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Liver parenchymal transection techniques

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ABSTRACT

While liver surgery has become safer with improvements in peri-operative management, parenchymal resection is the part of the procedure which is associated with major loss of blood and damage to important structures if not performed carefully. The ideal technique for hepatic parenchymal transection should be quick, easy to perform, reduce intra-operative blood loss and transfusion requirement, reduce post-operative bile leakage, and cause minimal damage to the surrounding hepatic parenchyma- preferably at the lowest cost possible. This paper is a review of commonly used techniques for liver parenchymal transection during liver resections. According to the literature, there is little benefit of using the complicated and expensive devices over the simpler clamp crushing technique. We in our institution, who perform a large number of liver resections and living donor transplants, prefer to use the clamp crushing technique with a bipolar cautery for most resections and cavitron ultrasonic aspirator(CUSA) with a bipolar cautery for removal of part of the liver from a living donor.

Keywords: Hepatectomy; Liver resection; Parenchymal transaction.

INTRODUCTION

A better understanding of the anatomy and physiology of the liver, an enhanced accuracy from new imaging techniques, an increased precision of dissection, and improvements in anaesthesia have all resulted in improved patient selection which, together with close peri-operative management have now made operations on the liver fairly safe. Liver resection has evolved from a phase of non-anatomic resections for trauma to precise anatomical resections performed in living donor hepatectomy and isolated caudate tumours. After the vessels and bile ducts are isolated, it is necessary to transect the liver parenchyma, a procedure which was previously associated with major blood loss. However, there are now various new techniques for dividing the liver parenchyma, modifications of which may be needed for specific situations. Additionally, vascular exclusion may be used to a varying extent during parenchymal transection to facilitate the manoeuvre. Maintaining a low central venous pressure during parenchymal transection helps reduce intra-operative blood loss thereby reducing the need for inflow occlusion during hepatic parenchymal transection. An ideal technique for hepatic parenchymal transection should be quick, easy to perform, reduce intra-operative blood loss and transfusion requirements, reduce post-operative bile leakage, and cause minimal damage to the surrounding hepatic parenchyma-preferably at the lowest cost possible. The search for such a device has resulted in the use of various devices and /or techniques and their various combinations for liver parenchymal transection.

These include

1. Kelly clamp crushing technique
2. Cavitronultrasonic aspirator (CUSA)
3. Hydro-jet devices
4. Radiofrequency (RF) devices
5. Ultrasonic scalpel
6. Bipolar sealing devices
7. Stapling devices
8. Miscellaneous devices

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Kelly clamp crushing technique

Lin introduced the finger fracture technique in 1958 for hepatic parenchymal transection[1]. In this technique, the hepatic parenchyma is crushed between the surgeon's fingers to reveal the portal and hepatic venous structures which can then be ligated or more recently divided usingLigaSure (Covidien-Medtronic, MN, USA). This technique has been modified to use a Kelly clamp (Figure 1) for crushing the hepatic parenchyma for a finer dissection and identification of smaller portal structures and hepatic veins. This technique usually requires a Pringle's manoeuvre (continuous or intermittent obstruction of the structures in the free edge of the lesser omentum) for inflow occlusion during hepatic parenchymal transection which helps reduce the intra-operative blood loss. This technique is quick, does not require any special instruments and is easy to learn.

Figure 1. Kelly clamp

Additionally, there is difficulty in identifying major vascular and biliary channels during the parenchymal transection, making it unsuitable for use in donor hepatectomy.

Ultrasonic energy based devices

Cavitron ultrasonic aspirator (CUSA)(Figure 2)

Since the first report of use of this device by Hodgson and DelGuercio for hepatic parenchymal transection[2], this has now become one of the most useful methods used for hepatic parenchymal transection.

Ultrasonic dissection devices create a cavitation effect at the tip of the instrument with simultaneous irrigation and aspiration. The cavitation effect results in fragmentation of cells by rapid formation and collapse of vapour bubbles in the tissues exposed to ultrasonic vibration. Simultaneous irrigation with saline helps in dissipation of heat as well as facilitating suction of the fragmented tissues by the suction device. The coagulation effect is very little because of the narrow tissue contact and cooling by the saline irrigation. Tissue selectivity results from the fact that tissues with higher water content are fragmented whereas tissues with a lower water and higher collagen content such as the vascular endothelium and bile ducts are preserved and thus can be better identified and tackled.

