Abstract

**Background:** Major liver resection is associated with haemodynamic, hepatic and renal changes as a result of the procedure.

**Aim:** To compare Desflurane (D) versus Sevoflurane (S) on hepatic, renal functions, haemodynamics and perioperative course for cirrhotic patients undergoing major liver resection.

**Patients and Methods:** A prospective randomized control study with 50 patients (Child A) (D, n=25 and S, n=25). End tidal D or S adjusted with Entropy (40-60). Haemodynamics monitored with invasive blood pressure and trans-oesophageal Doppler (TED). Liver and kidney function tests, blood Glutathione-S-transferase (GST), urinary microalbuminuria (Microalb) were assayed. Extubation time and anaesthetic consumption were recorded.

**Results:** Systemic vascular resistance (SVR) post-resection and stroke volume of D vs S were 855.04±12.02 vs 778.16±11.97 dyn sec cm⁻⁵, \( P < 0.01 \), and 85.72±2.95 vs 76.16±6.52 ml, \( P < 0.01 \) respectively. Doppler corrected flow time (FTc) between groups were comparable \( (P > 0.05) \). No difference post-operatively regarding hepatic and renal functions, and urine Microalb (14.76±3.95 vs 14.24±8.65 µg/ml, \( P = 0.78 \)), but a statistically difference was found with GST (0.046±0.003 vs 0.043±0.002 IU/ml, \( P < 0.01 \)). Despite a higher D consumption (73±17 vs 64±22 ml, \( P = 0.102 \)), cost in Egyptian pounds (LE) was lower with D (141.14 ± 32.90 vs 320.60 ± 114.01, LE, \( P < 0.01 \)). Extubation time and ICU stay with D vs S (4.52±2 vs 7.72±2 min, \( P < 0.01 \)) and (1.40 ± 0.50 vs 1.64 ± 0.48, days \( P = 0.09 \)) respectively.

**Conclusion:** Neither D nor S were clinically superior to the other with respect to liver and kidneys functions, but D was found to preserve better the haemodynamic parameters and enhance recovery at a lower cost.

**Keywords:** Desflurane, Sevoflurane, Cirrhosis, Liver resection.
Introduction

Egypt has a high Hepatitis C virus (HCV) prevalence and accordingly a high morbidity and mortality from chronic liver disease, cirrhosis, and hepatocellular carcinoma1,2. This increases the incidence of cirrhotic patients undergoing liver related and unrelated surgeries3. Liver resection improves overall survival in patients with small hepatocellular carcinoma, non-invasive and non-metastatic4,5; however, this surgery may be followed by clinical or subclinical hepatocellular derangements, metabolic abnormalities, hemodynamic changes due to temporary liver dysfunction frequently encountered in the immediate postoperative period6-9. The anaesthetic technique and the choice of inhalational agent used during liver resection surgeries are very crucial to minimize the unwanted effects of anesthesia on different organs especially the liver and the kidneys. The aim of the current study is to compare Desflurane to Sevoflurane based anesthesia for cirrhotic patients undergoing major liver resection in regards to hepatic and renal functions, hemodynamic parameters, and inhalational agent consumption and cost.

Patients and Methods

In this double-blinded prospective randomized controlled study, written informed consent and local Institutional Research and Ethics Committee approval (12/2013) were obtained. The study was registered at the Cochrane research data base of South Africa (PACTR201404000804408) (www.pactr.org).

Fifty three adult cirrhotic (Child A) patients were presented for major liver resection. Three patients did not meet the inclusion criteria and only fifty were randomized and equally divided into two groups using the closed envelope technique; the desflurane group (group D) and the sevoflurane group (Group S).

Included patients were those with written informed consent, age 25 years or older, scheduled for elective major liver resection surgery and classified as Child A and ASA II or III according to the Child-Pugh classification and American Society of Anesthesia classification, respectively. Patients with a history of esophageal disease, or contraindication for esophageal Doppler insertion (esophageal or nasopharyngeal pathology, coarctation of the aorta), any patient with pre-operative arrhythmia (frequent ectopic beats) or history of bleeding tendency, recent anesthesia (within 7 days before the resection surgery), re-operation and patients with preoperative renal dysfunction were excluded from the study.

Both groups received entropy guided general anesthesia induction (Anesthesia Depth monitor, General Electric, Helsinki, Finland) with fentanyl (1-2 µg/kg), propofol (1-1.5 mg/kg) and rocuronium (1 mg/kg). Two large peripheral venous lines (16 gauge or larger), multi-lumen central venous catheter in the right internal jugular vein (ultrasound guided) and an arterial catheter in the non-dominant hand were inserted. End-tidal inhalational concentration during the induction was limited to 1 MAC. General anesthesia was maintained with a 50% mixture of air and oxygen with either desflurane or sevoflurane at a fresh gas flow of 2 litres/min. Inhalational agent concentrations were adjusted according to an entropy between 40 and 60. Ventilation was controlled to maintain ETCo2 between 32 and 36 mmHg. If mean arterial blood pressure (MAP) or heart rate (HR) remained elevated after 5 minutes, supplemental doses of fentanyl (0.5 µg/kg) were given. Atropine 0.5 mg was given intravenously if HR drops below 45 beats/min. A trancesophageal Doppler (TED) probe (Cardio QP) for cardiac output (CO) monitoring (EDMTM; Deltex Medical, Chichester, UK) was inserted orally into the mid-oesophagus till the aortic blood flow signals were identified during hepatic dissection and after insertion of the surgical abdominal retractors. Preoperative prothrombin activity and platelet count were checked prior to insertion of the probe. Replacement of intraoperative fluid loss was guided with the TED parameters.

