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Editorial

Choosing the optimal tools and techniques for parenchymal liver transection

The modern era of safe liver resection is based on notable advances in non-invasive solid organ imaging, improved anaesthetic management, enhanced knowledge of segmental liver anatomy as described by Couinaud,[1] better surgical technique, an appreciation of the functional reserve of the liver remnant, and the remarkable capacity of normal liver to regenerate.[2-5] The evolution and development of the surgical techniques utilised during liver resection are largely an account of the efforts to minimise bleeding during hepatic parenchymal transection. Three decades ago, major liver resection was associated with mortality rates of up to 20%, and excessive bleeding was an important and common cause of operative mortality.[6] Liver resection can now be accomplished with mortality rates of less than 3% in most specialised hepato-pancreato-bilary (HPB) centres.[7] While better patient selection and improved assessment of intrinsic liver reserve are important factors,[8] reduced blood loss and the diminishing need for blood transfusion have been additional reasons for improved peri-operative outcome.[5,8,9] Other advances in operative technique, including improved delineation of the optimal transection plane with intra-operative ultrasound[10] and the benefit of intermittent inflow occlusion, have also contributed to a reduction in blood loss during major liver resections.[8]

The most significant operative hazard during major liver resection is uncontrolled bleeding.[4] Avoiding excessive blood loss is the most important factor affecting peri-operative outcome, and there is a close relationship between increasing blood loss during transection and an unfavourable result.[11] Significant bleeding may occur at any of three stages during a liver resection.[11] The first is during initial mobilisation of the lobe to be resected, especially if the patient is deep-chested and the tumour is bulky, posteriorly situated, adjacent to the right or middle hepatic veins and adherent to diaphragm or retrohepatic vena cava. The second is during transection of friable, steatotic or cirrhotic parenchyma in a liver in which parenchymal division is aggravated by distortion or displacement of intrahepatic veins by tumour. The third stage of bleeding may occur from parenchyma at the resection margin or from divided hepatic vein branches after completion of the transection.[11]

In an endeavour to make liver resection safer, a number of clinical studies have evaluated the efficacy of tools available for parenchymal transection. Among the earliest purpose-developed tools developed were a variety of liver clamps designed to fit snugly around a liver lobe, which could be tightened to compress parenchyma and vessels in order to minimise blood loss during liver resection. Pioneering liver clamp or tube tourniquet designs were assessed by Storm and Longmire,[12] Lin,[13] Kanematsu *et al.*[14] and Li and Mok.[15] In this issue of *SAJS*, investigators from Zhangzhou in China evaluate the effectiveness of a novel liver clamp.[16] Clinical data on 117 patients who had a hepatectomy between 2004 and 2009 were analysed retrospectively. Forty-two patients had a liver resection with the aid of a vascular clamp placed proximal to the resection margin, 35 had a resection with prior dissection and hilar vascular control, and 40 had a resection with intermittent inflow control using a Pringle manoeuvre. Blood loss, operative time, postoperative hepatic function and complications were compared. Mean blood loss, operative time and liver function were significantly better in the liver clamp group. Although the concept is appealing, liver clamps have not become widely used as most are cumbersome and do not combine the required robustness and stability with the flexibility and purchase necessary to avoid dislocation at critical junctures during parenchymal transection and manipulation of the liver.[15]

Various other methods have been used to decrease blood loss during liver parenchymal transection.[4] The ideal instrument for liver transection should be able to fragment and selectively divide hepatic parenchyma while preserving vital structures such as intrahepatic vessels and bile ducts.[17] Over the past 3 decades technological research has resulted in a number of tools, using different energy sources and each with varying advantages and disadvantages and degrees of sophistication and complexity. Equipment advances have led to the development of specific instruments for liver transection such as the ultrasonic dissector, water jet, harmonic scalpel, Ligasure and TissueLink dissecting sealer, as well as biological glues and stapling techniques.[2,18]

Finger fracture and subsequently the clamp-crush method were the first techniques used for transection of liver parenchyma.[19] Clamp crushing is a low-cost technique but does require substantial experience to be used effectively for liver transection, especially in patients with cirrhotic livers. The Cavitron Ultrasonic Surgical Aspirator (CUSA) was first evaluated experimentally in 1978[20] and used clinically thereafter.[21,22] In many centres worldwide, ultrasonic dissection using the CUSA has become the standard technique of liver transection. With this technology, liver parenchyma is fragmented with ultrasonic energy and aspirated, exposing vascular and ductal structures that can be ligated or clipped and divided. The CUSA can be used in both cirrhotic and non-cirrhotic livers, is associated with low blood loss, and is safe with a low risk of postoperative bile leakage.[8] The CUSA is particularly useful in major hepatic resections when dissection of the major branches of the hepatic veins is required or in cases where the tumour is in close proximity to major hepatic veins.[8]

