Differences between bipolar compression and ultrasonic devices for parenchymal transection during laparoscopic liver resection

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Abstract

Objectives: In laparoscopic liver resection, multiple options for parenchymal transection techniques exist; however, none have emerged as superior. The aim of this study was to compare operative characteristics and outcomes between bipolar compression and ultrasonic devices used for parenchymal transection during laparoscopic liver resection.

Methods: A review of a prospective hepatopancreatobiliary database from December 2002 to August 2009 identified 54 patients who underwent laparoscopic liver resection with parenchymal division using either a bipolar compression (n = 35) or an ultrasonic (n = 19) device. Operative data, histology and 90-day complication rates were compared between the groups using analysis of variance (ANOVA) and Pearson’s chi-squared test.

Results: The two groups did not differ significantly in terms of age, body mass index, parenchymal steatosis/inflammation or number of segments resected. A shorter time of parenchymal transection was noted for the bipolar compression device (median: 35 min; range: 20–65 min) vs. the ultrasonic device (median: 55 min; range: 29–75 min) (P < 0.001). Median total operative time was also shorter using the bipolar compression device (130 min) than the ultrasonic device (180 min) (P = 0.050). No significant differences between device groups were noted for estimated blood loss, complications of any type or liver-specific complications.

Conclusions: Bipolar compression devices may offer advantages over ultrasonic devices in terms of decreased transection time and total operative time. No differences in postoperative complications in laparoscopic liver resection emerged between patients operated using the devices.

Keywords
hepatic, resection, transection, bipolar compression device, ultrasonic device, laparoscopic

Introduction

Recent reports and consensus statements continue to demonstrate the safety, minimal mortality and low morbidity rates associated with hepatic resection. In part, better outcomes can be attributed to advances in techniques for parenchymal transection, which have facilitated a reduction in transection-related blood loss.

The mode of parenchymal transection in hepatic resection has been a topic of great debate for decades and a multitude of different techniques and technologies have been available to surgeons. Hepatic resections have now evolved from strictly open operations into laparoscopic and robot-assisted procedures. Morbidity and mortality after hepatic resection have progressively decreased over the years as a result of improvements in equipment, operative technique and anaesthesia management.

The subsequent expansion in the volume of procedures conducted means patients can now be offered resection at centres that are committed to excellence in liver surgery. Prior to 1980, mortality rates were reported to be in the 10–20% range and many deaths were related to perioperative haemorrhage. Perioperative

DOI:10.1111/j.1477-2574.2011.00414.x

HPB 2012, 14, 126–131 © 2012 International Hepato-Pancreato-Biliary Association
mortality has since dropped significantly to approximately 5%. The clamp-crush technique, first reported in 1974, has been used for decades and remains the standard means of parenchymal division for many surgeons. Control of intraoperative haemorrhage has been one of the principle technical challenges in advancing liver surgery. Excessive blood loss and intraoperative blood transfusions have been shown to be associated with increased perioperative mortality and morbidity, including an increased rate of hepatocellular carcinoma recurrence. Transfusions are also associated with increased postoperative infection and with increased cost. The overall cost of blood transfusions in surgical patients was recently examined. Each red blood cell unit was found to cost US$522–1183 when all major processes to preserve and administer blood were considered.

Many devices for the division of the liver parenchyma in both open and minimally invasive surgery are now available to surgeons (Table 1). These devices include the bipolar compression device (a device that uses bipolar energy and pressure in order to fuse collagen and elastin within the tissue), which has been shown to be safer for the patient and less expensive to use. However, studies have reported that ultrasonic energy devices shorten operative time and decrease postoperative complications.

The goal of this study was to compare the operative outcomes of laparoscopic hepatic transection performed using the bipolar compression and ultrasonic devices, respectively.

### Materials and methods

A prospective hepatopancreatobiliary database for patients operated from December 2002 to August 2009 at the University of Louisville was analysed. This study identified 54 consecutive patients who underwent laparoscopic liver resection with parenchymal division using either a bipolar compression device (Enseal®; Ethicon Endo-Surgery, Inc., Cincinnati, OH, USA) \((n = 35)\) or an ultrasonic scalpel (Harmonic Scalpel®; Ethicon Endo-Surgery, Inc.) \((n = 19)\).