Figure 2. CUSA handpiece with the inset showing the attachment for irrigation and suction

The instrument comprises an ultrasonic generator which usually operates at a frequency of 23000-25000 Hz which is the lowest inaudible frequency with a maximal possible amplitude. The hand piece of the instrument is composed of an acoustic vibrator with a system for simultaneous irrigation and suction.

In this technique, the liver capsule is first incised with an electrocautery along the line of proposed transection before dividing the parenchyma. These devices offer the potential advantages of being accompanied by a lower intra- operative blood loss and better control of the small bile duct radicles. Another major advantage is the clear identification of the biliary structures and hepatic veins which can then be carefully ligated or preserved for reconstruction in the recipient. Ultrasonic dissection devices are particularly useful for hepatic parenchymal transection in living donors during donor hepatectomy for living donor liver transplantation.

Koo et al have reported a higher incidence of pulmonary embolism with CUSA[3], However this observation has not been confirmed by other studies. The instrument is not useful to divide connective tissues, which, therefore need to be tackled with electrocautery. Further, operative time tends to be longer with use of CUSA than with a Kelly clamp. A few retrospective studies have shown a reduction in blood loss, need for inflow occlusion and postoperative morbidity with a similar transection time for CUSA compared to the clamp crushing technique[4,5]. However, in randomized trials these advantages have not been clearly shown as elaborated later.

The authors prefer to use CUSA along with bipolar coagulation for parenchymal transection for donor hepatectomy. In this technique, CUSA is used to transect the hepatic parenchyma (Figure3). Small branches of portal structures and hepatic vein tributaries can then be either divided between metal clips (Figure 4) or coagulated by bipolar coagulation. The bipolar coagulation is accompanied by a system for continuous irrigation of the tip of the coagulation device with saline to reduce stickiness at that site. Another potential disadvantage is the risk of transmission of infection to the operating team in patients with Hepatitis B or C undergoing liver resection

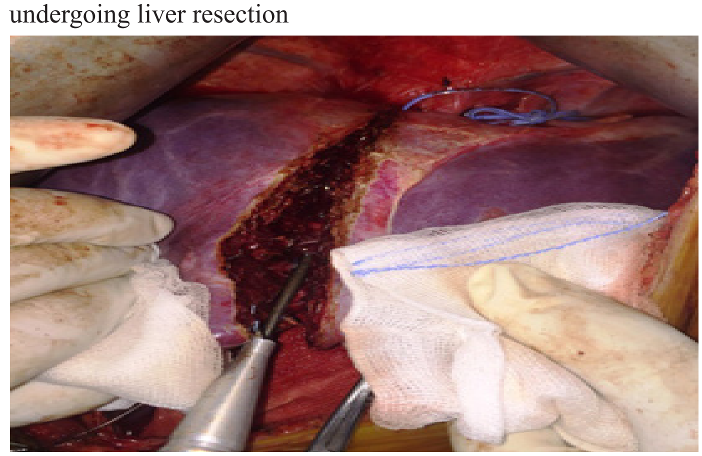

Figure 3. CUSA being used in identification and isolation of small venous branches during donor hepatectomy

Figure 4. Disposable ligaclip applicator

Harmonic scalpel

This instrument comprises an ultrasonic generator, a piezoelectric transducer which is situated in the hand piece and a specially designed tip in which the cutting edge is placed below and the grasping/ inactive edge placed above. The transducer converts electrical energy into mechanical vibration with a frequency ranging from 23.5-55.5 kHz depending on the manufacturer. Rapid vibration of the tip results in denaturation of proteins by breaking of hydrogen bonds. Compared to electrosurgery, ultrasonic scalpels work at a lower temperature resulting in relatively lesser collateral tissue damage. There is minimal charring with the use of this device.

The ultrasonic scalpel is particularly useful in laparoscopic liver resections wherein it results in less mist formation and better haemostasis compared to the CUSA or electrocautery. Schmidbauer et al have reported their experience with the use of an ultrasonic scalpel in open and laparoscopic liver resections with good results[6].

