Open hepatic parenchymal transection using ultrasonic dissection and bipolar coagulation

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Abstract
Liver transection is the most challenging part of liver resection due to the risk of massive blood loss which is associated with increased postoperative morbidity and mortality, as well as reduced long-term survival after resection of malignancies. Among the devices used for open parenchyma transection, ultrasonic dissection with bipolar cautery forceps is one of the most widely used technique worldwide. We identified four retrospective comparative studies and three randomized controlled trials dealing with the efficacy of ultrasonic dissector (UD) compared with other techniques including the historical clamp crushing technique. UD is associated with similar blood loss and slower resection time compared with water-jet or clamp crushing technique. However, it seems to be more precise in dissecting vessels. Its use does not impact on morbidity and hospital stay compared with other techniques. From an economic point of view, UD is the most expensive technique and may be a disadvantage for low centre volume. UD with bipolar cautery is one of the safest and the most efficient device for liver transection, even if its superiority over the clamp crushing technique has not been well established. It is considered as a standard technique for liver transection.

Key Words: Liver transection, ultrasonic dissector, clamp crushing, bipolar coagulation

Introduction
Liver resection has been increasingly performed over the last two decades worldwide due to improved postoperative outcomes and evidence that this approach offers the only chance of cure in many patients [1–4]. Technical innovations have mainly focused on minimizing bleeding during transection of the hepatic parenchyma [5,6] since excessive hemorrhage and the need for blood transfusion are associated with increased postoperative morbidity and mortality [7], as well as reduced long-term survival after resection of malignancies [7–9]. Indeed, associated-blood loss immunosuppression leads to a higher risk of tumor recurrence [7,10]. Inflow occlusion (Pringle maneuver) has been used since the early 20th century [11] to prevent bleeding during parenchyma transection [12–15]. The concomitant use of low central venous pressure (CVP) anesthesia further minimizes blood loss by preventing retrograde bleeding from the hepatic veins [16,17].

Beyond inflow occlusion and low CVP, there has been a growing interest in using new devices that facilitate bloodless transection. These include ultrasonic dissector (UD), water-jet, TissueLink dissecting sealer, or Ligasure. Parenchymal transection under routine inflow occlusion has been performed with finger fracture technique (digitoclasy) [18], where liver parenchyma was crushed between the thumb and one finger isolating vessels and bile ducts, which can then be ligated and divided. This technique was subsequently improved through the use of surgical instruments such as small Kelly or Pécan clamps (clamp crushing) for blunt transection [19]. The second most common device used worldwide for liver transection is the UD (Cavitron Ultrasonic Surgical Aspirator (CUSA) or Dissectron, both Integra NeuroSciences). It was introduced in 1984 by Hodgson and DelGuerco as an instrument for parenchymal transection during hepatectomy [20]. With this technology, the liver parenchyma is fragmented by ultrasonic energy and aspirated, thus exposing vascular...
and ductal structures that can be ligated or clipped. However, successive ligation of peripheral fragile Glisson’s tissue and the very thin hepatic veins is not only time-consuming, it can also be unsuccessful. To improve bleeding and bile leak control, UD has been associated with bipolar cautery to coagulate the tiny structures. To avoid coagulated tissue to stick to and to tear off frail vessels, the tip of bipolar cautery has been equipped with a channel for water dripping [21].

This article deals with the efficacy of UD associated with bipolar cautery for liver transection based on our experience and review of the literature. It also points out the usefulness and the efficacy of a new irrigation-free bipolar cautery forceps (Isocool, Codman, Raynham, USA).

Material and methods

An electronic search of Medline was undertaken to identify original articles, comparative studies, randomized controlled trials (RCT), and reviews about the subject. The terms “liver resection”, “liver transection” and “UD” were used in various combinations. The search terms were identified in the title, abstract, or medical subject heading (MeSH). With few exceptions, only original articles published in English were selected for further analysis. Manual cross-referencing was also used to find further relevant articles. All articles were classified according to their level of evidence. The classification proposed by the Oxford Center for Evidence-based Medicine was used to rank each publication [22,23]. According to literature, we assessed ultrasonic dissection associated with bipolar cautery regarding its impact on peroperative blood loss, resection time, tumor-free resection margin, postoperative morbidity and cost-effectiveness.

Ultrasonic dissection

The principle of the ultrasonic dissection is a cavitation effect which occurs at the tip of the vibrating rod of the device. The handpiece delivers ultrasonic vibration and provides simultaneous aspiration and irrigation. The ultrasonic probe divides parenchymal cells (because of their high water content) by the cavitation effect with minor injury to structures with a high content of fibrous tissue, e.g., bile ducts and blood vessels [24,25]. Once skeletonized by the probe, these elements are then clipped, ligated or coagulated if small (Figure 1). Additional electrocoagulation functions are optionally available. The ultrasonic and high frequency currents can be activated simultaneously to divide and coagulate vessels, ducts, and nerves.