The Harmonic Scalpel® utilizes the ultrasonic vibration of two blades to cause the destruction of hydrogen bonds. This disruption of hydrogen bonds causes protein denaturation, coagulating small vessels of <3 mm in diameter. The parenchyma is then cut by the saw-like motion of the device’s blades.

The senior author (RCGM) at the Louisville Medical Center performed all operations. The decision to use the bipolar over the ultrasonic device or vice versa was made at the discretion of the treating surgeon, who took the complexity of the operation and the level of comorbidities in the patient into account when deciding whether the operation should be performed laparoscopically, as well as the availability of the device at a certain hospital. Each device was only available at a certain hospital and thus the decision of which device to use was not influenced by the surgeon. The surgical technique has been published previously; in short, the abdomen is explored laparoscopically and the liver is mobilized and surveyed using laparoscopic ultrasound. The line of transection is identified and marked with electrocautery. Inflow may be occluded via intermittent Pringle application and the liver parenchyma is transected using a combination of haemostatic assisting devices, clips and vascular staplers. In the majority of patients, inflow and outflow are controlled intraparenchymally during parenchymal transection.

In this cohort of hepatic resection patients, anatomic segmental resections were performed and classified as described by Couinaud. The group agreed to and used the recent Society of Surgical Oncology and the American Hepato-Pancreatico-Biliary Association Consensus Conference definition of resectability, defined as allowing the resection of all visible disease and the leaving of enough liver for an appropriate recovery time.

Standard preoperative evaluation of patients with metastatic colorectal cancer included three-phase computed tomography of the abdomen and pelvis, and chest X-ray. Prior systemic chemotherapy of any type and duration was not regarded as indicating exclusion from laparoscopic resection and did not influence the choice of device utilized for parenchymal transection.

### Table 1 Reported comparisons of different transection devices for hepatectomy

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Patients, (n)</th>
<th>Devices compared</th>
<th>Conclusions from study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torzilli et al.</td>
<td>2008</td>
<td>76</td>
<td>Monopolar floating ball (MFB) vs. bipolar forceps (BF)</td>
<td>MFB has no significant benefit over BF</td>
</tr>
<tr>
<td>Jagannath et al.</td>
<td>2010</td>
<td>NS</td>
<td>Multiple instruments</td>
<td>No convincing evidence for the superiority of any single technique</td>
</tr>
<tr>
<td>Nanashima et al.</td>
<td>2010</td>
<td>33</td>
<td>Combination of crush clamping and vessel sealing</td>
<td>Safe and allows rapid completion</td>
</tr>
<tr>
<td>Burdio et al.</td>
<td>2003</td>
<td>8</td>
<td>Radiofrequency-assisted device</td>
<td>Reduced blood loss</td>
</tr>
<tr>
<td>Gehrig et al.</td>
<td>2011</td>
<td>14</td>
<td>LigaSure vs. conventional</td>
<td>LigaSure is feasible and safe and may lead to reduction in cost</td>
</tr>
<tr>
<td>Lesurtel et al.</td>
<td>2005</td>
<td>100</td>
<td>Crush clamp vs. compact ultrasonic surgical aspirator (CUSA) vs. hydrojet</td>
<td>Crush clamp was the most efficient device in terms of resection time, blood loss and blood transfusion</td>
</tr>
<tr>
<td>Takayama et al.</td>
<td>2001</td>
<td>132</td>
<td>Crush clamp vs. ultrasonic dissection</td>
<td>No difference in techniques</td>
</tr>
</tbody>
</table>

