Open Access Journal of Cancer & Oncology

# Techniques and Energy Sources for Liver Resection: When and How?

Research Article

Volume 2 Issue 1

**Received Date**: January 03, 2018

**Published Date:** January 17, 2018

DOI: 10.23880/oajco-16000117

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## Abstract

Liver resections has always been a very interesting point of discussion among surgeons and so far various techniques and devices have been proposed in literature to reduce morbidity and mortality associated with the liver surgeries. Knowledge and expertise of vascular control is a key to achieve decreased intraoperative blood loss and to improve perioperative outcome. Better understanding of liver anatomy, improved perioperative care, and advanced equipments and energy sources has improved this aspect of patient care. This review article describes the various approaches and techniques for liver resection and also highlights the comparison among the various techniques which might be helpful to understand this vast subject.

**Keywords:** Liver resection; Energy sources; Liver anatomy; Perioperative care

## Introduction

Techniques of liver resection has always been an evolving process over the era ever since it was first described by Lortat-Jacob's where they first reported a true anatomical right hepatectomy for cancer in 1952 [1]. However, the subsequent experience was not very encouraging when in a multicenter analysis of 621 hepatic resections was highlighted by Foster and Berman in 1977, where the reported operative mortality was 13% and over 20% for major resections with mortality rates reaching 20% of the deaths resulting from haemorrhage [2]. With the advancements in surgical technique and energy sources, the skilled liver surgeon is able to reduce morbidity and mortality rates to 3% and 5% respectively and it can now be accomplished with mortality rates of less than 3% in most specialised hepatopancreato-bilary (HPB) centres as shown by Jarnagin, et al. [3]. The most important factor for determining better postoperative outcome is reduced blood loss due to improvement in surgical techniques. Liver transaction is the most challenging part of liver resection, associated with a risk of massive haemorrhage. Significant bleeding usually occurs at three phases during a liver resection. The first phase is during initial mobilisation especially if the tumour is bulky, posteriorly situated, adjacent to the right or middle hepatic veins and adherent to diaphragm or retrohepaticvena cava. The second phase is during transaction of friable, steatotic or cirrhotic parenchyma in a liver in which parenchymal division is aggravated by distortion or displacement of intrahepatic veins by tumour and the third stage where bleeding may occur from parenchyma at the resection margin [4]. The present reviews and discusses the advantages and limitations which the surgeon encounters during parenchymal division and evidence from the literature on the efficacy of different techniques.

## Approaches and Techniques

There are many techniques and devices for liver transection have been proposed and invented so far but yet no consensus on the best method has yet been established. Understanding the segmental anatomy of the liver and delineation of the proper transection plane using intraoperative ultrasound are prerequisites to safe liver transection because better patient selection in terms of liver function reserve is also an important and major factor for improved perioperative outcome [5].

Excessive haemorrhage and perioperative blood transfusion not only increase the risk of operative morbidity and mortality, but also jeopardize long-term survival after resection of liver malignancies. Recent reduction in perioperative blood transfusion after resection of hepatocellular carcinoma has contributed to improved long-term patient survival [6]. Clamp crushing and ultrasonic dissection are the two most widely used transection techniques Various techniques and devices reported so far, have been compared (Table 1) and Clamp- crushing resection (CCR) or Finger fracture technique is a gold standard one for transection of liver parenchyma against which all other techniques have been compared in literature [7].

| Authors | Patients | Technique | Blood loss/ transfused patients | Operative Time( min) | Transection Speed (cm2/s) |
|---|---|---|---|---|---|
| Takayama, et al. | 132<br>(66 vs. 66) | CCR<br>CUSA | 452a/NA515a/NA | 54b<br>61b | 1.0<br>1.1 |
| Rau, et al. | 61 | Hydrojet dissector<br>CUSA | NA/1.5<br>NA/2.5 | 28b<br>46b | NA |
| Koo, et al. | 50<br>(25 vs. 25) | CCR<br>CUSA | 792a/NA<br>875a/NA | 119<br>139 | NA |
| Lesurtel, et al. | 100<br>(4 groups, 25 each) | CCR<br>CUSA<br>Hydrojet dissector<br>RF dissecting sealer | 1.5cNA<br>4c/NA<br>3.5c/NA<br>3.4c/NA | NA | 3.9<br>2.3<br>2.4<br>2.5 |
| Arita, et al. | 80(40 vs. 40) | CCR<br>RF dissecting sealer | 733a/0<br>665a/2 | 80<br>79 | 0.89<br>0.99 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | |

Table 1: Comparison of different techniques in liver transection [7-12]
Only randomized trials are reported; NA : Not available in the study.
a: Blood loss(ml) ; b: Value refers only to transection time; c: Blood loss( ml/cm2)
CCR: Clamp-crushing resection Technique; RF: radio frequency dissecting sealer
CUSA: Cavitron ultrasonic surgical aspirator
The number of patients transfused is expressed as a mean only in the trial by Rau, et al. [9].