Bipolar electrocautery

After sonication of parenchymal cells, the tissue of small branches of Glisson’s tree or small tributaries of the hepatic veins are coagulated by bipolar electrocautery before being cut by scissors. The use of bipolar cautery is not always satisfactory because coagulated tissue often sticks to the electrocautery blades and tears frail vessels. Therefore, bipolar cautery equipped with saline irrigation channel has been developed [21]. Irrigation with saline droplets was carried out to prevent adhesion of debris to the cautery blades and to facilitate their smooth removal from coagulated vessels without tearing fragile tissue. Furthermore, it prevents blades to char. On the other hand, the use of an irrigated bipolar cautery is not always convenient due to self-made system or not comfortable due to continuous wet operating field. Since a short time, we have used a very efficient irrigation-free bipolar cautery forceps plated with gold-polytetrafluoroethylene (PTFE) composite film, which reduces sticking and charring while coagulating (Isocool, Codman, Raynham, USA) [26]. Thanks to an active heat transfer technology, it continuously transfers excess heat away from the single-use gold tips and allows effective coagulation temperatures to be achieved. Eliminating sticking and charring of delicate tissue, it minimizes the need to remove the forceps from the surgical site, clean them, and then reorient (Figure 2).

Results

We identified four retrospective comparative studies [21,27–29] and three RCT [30–32] dealing with the efficacy of UD compared to other techniques including the historical clamp crushing technique. The data are summarized in Table 1.

Peroperative blood loss

All the selected articles assessed peroperative blood loss according to the device used for liver transection. All but one retrospective studies reported lower peroperative blood loss using UD compared with
clamp crushing [21,27,29]. Inversely, two of the RCT did not showed any difference in terms of peroperative blood loss in patients undergoing liver transection with UD compared with clamp crushing [31] or with water-jet [30]. The RCT by Lesurtel et al. reported significant higher blood loss during liver transaction with UD than with clamp crushing [32].

These discrepancies may found several explanations. First, the methodology of retrospective comparative studies is inherently associated with a bias since they compared patients undergoing liver transection with UD with historical former cohorts of patients operated on using clamp crushing. It is noteworthy that these retrospective studies reported very high means of peroperative blood loss ranging from 700 mL to 3400 mL [21,27–29]. Over the recent years, experimented surgical teams reported lower means of blood loss even for major hepatectomies [1,33]. Second, in the RCT by Lesurtel et al. [32], clamp crushing was associated with systematic inflow occlusion while inflow occlusion was an endpoint in the three other techniques. This choice was made because new devices like UD were marketed with the claim that they were safer and can be used without the need of inflow occlusion.

In summary, there are no convincing data that UD is associated with less blood loss compared with clamp crushing or water-jet.

Resection time

Only two RCT reported slower resection speed (twice less) using UD compared with water-jet [30] and clamp crushing [32]. All the other studies did not show any significant different resection time whatever the technique of liver transection used [21,27–29,31]. Only two RCT standardized the resection speed to the transection area (cm²/min) [31,32]. Takayama et al. [31] did not show any significant different transection speed between UD and clamp crushing, while UD was slower than clamp crushing in the trial by Lesurtel et al. [32].

Tumor resection margin

Two studies tried to assess tumor-free margin using UD [27,31]. In the study by Fan et al. [27] hepatectomy was performed with UD for hepatocellular carcinoma. UD resulted in a wider tumor-free margin because of a more precise transection plane. On the other hand, in the RCT by Takayama et al. [31] UD was associated with more frequent histologically proven tumor exposure at the surgical margin, while not significant. Using a grading system to grade the quality of liver transection, the group demonstrated better quality of hepatectomy using the clamp crushing technique.

Postoperative morbidity and hospital stay

Only two retrospective comparative studies reported a decreased morbidity rate in patients undergoing liver transection with UD [21,27]. In the study by Fan et al. [27], half of the patients who underwent hepatectomy for hepatocellular carcinoma had a cirrhosis. There were significantly more postoperative complications in patients undergoing liver transection using clamp crushing than with UD. The mortality rate was significantly higher in the clamp crushing group and was associated with massive intraoperative bleeding that led to fatal hepatic coma. However, surgery was noteworthy associated with very high mean of blood loss ranging from 2400 mL to 3400 mL in both groups. Yamamoto et al. [21] showed that UD and irrigated bipolar cautery enabled to perform liver transection without inflow occlusion. They reported a decreased morbidity in patients who have less hepatic functional reserve by avoiding ischemic stress. None of the other studies were able to show any different morbidity rate between UD and clamp crushing techniques [28–32]. The article by Nakayama et al. which focused on the risk of bile leak following liver transection with clamp crushing, microwave coagulation and UD, did not demonstrate any difference between clamp crushing and UD [28].

Finally, the hospital stay following liver resection was similar regardless the technique of liver transection used [28,32].

Cost

There is only one RCT which assessed the cost of devices used for liver transection [32]. The clamp crushing technique was the least expensive device and appeared to provide significant cost savings regardless of the volume of liver resections performed per year. Inversely, UD was the most expensive technique due
Table 1. Studies assessing ultrasonic dissector.