A retrospective study by Kim et al reported a lower operating time, and a trend towards reduced intra-operative blood loss and transfusion requirements at the expense of higher bile leak rates[7]. The combined use of an ultrasonic aspirator and an ultrasonic scalpel has been reported to result in lower operating time and post-operative bile leak rates.

Water-jet dissection devices

These devices use a jet of water at a high pressure to remove the liver parenchymal tissue thereby enabling identification of small vascular and biliary structures. As with CUSA, the identified vessels and bile duct branches can then be tackled with ligation, bipolar coagulation, ligaSure or a combination of these. A major advantage of this technique over CUSA is that there is no thermal damage to the remnant liver parenchyma or biliary structures. In the largest reported experience of this device, Rau et al have reported lower blood loss, requirement for blood transfusion, need for inflow occlusion and resection time compared to the clamp crushing technique or CUSA[8]. In another smaller study, Vollmer et al have reported similar results using water jet dissection devices.

Radiofrequency (RF) devices

RF-assisted liver resection

The use of this technique has been proposed and propagated by a group led by Nagy Habib who reported the initial experience with this technique. The authors reported no need for inflow control with the use of this device[9]. In this technique, RF energy is delivered on either side of the transection line before actual parenchymal division thereby pre-coagulating blood vessels. The parenchymal division can then be done with a scalpel or scissors. This technique however results in significant damage to surrounding normal liver parenchyma with higher infectious and biliary complications following liver resections[10].

Saline linked RF sealing device

This device couples radiofrequency energy and cool saline which acts as a conductor of the energy at the tip of the device. This helps in hepatic parenchymal dissection along with sealing of small vessels on the hepatic surface. This helps identify the larger vessels which can then be tackled appropriately. Additionally, cool saline helps prevent excessive heating and thereby reduces charring at the hepatic surface. The device is available for both open and laparoscopic surgeries. This device is particularly useful for hepatic parenchymal transection in patients with cirrhosis.

Bipolar sealing devices

Bipolar sealing devices work on the principle of a bipolar cautery and therefore cause less damage to surrounding normal parenchyma. These devices help in sealing small vessels within the hepatic parenchyma before their division during hepatic transection. LigaSure vessel sealing system (Covidien-Medtronic, MN, USA) can seal vessels upto 7 mm in diameter by compressing the tissue before application of electric current for coagulation, thereby achieving good haemostasis.

Stapling devices

Stapling devices have been used both in open and laparoscopic liver resections, but more so in laparoscopic liver resections. Stapling devices provide for faster and reliable sealing of tissues with division of intervening parenchyma. Stapling devices have also been used for securing hepatic veins and major portal vein and hepatic arterial branches even in open liver resections. Multiple stapler cartridges are required for major liver resections and are probably best used in a left lateral segmentectomy wherein only a small bit of liver parenchymal resection needs to be done. The use of stapling devices increases the cost of the surgical procedures substantially. Another disadvantage with stapling devices is the need for Pringle's manoeuvre for inflow control and requirement for additional devices for achieving haemostasis.

There are numerous surgical series describing the use of staplers in liver resection. In a series of 101 patients undergoing minor or major liver resections, Balaa et al reported a median operating time of 336 minutes, 10% requirement of blood transfusions, an average post-operative length of stay of 6 days and requirement of 8-10 stapler cartridges for complete parenchymal transection for a right hepatectomy[11]. In another series, Delis et al, reported their experience of using stapling devices in 62 patients requiring minor or major liver resections. They reported a median total operative time of 150 minutes, a median transection time of 35 minutes, and a median hospital stay of 8 days[12].Schemmer et al reported the largest experience with the use of stapling devices for liver transections. They reported that the additional cost of the stapling devices may be partially offset by reduced operating time and need for blood transfusions[13].

Reddy et al have published a comparative analysis of vascular staplers with clamp crushing technique. They have reported overall lower operating time, blood loss and need for blood transfusions with the use of vascular staplers compared to clamp crushing technique[14].