## Methods for Vascular Control

In order to perform safe and secure liver resections and to minimize blood loss one should be well aware of all methods of hepatic vascular occlusion techniques and these are based upon three factors mainly: (i) type of resection to be performed, (ii) tumor size and location, and (iii) preoperative liver function.

The various techniques have been proposed so far in literature ranging from Pringle's manoeuver (portal triad clamping) to total hepatic vascular exclusion, including inflow occlusion (selective or total), hemi-hepatic clamping, and ischemic pre-conditioning [13].

Inflow occlusion by hepatic pedicle is a consistent method of vascular control, and is not very demanding technically. Though it addresses the portal vein and hepatic artery but it does not prevent back-bleeding from the hepatic veins [14].

The Pringle maneuver can be performed continuously or intermittently, when performed intermittently, the portal triad is typically clamped for 10 minutes and then unclamped for 3 minutes (the clamping on and off time varies). This allows for a longer total occlusion time of up to 2 hours in the normal liver, which can be useful for more prolonged complex liver resections [15]. A prospective, randomized study by Clavien, et al. demonstrated that a 10 minute sequence of ischemia and reperfusion proceeding a longer 30 minute period of continuous vascular occlusion was a protective strategy in humans. Clavien, et al. in their study, reported this to be more effective for younger patients requiring a prolonged period of inflow occlusion [16]. In a recent met analysis, when ischemic preconditioning was compared with intermittent Pringle did not show any significant difference in terms of blood loss [17]. The continuous Pringle maneuver allows for shorter total occlusion time, and has the advantage of avoiding interruption of the parenchymal transaction [18]. Both the continuous and intermittent methods should be used for shorter time periods in the setting of cirrhotic liver or patients who have undergone preoperative chemotherapy.

Total hepatic vascular exclusion is another method of reducing blood loss during liver resection by occluding the inflow and outflow. This technique prevents the risk of retrograde hepatic vein bleeding and hence also decreases the risks of air embolism. Though it's a bit technically difficult than pedicle clamping alone, this method may be performed by clamping the portal triad in addition to clamping the infrahepatic and suprahepatic vena cava, or more selectively by clamping the hepatic veins extra- parenchymal and preserving caval flow. One of the major challenges of total hepatic vascular occlusion is the hemodynamic alteration, which may be poorly tolerated in up to 15% of patients. It is associated with an increased risk of postoperative complications, increased operative time, and lacks significant benefit over portal triad clamping alone with regards to blood loss, transfusion requirements, and liver failure [13].

Intrahepatic pedicle ligation is another technique important in decreasing blood loss and operative time. Right, left or smaller branches of the portal vasculature are ligated as per the location of tumor and segment of the liver to be resected [13].

## Energy Devices and Techniques

Multiple approaches have evolved to reduce intraoperative bleeding resection and in order to reduce postoperative morbidity as well. Postoperative outcome is correlated well with intraoperative and perioperative bleeding and requirement of blood transfusion and also contributes to improved overall survival when done for malignant mass lesions [11,19]. We shall discuss following devices in detail highlighting their role in liver parenchymal transection;

1. Clamp crushing/ Finger fracture techniques
2. Ultrasonic dissection
3. Water jet
4. Ligasure
5. Harmonic Scalpel
6. Tissue-Link dissecting sealer
7. Radiofrequency-assisted liver transection

## Techniques

1. Fusion techniques
2. Vascular staples

**Clamp Crushing/ Finger fracture Technique**: It's a gold standard one and still one of the most widely used techniques of liver transection. Cirrhotic liver further poses more challenges to the hepatic surgeon due to the fibrotic and friable nature of liver tissue. The finger fracture technique, first introduced by Lin et al. in 1958, involves crushing of liver parenchyma by fingers under inflow occlusion to isolate vessels and bile ducts for ligation [20]. This technique was subsequently improved by the use of surgical instruments such as a Kelly clamp for blunt dissection (clamp crushing) hence it's synonymous to clamp crushing resection (CCR) technique [20].