NS, not significant.
Radiofrequency ablation was performed in patients with bilobar disease, in whom the treating surgeon attempted to spare more normal, non-tumour-bearing parenchyma and performed the procedure using intraoperative ultrasonography guidance in order to achieve an ablation margin of ≥1 cm around the tumours. The technique for anaesthetic management during hepatectomy has been previously reported. In principle, low central venous pressure (<5 mmHg) was achieved and urine output of 25 ml/h and systolic blood pressure of >90 mmHg maintained during parenchymal transection. In the event that a synchronous colonic resection was planned, the liver resection was performed first so that the central venous pressure could be normalized during the subsequent colonic resection. Packed red blood cells and autologous blood were given to maintain a haemoglobin level >10 g/dl in patients with evidence of either coronary or cerebrovascular disease. Intraoperative blood products were not administered until blood loss exceeded 25% of total blood volume.

Outflow control of the hepatic veins, defined by the encircling of the vein with a short umbilical tape or complete dissection to allow for ease of control if needed, was performed prior to parenchymal division in all lobectomies or extended resections. The liver parenchyma was divided using the selected device with staple transection of major inflow and outflow vasculature. Intermittent inflow vascular occlusion (the Pringle manoeuvre) was used and applied for intervals of 5–10 min, released briefly and reapplied as necessary. Pringle time was recorded as the total cumulative Pringle time applied during parenchymal transection.

Postoperative complications and length of hospital stay were recorded and graded using a previously reported standard classification scale of complications. For patients with more than one complication, in-hospital and 90-day postoperative complications were compared according to the complication with the highest severity for each patient. Earlier cardiac history was defined as history of angina, previous coronary artery disease defined by cardiac catheterization, previous myocardial infarction, cardiac valve dysfunction requiring medication, or a history of congestive heart failure or tachyarrhythmia. Earlier pulmonary disease history was defined by an abnormal pulmonary function test, history of asthma requiring daily metre-dosed inhalers, or a history of tobacco use of >25 pack-years. All patients were reviewed and classified using a preoperative clinical risk prognostic scoring system defined for colorectal metastases. This 5-point, preoperative, clinical scoring system evaluates patients on five factors: a disease-free interval of <12 months; carcinoembryonic antigen (CEA) >200 ng/ml; the presence of lymph node-positive primary disease; the presence of more than one hepatic lesion, and the presence of a hepatic lesion ≥5 cm in size. Operative data, histology and 90-day complication rates were compared in order to investigate differences in outcomes between parenchymal transection devices.

Analysis of variance (ANOVA), Pearson’s chi-squared test and the Mann–Whitney U-test for normal, continuous and ordinal variables were used to evaluate the associations of independent variables with surgical completion. Proportional hazards analysis was performed on all variables found significant by univariate analysis. Relative risk (RR) with a 95% confidence interval was calculated as a measure of association. Analyses were performed using JMP Version 9.0 (release 2008) (SAS Institute, Inc., Cary, NC, USA). P-values of <0.05 were considered to indicate statistically significant differences.

Results

Fifty-four patients underwent laparoscopic liver resection with parenchymal division using either a bipolar compression device (n = 35, 65%) or an ultrasonic device (n = 19, 35%) (Table 2). The two groups were similar in terms of age, body mass index (BMI), parenchyma steatosis/inflammation, number of Couinaud segments resected, and distribution of abnormal parenchyma. Median operative blood loss was 100 ml (range: 20–1000 ml) in procedures performed using the bipolar compression device and 175 ml (range: 50–700 ml) in procedures performed using the ultrasonic device (P = 0.580).

Median time for parenchyma transection was 35 min (range: 20–65 min) in the bipolar compression device group and 55 min (range: 29–75 min) in the ultrasonic device group (P < 0.001) (Table 3). Median total operative duration was 130 min (range: 70–180 min) in the bipolar compression device group and 180 min (range: 80–240 min) in the ultrasonic device group (P = 0.050) (Table 3).

When complications in the two groups were examined post-surgery, there were no significant differences in terms of estimated blood loss (EBL), complications of any type or liver-specific complications (postoperative haemorrhage or bile leak) (Tables 3 and 4).