Miscellaneous devices

Peng's multifunction operative dissector (PMOD)

This device is an electrosurgical pencil with an inbuilt system for coagulation, cutting, aspiration and dissection. This device was developed by Professor SY Peng in China in 1990 (Hangzhou Shuyou Medical Instrument Co, Hangzhou, Zhejiang, PR China) where it is being used extensively. The device is initially used to scrape the liver parenchyma. Suction ensures clear visibility of the bile ducts and vessels which can be simultaneously tackled with the same instrument without a need for change of instrument. This technique is also known as Curettage and Aspiration Dissection Technique (CADT). The same group has reported excellent transection speed and reduction in blood loss with the use of this device. In this technique, two devices can be simultaneously used, one in the operating surgeon's hand and the other in the assisting surgeon's hand, ensuring no need for frequent change of instruments. This technique can also be used in laparoscopic liver resections[15]. A major disadvantage with the use of this device is that intermittent inflow occlusion is required making it unsuitable for donor hepatectomy.

Literature evidence in techniques of hepatic parenchymal transection

Meta-analysis

Rahbari et al have reported a meta-analysis of clamp crushing vs other techniques of hepatic parenchymal transection. They reported no definitive advantage of other techniques compared to clamp crushing technique in terms of blood loss, transection time or hospital stay[16].

Gurusamy et al in a Cochrane review have reported no significant advantage of costlier techniques over clamp crushing technique.

Randomized trials

Dissecting sealer vs clamp crush

Arita et al have published a randomized trial comparing dissecting sealer and clamp crushing technique with 40 patients in each arm. There was no significant difference in blood loss, operating time or post-operative outcomes in the two groups[17].

Clamp crush vs ultrasonic dissector, water jet, dissecting sealer

Lesurtel et al, in a randomized trial in patients with noncirrhotic non-cholestatic liver, reported the lowest blood loss and fastest transection with clamp crush. Blood transfusion requirement was lowest with clamp crushing technique. There was no significant difference between the rest of the three groups. There was a higher need for inflow occlusion with clamp crushing technique. For obvious reasons, clamp crushing was associated with the lowest costs[18].

Radio-frequency vs clamp crushing

Lupo et al reported a randomized trial comparing radiofrequency-assisted liver resection with clamp crushing technique. The trial included 50 patients, 24 in the RF, and 26 in the clamp crushing groups. There was similar blood transfusion requirement in the two groups. There was a higher incidence of infective and biliary complications in the RF arm[10].

LigaSurevs clamp crush

Ikeda et al reported a randomized trial comparing LigaSure with clamp crushing technique. This trial, with 60 patients in each group reported similar transection time and blood loss in both the groups[19].

Saiura et al, in a randomized trial with 30 patients in each arm reported less blood loss and a trend towards higher bile leak rates with LigaSure compared to clamp crushing technique in minor hepatectomy, but not overall[20].

CUSA vs clamp crush

Takayama et al reported a randomized trial with 132 patients. Parenchymal transection was done in all patients under inflow control. There was no difference in the two groups with respect to blood loss, transection time, with poor quality of hepatic transection[21].

Hydrojet vs CUSA

Rau et al have reported reduced transection time, need for inflow control, blood loss and transfusion requirement with hydrojet compared to CUSA in a randomized trial involving 61 patients, with no difference in mortality.

CUSA with bipolar cautery vs CUSA with RF coagulator

Moghazy et al reported a randomized trial comparing the use of bipolar cautery and RF energy (both in combination with CUSA) in 24 living liver donors. They reported lower blood loss and faster transection with RF energy with similar morbidity in both the groups[22].

Clamp crush vs stapler hepatectomy

The CRUNSH trial is an ongoing German trial comparing clamp crushing with stapler hepatectomy in open liver resections. The planned sample size is 130 in each group[23]. This is an ongoing trial and no results are available.

CONCLUSIONS

There are a large number of techniques for resecting the liver parenchyma. According to the literature, there is little benefit of using the costlier devices over the clamp crushing technique. However a major disadvantage of clamp crushing is the need for inflow occlusion and this limits its applicability in donor hepatectomy. The clamp crushing technique is also not possible in laparoscopic liver resections. The authors prefer to use clamp crushing technique with a bipolar cautery for most liver resectionsand CUSA with a bipolar cautery for donor hepatectomy.

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