vessels. However, Ligasure does not seem to work so well in cirrhotic livers, when compared with non-cirrhotic livers[55].

The harmonic scalpel, an ultrasonically activated shear, has also been used for liver resection. It causes protein denaturation and coagulation by high frequency ultrasound vibration. Although it could reduce operative time and blood loss, when compared with clamp crushing, it was shown to have an increased incidence of biliary fistulae[56].

Hydrojet is another useful device to wash off softer liver tissue from the tougher vessels by a jet of water from a high pressure pump conducted by a hose to the nozzle. One randomised study showed that Hydrojet reduced the need for blood transfusion and decreased liver ischaemic time as well as transection time, when compared with CUSA[57].

Microwave tissue coagulation has been employed to induce tissue coagulation by insertion of the microwave probes before transection is carried out[58]. However, there was a much higher incidence of bile leakage (27% vs. 3%), when compared with the clamp crushing method[59].

Another new device, the TissueLink dissecting sealer, employs radiofrequency energy delivered through a continuous stream of saline dripped from the device tip to coagulate small vessels and liver parenchyma . Unlike standard diathermy, the TissueLink device does not lead to char formation. The combination of such a device with CUSA was shown to be superior to CUSA alone in terms of clamp time, operative time and blood loss[60].

A recent randomised controlled trial comparing four different transection methods in liver resection showed that the clamp crushing method remained the most efficient device in terms of resection time, blood loss, and blood transfusion frequency, when compared with CUSA, hydrojet and the dissecting sealer, and was also the least expensive[61].

Radiofrequency (RF) ablation has been employed as a means for liver resection. In brief, this entails the serial applications of RF along the line of liver transection by multiple insertions of RF probes so as to create a ‘zone of coagulation necrosis’, before the liver is divided with a scalpel. In the series from Habib et al., the mean blood loss was only 30 +/- 10 ml in 15 patients receiving RF-assisted hepatectomy, including one major hepatectomy[62]. No mortality or morbidity was noted in the same series.

The use of vascular staplers is increasingly common for the division of hepatic veins and portal branches. Their use for transection of liver parenchyma has also been reported recently. The procedure starts by dividing the liver capsule by diathermy, followed by fracturing the liver tissue with a vascular clamp in a stepwise manner, and subsequently divided with endo-GIA vascular staplers. In a large series of 300 stapler hepatectomies, including 193 major hepatectomies, mortality of 4% and morbidity of 33% were reported, which is comparable with conventional liver resection techniques[63]. Vascular control was only necessary in 10% of patients in the same series, with overall median blood loss of 700ml. Although the technique appears attractive, the financial cost for the staplers is a serious drawback.

Various Adjuncts in Hepatectomy

Intra-operative ultrasound (IOUS) is an essential tool for hepato-biliary surgeons. IOUS can be used to locate known liver lesions, to detect further liver lesions on-table, to guide the line of transection and to mark important vascular patterns. IOUS allows accomplishment of anatomical resections such as segmentectomy, and it also allows better tumour clearance in non-anatomical resections[64,65]. A special technique of trans-parenchymal vascular control has been described and it utilises IOUS for precise localisation of target vessels before application of vascular staplers[66].

The routine use of fibrin glue as a means to augment haemostasis and to reduce post-operative bile leakage has not been supported by prospective randomised trials although it has been quite extensively used by many centres[67-70]. While it is illogical to assume fibrin glue can seal all cases of major bile leakage, intra-operative leakage testing was advocated, particularly for high risk procedures in patients with cirrhosis[71].

The routine use of abdominal drainage after hepatic surgery has been challenged. Studies showed that the use of a drain was not beneficial and may even be harmful, in terms of more wound complications, more septic complications and longer hospital stay[72,73]. Many centres have now stopped using the routine drainage after resections. However, in circumstances where an abdominal drain is deemed necessary, the drainage tube can be inserted through a subcutaneous tunnel to avoid the problem of leakage of ascitic fluid from the drain wound[74].

The Evolution of Laparoscopic Liver Resection

Discussion on the techniques of liver resection cannot be complete without discussing laparoscopic hepatectomy.

The pace of development of laparoscopic techniques for liver resection is relatively slow due to concerns about haemorrhage, air embolism, tumour seeding (port site and peritoneal) and oncological clearance. The first non-anatomical resection of benign liver tumour was done by Gagner et al in 1992[75]. In 1996, Azagra et al performed the first anatomical liver resection (left lateral segmentectomy)[76]. Although successful laparoscopic major hepatectomy have been reported, most authors agree that laparoscopic liver resection should be offered to selected patients[77-79]. Tumours located at segment II, III, IVb, V or VI, of size 5cm or less; lesions which are not close to major vascular trunks; and when there is no need for vascular or biliary reconstruction; were considered as favourable for laparoscopic resection[80]. Instruments which have been used in conventional open surgery are also modified for laparoscopic use, like laparoscopic CUSA, harmonic scalpel, Ligasures, the TissueLink device, argon beam coagulator, Hydrojet, radiofrequency ablation, endovascular stapler and even the fibrin glue spraying devices. Needless to say, IOUS is even more important than in open surgery as tactile sense is lost in the laparoscopic approach. The PM can be applied similarly as in open surgery. In addition, hand ports can be inserted for hand-assisted laparoscopic resections, especially when major hepatectomy is attempted. The wound of the hand port can also be used conveniently for specimen retrieval.

Studies comparing laparoscopic versus open hepatic resections have shown that patients having laparoscopic resections had shorter hospital stay, less analgesic requirement and quicker resumption of oral intake, while complications and conversion rates were acceptable[81]. Since only limited long-term results are available, the role of laparoscopic resection for malignant liver tumours remains to be evaluated[80]. Without doubt, laparoscopic liver resection is technically demanding and can only be safely accomplished by liver surgeons with experience in both laparoscopic procedures and open hepatic surgery.

Conclusion:

The presence of a wide range of operative techniques and instruments for liver resection merely implies that there is no one single method which is overtly superior and it reflects the surgeon’s unceasing quest for the perfect instruments and techniques for liver transection. The adoption of a particular technique is related to the surgeon’s preference and to the particular circumstances of resection, although many surgeons still favour clamp crushing for parenchymal transection and IPM for vascular control. Nevertheless, it is desirable that liver surgeons are familiar with various techniques as situations may arise that necessitate alternative ways of performing the operation. One obvious example is the resection of very large right lobe tumours. It is undesirable, if not impossible, to stick to the conventional way of liver resection by firstly fully mobilising the right lobe before transecting the liver. Another example is the ability to promptly apply inflow vascular occlusion, or even TVE, in case torrential haemorrhage is encountered during hepatectomy.

The risks associated with liver resection are now less. However, the relatively better results are mainly reported by specialised and high volume centres., liver resection should be performed in a specialised centre by experienced teams. Similarly, although we are quite certain that laparoscopic liver resection is not only feasible but can also convey the additional advantage of being minimally invasive, without jeopardising oncological clearance, the technical skills involved are rather demanding. Such operations should only be performed by surgeons who have mastered both open liver surgery and laparoscopic surgery.

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