Discussion

New techniques, such as laparoscopic liver resection, have been proven as effective and safe for the treatment of cancers that are occurring at increasing incidences. At least 10 different techniques are available, but no convincing data evidencing the superiority of any single technique have emerged. The current study compared two devices used for liver resection, primarily because these devices: (i) were readily available within local institutions; (ii) have minimal set-up requirements, and (iii) have been established as effective in other gastrointestinal operations. Data from the current study showed no significant differences among patients in terms of age, BMI, parenchyma steatosis/inflammation or number of Couinaud segments resected. In addition, when postoperative outcomes were examined, no significant differences between the two devices used emerged. No differences were found in blood loss, complications of any type or liver-specific complications, such as haemorrhage or bile leak.

However, the data did show clinically significant differences between the techniques in median operative time and transection time (Table 3). Based on these data, bipolar compression devices...
may offer advantages of decreased transection time and total operative time over ultrasonic devices without causing any difference in rates of postoperative complications during laparoscopic liver resection. Other potential advantages of the bipolar compression device include less thermal spread. This is particularly beneficial in preventing collateral damage to surrounding structures, as well as the operating surgeon’s hands, in hand-assisted laparoscopic liver resection.

The issue of which means of technology in parenchymal division is safest and most efficacious in open and minimally invasive surgery is still a matter of debate. However, the bipolar compression device has shown promise in several studies.

Table 2 Clinical and demographic data for patients undergoing laparoscopic hepatectomy using either the bipolar compression device or the ultrasonic device

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Bipolar compression device (n = 35)</th>
<th>Ultrasonic device (n = 19)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years, median (range)</td>
<td>63 (42–83)</td>
<td>57 (29–81)</td>
<td>0.092</td>
</tr>
<tr>
<td>Gender, n</td>
<td>17 male</td>
<td>11 male</td>
<td>0.114</td>
</tr>
<tr>
<td></td>
<td>18 female</td>
<td>8 female</td>
<td></td>
</tr>
<tr>
<td>Cardiac history, n</td>
<td>7</td>
<td>2</td>
<td>0.084</td>
</tr>
<tr>
<td>Pulmonary history, n</td>
<td>5</td>
<td>2</td>
<td>0.121</td>
</tr>
<tr>
<td>Diabetes, n</td>
<td>6</td>
<td>9</td>
<td>0.142</td>
</tr>
<tr>
<td>Alcohol history, n</td>
<td>6</td>
<td>8</td>
<td>0.063</td>
</tr>
<tr>
<td>Past surgical history, n</td>
<td></td>
<td></td>
<td>0.523</td>
</tr>
<tr>
<td>Hysterectomy (abdominal), n</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Cholecystectomy, n</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Colectomy, n</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Appendectomy, n</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>BMI, median (range)</td>
<td>28.0 (21.1–38.0)</td>
<td>28.3 (18.4–43.7)</td>
<td>0.914</td>
</tr>
</tbody>
</table>

BMI, body mass index.

Table 3 Operative characteristics and postoperative outcomes in each device group

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Bipolar compression device (n = 35)</th>
<th>Ultrasonic device (n = 19)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major hepatectomy (≥3 segments), n</td>
<td>21</td>
<td>11</td>
<td>0.912</td>
</tr>
<tr>
<td>Specific hepatectomy, n</td>
<td></td>
<td></td>
<td>0.042</td>
</tr>
<tr>
<td>Right lobectomy</td>
<td>9</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Left lobectomy</td>
<td>8</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Left lateral-segmentectomy</td>
<td>18</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Concomitant laparoscopic procedure, n</td>
<td></td>
<td></td>
<td>0.313</td>
</tr>
<tr>
<td>Colectomy</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Diaphragm</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Stomach</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Adrenal</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Small bowel</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Abnormal parenchyma, n</td>
<td>28</td>
<td>17</td>
<td>0.504</td>
</tr>
<tr>
<td>Estimated blood loss, ml, median (range)</td>
<td>100 (20–1000)</td>
<td>175 (50–700)</td>
<td>0.584</td>
</tr>
<tr>
<td>Transection time, min, median (range)</td>
<td>35 (20–65)</td>
<td>55 (29–75)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Operative time, min, median (range)</td>
<td>130 (70–180)</td>
<td>180 (80–240)</td>
<td>0.0501</td>
</tr>
<tr>
<td>Pringle time</td>
<td>0</td>
<td>0 (0–9)</td>
<td></td>
</tr>
<tr>
<td>Complication, any type, n</td>
<td>9</td>
<td>2</td>
<td>0.211</td>
</tr>
<tr>
<td>Bile leak, n</td>
<td>1</td>
<td>0</td>
<td>0.531</td>
</tr>
<tr>
<td>Length of stay, days, median (range)</td>
<td>8 (3–33)</td>
<td>9 (3–28)</td>
<td>0.743</td>
</tr>
</tbody>
</table>