<table>
<thead>
<tr>
<th>Studies assessing ultrasonic dissection</th>
<th>Type of study</th>
<th>Level</th>
<th>UD compared with</th>
<th>No. of patients</th>
<th>Impact of ultrasonic dissector on</th>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Blood loss</td>
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<tr>
<td>Fan et al. [27] British J Surg 1996</td>
<td>Retrospective</td>
<td>3b</td>
<td>Clamp crushing</td>
<td>Clamp n = 96</td>
<td>lower</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>UD n = 69</td>
<td></td>
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<tr>
<td>Yamamoto et al. [21] World J Surgery 1999</td>
<td>Retrospective</td>
<td>3b</td>
<td>Clamp crushing</td>
<td>Clamp n = 108</td>
<td>lower</td>
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<td></td>
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<td></td>
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<td>UD n = 83</td>
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<tr>
<td>Rau et al. [30] Zentralblatt für Chirurgie 2001</td>
<td>RCT</td>
<td>2b</td>
<td>Water-jet dissector</td>
<td>Water-jet n = 31</td>
<td>ns</td>
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<td></td>
<td>UD n = 30</td>
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<tr>
<td>Takayama et al. [31] Arch Surg 2001</td>
<td>RCT</td>
<td>1b</td>
<td>Clamp crushing</td>
<td>Clamp n = 66</td>
<td>ns</td>
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<td></td>
<td></td>
<td></td>
<td>UD n = 66</td>
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<tr>
<td>Tanai et al. [29] Hepatogastroenterology 2002</td>
<td>Retrospective</td>
<td>3b</td>
<td>Clamp crushing</td>
<td>Clamp n = 40</td>
<td>lower</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>UD n = 25</td>
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<tr>
<td>Nakayama et al. [28] Hepatogastroenterology 2003</td>
<td>Retrospective</td>
<td>3b</td>
<td>Clamp crushing and microwave coagulation</td>
<td>Microwave n = 30</td>
<td>ns</td>
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<tr>
<td></td>
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<td>UD n = 29</td>
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<tr>
<td>Lesurtel et al. [32] Ann Surg 2005</td>
<td>RCT</td>
<td>1b</td>
<td>Clamp crushing</td>
<td>Clamp n = 25</td>
<td>higher compared with clamp</td>
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<tr>
<td></td>
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<td></td>
<td>Water-jet Dissecting sealer</td>
<td>Water-jet n = 25</td>
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<td>Sealer n = 25</td>
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<td>UD n = 25</td>
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</table>

RCT: Randomized controlled trial; UD: Ultrasonic dissector.
to capital equipment, costs of maintenance and costs of disposal material.

**Discussion**

Clamp crushing and UD are currently the two most popular techniques of liver transection [34]. Both techniques have been improved by the use of bipolar electrocoagulation to coagulate tiny bile ducts and vessels to allow better control of bleeding and oozing from the cutting surface. To minimize the blades sticking and charring, bipolar forceps equipped with saline irrigation channel has been developed [21]. We know use a new irrigation-free bipolar cautery forceps (Isocool, Codman, Raynham, USA), whose tips are plated with gold-PTFE composite film, which reduces sticking and charring without the drawbacks of saline irrigation [26].

Although several publications, convincing data about the superiority of clamp crushing, UD or other new devices for liver transection are lacking. Indeed, most of the data come from low evidence retrospective studies [21,28,29,35–41], inhomogeneous studies including cirrhotic and normal livers [27,31] or studies missing standardization of the endpoints to the transection surface. Therefore, the choice of the technique is often based on the individual surgeon’s preference or experience.

However, some recommendations can be made about UD and clamp crushing technique based on data from the literature and from our experience. First, according to Makuuchi’s group, it is likely that surgeons experienced in hepatic resection will achieve comparable levels of blood loss and transection time whatever clamp or UD used [31]. Second, UD is probably more precise for dissection of the major branches of the hepatic veins, or in case where the tumor is closed to a major hepatic vein. In spite its precision in dividing vessels, avoiding theoretically the need of inflow occlusion, Lesur et al. demonstrated that Pringle maneuver was needed in one third of patients undergoing liver transection with UD [32]. In other words, even if UD theoretically divides liver parenchyma without vessel injury, bleeding from smaller vessels, particularly veins, does occur impairing optimal visibility of the transection plan, leading to increase bleeding and slower transection speed. Third, clamp crushing is a simple and low-cost technique. Its use seems to be optimal and safe in association with inflow occlusion. It requires substan-

tial experience in the cirrhotic liver, while UD can be used in both cirrhotic and non-cirrhotic liver. However, there is no convincing data supporting this and we are going to initiate a multicentric RCT comparing clamp crushing and UD for transection of the cirrhotic liver.

The main drawbacks of UD would be its slow transection speed, its difficulty in handling at the resection bottom and its limitation in making a small-range curved plan [31]. Finally its cost could be a disadvantage for low center volume. Indeed, the equipment’s costs of UD depends strongly on the number of cases per year since it requires a large initial purchase with lower costs for disposal material.

In conclusion, UD associated with efficient bipolar forceps cautery is probably one of the safest and the most efficient device for liver transection, even if its superiority over the clamp crushing technique has not been well established. In spite of the wide development of many new devices since a few years, UD is still considered as a standard technique for liver transection.

**References**


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