**Ultrasonic dissection:** In many high volume centres ultrasonic dissection using Cavitron Ultrasonic Surgical Aspirator (CUSA) device has become method of choice for liver parenchymal transection (Figure 1). It vibrates with the frequency of 25K Hz and with this ultrasonic energy liver parenchyma tissue is fragmented with aspirated and vascular and biliary ductless thus exposed are ligated with prolene 4-0 suture and clipped with Titanium hemoclips. CUSA enabled a more selective identification and ligation of more tiny vessels arising from liver parenchyma. Lesurtel et al in their study compared CCR, CUSA and Hydrojet and RF sealer and concluded that CUSA being a better energy device than Hydrojet and RF sealer in terms of blood loss and transection speed [11]. In another retrospective conducted by Fan et al showed that the CUSA resulted in lower blood loss, lower morbidity and lower mortality compared with the CCR [21]. Furthermore, CUSAdelineates preciseretrasection plane and therefore results in a wider tumour-free margin. However, later in 2001 when a Japanese group conducted a randomized controlled trial comparing CUSA and CCR, no significant differences in blood loss, transection speed, tumour exposure at the surgical margin, or postoperative morbidity were observed [8].

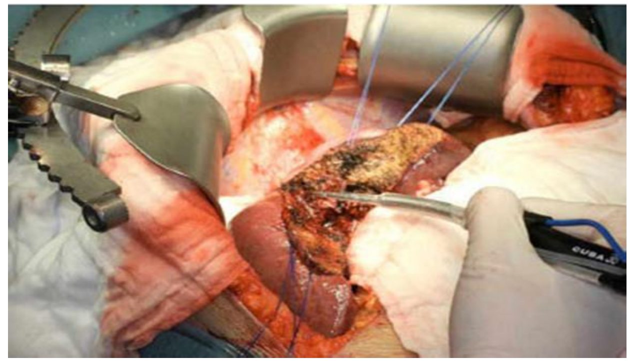

Figure 1: Parenchymal transection using CUSA.

**Water jet/Hydro jet**: It utilises pressurized jet of water instead of ultrasonic energy to fragment the liver parenchyma tissue and expose the vascular and ductal structures and only few randomised studies are in literature to compare this with the standard CCR or CUSA. One study by Rau et al, compared outcomes following liver resection using CUSA and Hydrojet concluded that Hydrojet transection reduced blood loss, blood transfusion, and transection time compared with CUSA. However, this technique has never gained popularity over CUSA and to date both CUSA and water jet techniques are quite good for dissecting out major hepatic veins where tumors are in close proximity and prevents positive resection margin [9].

**Ligasure**: Ligasure is another device effective in sealing vessels of 7 mm diameter by employing combination of pressurised compression and radio frequency (RF) energy. In a prospective randomised study by Romano et al, authors have reported no clinical evidence of bile leak when Ligasure was employed for liver parenchyma transection of 30 patients though it was failed to achieve good hemostasis in patients with cirrhotic liver [22]. In another published randomized controlled trial the effectiveness of combination of CCR and Ligasure was demonstrated where it resulted in lower blood loss and faster transection speed in minor liver resections compared with the conventional technique of electric cautery or ligature for controlling vessels in the transection plane however, the bile leakage rate with the use of Ligasure alone was 9% compared with 3% in the conventional technique group, but the difference was not statistically significant [23]. Constant et al in 2005 proposed laparoscopic Ligasure to be a useful instrument for laparoscopic liver transection of peripheral liver lesions where it was shown to have similar efficacy as Harmonic Scalpel [24].

**Harmonic Scalpel:** Ultrasonic/ Harmonic scalpel is a device which was developed to seal small vessels during liver resection. It uses ultrasonic waves to vibrate longitudinal blades at 55.5 kHz and it can be used alone or in combination with CCR or CUSA for better results in order to reduce blood loss and speed up the transection process and to shorten second phase of liver transection where liver parenchyma is transected. Ultrasonic waves coagulates protein by deturing them and generates the heat in vibrating tissue and there by coagulating blood vessels up to 2-3 mm in diameter. Schmidbauer et al, in 2002 studied 41 patients and published the efficacy of Harmonic Scalpel in both open and laparoscopic liver resections, with nobiliary leakage [25]. Aldrighetti L et al in 2006 proposed that when combined with ultrasonic dissection it may reduce the blood loss and it may also be useful in transection of cirrhotic liver, for which the clamp crushing technique may not be the very effective one [26].