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hpetic surgery is controversial.21 Because parenchymal transec-
tion, especially in laparoscopic liver resection, can have the great-
est impact on intraoperative blood loss, blood transfusion,
postoperative bleeding, bile leak and survival, this topic remains
under scrutiny.22

A number of randomized controlled trials (RCTs), as well as
retrospective reviews, have looked at the safety and efficacy of
many techniques and technologies in open hepatic resection
(Table 1).14,21,23–26 Some studies show limited differences in post-
operative outcomes;27 however, in one RCT, the clamp-crush tech-
nique with continuous inflow occlusion was shown to be superior
to other technologies in terms of blood loss, transaction time and
overall cost.28 This analysis sought to determine whether either
of the dissecting devices, the Harmonic Scalpel® or the Enseal®,
without inflow occlusion, would provide benefits in terms of
blood loss, blood transfusion, operative time or hospital stay
amongst other variables, while decreasing the occurrence of post-
operative complications, in the laparoscopic setting.

The decrease in EBL in the Harmonic Scalpel® cohort may be
explained by the fact that the Harmonic Scalpel® requires a great
crush before coagulation can occur, whereas, by contrast, the
Enseal® allows for the gradual compression and desiccation of
the tissue followed by a potentially more robust seal and coagulation.
The present experience proved the Enseal® to be a good primary
device, allowing for the coagulation of vessels. Median EBL in the
current study compares favourably with EBL data in other studies
looking at single-device29 and two-device30,31 parenchymal divi-
sion, in which EBL ranges from 300 ml to >1000 ml.

Although median operative time was shorter in the bipolar
compression device group, the difference between groups did not
reach statistical significance, perhaps because of the small sample
size. This use of the bipolar compression device appears to provide
comparable or faster operative times than the clamp-crush tech-
nique and the dissecting sealer technique, as previously reported
in patients undergoing major open resection in other groups.22

The complication of bile leaks in liver resection is always wor-
rísimo and may be affected by the device chosen for parenchymal
transection. Studies have produced conflicting data regarding the
occurrence of bile leak with the Harmonic Scalpel®, One study
reported biliary fistula rates as high as 24% with the Harmonic
Scalpel®, compared with a rate of 7% with the clamp-crush tech-
nique.31 This reportedly high fistula rate was clearly concerning in
the evaluation of a new device, but was not observed in this study,
which showed a very low biliary leak rate of 1%.

The limitations of this study include its relatively small sample
size and its retrospective nature; however, it remains the largest
review of the laparoscopic use of haemostatic transaction devices.
In addition, this study was not a randomized trial; however, the
surgical team was similar throughout the study period, which
removes some variability from the study. In addition, the surgeon
who performed these operations can be expected to have experi-
enced a learning curve bias and to have become more comfortable
with laparoscopic hepatic resections over time; however, both
devices were used during the most recent time period evaluated.

Conclusions
In conclusion, the findings of this study indicate that bipolar
compression devices may offer advantages over ultrasonic devices
in terms of decreased transaction time and shorter total operative
time. Rates of postoperative complications during laparoscopic
liver resection do not differ between the two modalities.

Conflicts of interest
RCGM is a consultant with Ethicon Endosurgery.

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