A more recent development is the water jet dissector, which uses a pressurised jet of water instead of ultrasonic energy to fragment liver parenchyma and expose vascular and ductal structures.[2] High-pressure water-jet dissection technology was originally developed for application in the steel and glass industries, where ultra-precise cutting and engraving were desirable, and has now been adapted for medical applications, with favourable results (Hydro-Jet®; ERBE, Tuebingen, Germany).[2] The advantages of this thin, laminar liquid-jet effect include precise, controllable, tissueselective dissection with excellent visualisation of, and minimal trauma to, surrounding fibrous structures.[2] As with the CUSA, water jet techniques are effective for dissecting out major hepatic veins when tumours are in close proximity.

More recently, new technologies that seal small vessels during transection of liver parenchyma have been developed to further reduce blood loss and transection time. These technologies include the harmonic scalpel, which uses ultrasonically activated shears to seal small vessels between the vibrating blades, and the Ligasure, which is designed to seal small vessels using a combination of compression and bipolar radiofrequency energy to cause shrinkage of collagen and elastin in vessel walls. The two newest devices are the TissueLink, which applies saline-linked radiofrequency energy to liver transection, and radiofrequency ablation, which uses thermocoagulation with parallel probes as devised by Habib.[23]

In order to identify the optimal transection tool, a Swiss trial randomised 100 patients without cirrhosis or cholestasis to undergo liver resection using one of four methods: crush-clamp, ultrasonic dissector, water jet or dissecting sealer.[9] The patients randomised to the crush-clamp technique underwent major hepatectomy with vascular inflow occlusion using a continuous Pringle manoeuvre, while in the other groups a routine Pringle manoeuvre was not used. The crush-clamp technique was associated with a shorter resection time, less blood loss and a lower frequency of blood transfusion, and proved to be the most effective method. The major criticism of this trial was that crush-clamp transection was always performed with total inflow control, while in the three comparator groups inflow was seldom used. Another trial[24] comparing the clamp-crush technique with CUSA did not employ routine vascular occlusion. This trial showed no difference in the blood transfusion requirements between the two groups.[24] A subsequent meta-analysis which included seven randomised controlled trials with more than 500 patients found no clinically significant benefit when the crush-clamp technique was compared with alternative transection methods in terms of blood loss, parenchymal injury response, transection time and hospital stay.[25] A 2009 Cochrane review of randomised data similarly did not show any significant difference with regard to mortality, morbidity, markers of liver parenchymal injury, or length of ICU and hospital stay when comparing crush-clamp with alternative methods.[26]

Surgical practice, as illustrated above by liver resection, is intimately related to advances in both surgical technique and understanding of anatomical and pathological principles.[27] The experienced liver surgeon today has a variety of options, and as available comparative data on the various liver transection techniques show no substantive differences, the choice of technique is often based on the individual surgeon's preference.[28] Newer instruments enhance the capability of haemostasis and may allow faster transection, but lack the precision provided by CUSA during dissection near major hepatic veins and may be associated with an increased risk of bile leakage.[8] Ultrasonic dissection currently remains the most widely used technique of liver transection. However, some surgeons question the justification for the use of expensive tools and equipment when randomised studies show that simple crush-clamp transection, albeit using routine inflow occlusion, may be quicker and cheaper. Whatever transection tool is used, the fundamental principles of liver resection remain constant. The Pringle manoeuvre remains a useful technique to reduce bleeding from inflow vessels, and maintenance of a low central venous pressure is an important responsibility of the anaesthetist in assisting the surgeon to reduce blood loss during liver transection.[19]

Hepatic resection has been a surgical growth area, stimulated in particular by the proven benefits of resection of primary and metastatic hepatic malignancies, and the upsurge in the number of liver resections over recent years is testimony to this.[19,27] Minimally invasive liver resection now encompasses methods ranging from total laparoscopic, hand-assisted laparoscopic and hybrid techniques to more recent robotic assisted liver resections.[4,29] Laparoscopic liver resection in most major HPB centres has become a standard procedure for small and moderately sized resections, such as left lateral sectionectomy.[29] In addition, liver transplantation and laparoscopic resection have further merged in the performance of live-related liver transplantation and laparoscopic donor resection.[30] Because the quality of the donor segment in live-related liver transplantation is critical for subsequent optimal graft function, inflow control is seldom used during transection. This constraint puts the emphasis on precise parenchymal transection with initial preservation of major inflow and outflow vessels. These laparoscopic advances have further expanded the application of resection techniques and are the next evolving frontier in hepatic surgery.[31]

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