**Tissue-Link Dissecting Sealer**: In this instrument, saline flows down to the tip of the electrode and couples with the RF energy on to the liver surface and achieve dissection and coagulation simultaneously with the pointed tip. Poon et al in their preliminary experience of Tissue-Link dissecting sealer without the use of CUSA or CCR for liver parenchyma resection in 10 cases reported the median blood loss of 100 ml (range 30-700 ml) with no postoperative bile leakage. This can also be successfully employed in laparoscopic liver resection [27].

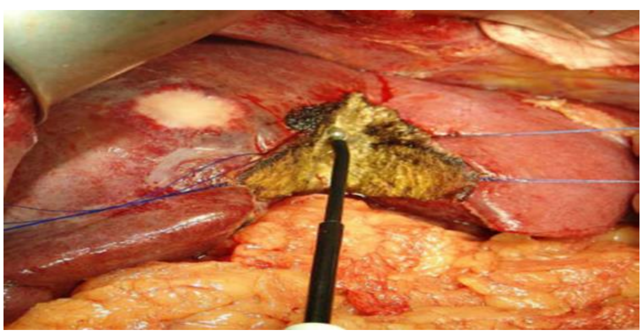

Figure 2: Tissue Link dissector sealer dissecting liver parenchyma

**Radio-frequency assisted liver transection**: This is relatively newer modality of liver parenchymal transection and first applied in detail by Weber et al when he studied its role in 15 patients where he reported mainly segmental or wedge resection and the mean blood loss was only 30+/- 10 ml, and no complications such as bile leakage was observed [28]. Stella et al in 2003 also reported the same results with this technique [29]. One potential disadvantage of these techniques that approximately 1 cm of the normal remnant liver parenchymal tissue is jeopardised at the transection margin which may not be acceptable in patients with liver cirrhosis. Possible thermal injury to the Hilary structures and hepatic veins is another major concern with this device [30]. However, this device is a safe and good option for laparoscopic wedge resection or segmentectomy. This device has been shown to reduce bleeding compared with CUSA in a pilot study [31].

## Techniques

### Fusion Technique

This technique came in picture in order to overcome limitations of Harmonic Scalpel and hence Harmonic FOCUS (HF) was evolved. This device crushes the liver parenchyma by the non-activated HF, and the tiny areas of residual tissue are completely sealed with the activated HF. This device there by allows accurate exposure and sealing "under direct vision" and appears to reduce bleeding as well as postoperative bile leakages. This new technique has been called "fusion technique" or the so called focus-clysis or 'fusion technique'. This technique is able to coagulate vessels of 1- 5 mm diameter and vessels larger than this needs to be divided and ligated in a traditional fashion [32,33].

### Vascular Staplers

Inflow and outflow controls and liver parenchyma resection, both are important and crucial steps in reducing blood loss in liver surgery and both aims can be achieved by using Staplers [34]. Particularly when it comes to divide major trunk of hepatic veins or the middle hepatic vein in deeper trasection planes. Vascular staplers also can be used to divide the hepatic duct pedicle in right or left hepatectomy and this saves time from time consuming suturing. One problem associated with the use of a stapler is increased risk of bile leak, since the stapler is not very effective in sealing Small bile ducts [35].

| Device | Advantages | Disadvantages |
|---|---|---|
| CUSA | Accurate vessels identified by tactile feedback | Difficult to coagulate vessels in cirrhotic liver |

| | | |
|---|---|---|
| Water Jet | Selective dissection<br>Minimal marginal necrosis | Splash |
| Harmonic Scalpel | Simultaneous cutting and coagulation | Blind dissection |
| Ligasure | Simultaneous cutting and coagulation | Precoagulation technique, blind dissection |
| Tissue Link | Friendlie | Low precision, steam popping |
| Stapler | Speed | Not good for larger and deeper tumors |

Table 2: Comparative ranking of various energy devices [27]

Table 2 subjectively ranks the six instruments according to perceived usefulness in various clinical scenarios. For resection of malignancies, usually CUSA is ranked number one because of its ability to stay within tissue planes during resections while preserving vessels for ligature.

## Conclusion

Clamp crushing and ultrasonic dissection is currently the two most popular techniques of liver transection. The role of new instruments such as ultrasonic scalpel and RF ablation devices in liver transection remains unclear, with few data available in the literature. The role of Pringle man oeuvre seems to be decreasing with improved transection technique. However, it remains a useful technique in reducing bleeding from inflow vessels, especially for surgeons with less experience in liver resection.

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