The parameters obtained by the TED include: the corrected flow time (FTc) which is the systolic flow time corrected for heart rate, the stroke volume (SV), the cardiac output (CO) and the systemic vascular resistance (SVR).

In both groups, boluses of colloid (6% HES 130/0.4 Voluven; Fresenius-Kabi, Bad Homburg, Germany) were administered, guided by an algorithm depending on the Doppler estimations of stroke volume
and FTc. This algorithm was similar to that used by Sinclair et al.

Ringer acetate in both groups was infused intraoperatively at approximately a constant rate (6 ml/kg/hr) via an infusion pump to cover fluid deficit and basal fluid requirements.

Packed red blood cells (300 ml) were transfused when haematocrit (Hct) was <25 %. Fresh frozen plasma (200 ml) was administered when aPTT > 70 s or International Normalized Ratio (INR) > 2. Patients were planned to be extubated in the operating room after surgery.

**Measurements**

Liver function tests including aspartate aminotransferase (AST) (U/L), alanine aminotransferase (ALT) (U/L), glutathione-S-transferase (GST) (IU/ml), total bilirubin (TB) (mg/dl), prothrombin activity (PA) (%), albumin (g/dl), and lactate (mg/dl) were obtained in both groups.

Renal functions tests monitored included serum urea (mg/dl), creatinine (mg/dl), creatinine clearance (ml/min) and microalbuminuria (µg/ml). Samples were collected preoperatively, immediately and 48 hours postoperatively.

Hemodynamic parameters were monitored continuously and recorded before induction (T0), immediately after induction and before intubation (T1), 15 min after the intubation (T2), during dissection (liver mobilisation) (T3), during hepatic resection (T4), and post resection near the end of surgery (T5).

TED parameters were only monitored at T3-T5 when the probe was inserted after intubation.

Total amount of inhalational agent used intraoperatively was calculated automatically by using the Aisys® GE Healthcare Finland (Datex-Ohmeda, Helsinki, Finland) anesthesia machine and then recorded. An experienced anesthesiologist who was blinded as to the type of inhalational agents delivered was in charge of collecting all the needed data.

A power analysis based on the liver function test ALT as the primary outcome (clinically significant difference of 25 IU/L and a standard deviation of 23.5 IU/L) and considering a Type I error of 5 % and a Type II error of 20% indicated that 25 patients would be needed in each group.

Data were collected and analyzed using SPSS (Statistical Package for Social Science) program for statistical analysis. Data were entered as numerical or categorical normal distribution of the data was confirmed by Kolmogorov-Smirnov test. Data were described using minimum, maximum, mean and standard deviation. Comparisons were carried out between the two studied groups using independent t-test. Within group comparison was carried out using repeated measures ANOVA. Chi-square test and fisher exact test were used to measure association between qualitative variables. The level of statistical significance was considered at p<0.05 level.

**Results**

The patients’ demographical characteristics were similar in both groups (Table 1).

<table>
<thead>
<tr>
<th>Demographic data</th>
<th>Sevo group (n=25)</th>
<th>Des group (n=25)</th>
<th>test of significance (p value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age(years)</td>
<td>52.00 ± 4.769</td>
<td>52.72 ± 5.820</td>
<td>t= .478</td>
</tr>
<tr>
<td>Gender (M/F)</td>
<td>21/4</td>
<td>17/8</td>
<td>X²=1.754</td>
</tr>
<tr>
<td>Weight</td>
<td>79±9.02</td>
<td>76±10.33</td>
<td>t=1.181</td>
</tr>
<tr>
<td>Height</td>
<td>165.3±7.2</td>
<td>167.2±5.8</td>
<td>t=1.028</td>
</tr>
<tr>
<td>Anesthesia time</td>
<td>220±26.496</td>
<td>222.60±10.32</td>
<td>p= 0.65</td>
</tr>
</tbody>
</table>

Except for GST in the immediate post-operative period and the preoperative creatinine clearance, there were no differences in the liver or renal functions between the two groups (Table 2 & Table 3). The GST (a more sensitive hepatic marker) was significantly lower in the desflurane group only in the immediate postoperative period (Table 3).
while MABP was higher in the desflurane group compared to the sevoflurane group near the end of the surgery (Figure 3). CVP and Doppler corrected flow time FTc in both groups were comparable and within normal ranges throughout the surgery, with similar intraoperative total (colloid volumes) (1.18 ± 1.06 vs 0.94 ± 0.33 liters, \( P=0.258 \)), crystalloids (Ringer Acetate) (3.58 ± 1.36 vs 3.80 ± 0.59 liters, \( P=0.225 \)) infused for D and S groups respectively.

The systemic vascular resistance (SVR) was better preserved in Group D compared to Group S both during hepatic resection and near the end of the surgery (Figure 1). The stroke volume was consistently higher in the desflurane group compared to the sevoflurane group (Figure 2). The mean arterial pressure was higher in the sevoflurane group compared to the desflurane group during the hepatic resection.

### Table 2

 Liver function tests. Data is presented as mean±SD

<table>
<thead>
<tr>
<th>Variables</th>
<th>Time</th>
<th>Group S (n=25)</th>
<th>Group D (n=25)</th>
<th>( p )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AST (U/L)</td>
<td>T1</td>
<td>56.04±19.95</td>
<td>52.76±30.01</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>165.80±145.46</td>
<td>137.88±54.23</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>177.60±83.40</td>
<td>207.76±56.81</td>
<td>0.142</td>
</tr>
<tr>
<td>ALT (U/L)</td>
<td>T1</td>
<td>54.92±25.18</td>
<td>44.60±26.52</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>136.76±135.99</td>
<td>88.00±65.11</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>168.76±104.06</td>
<td>165.91±134.67</td>
<td>0.93</td>
</tr>
<tr>
<td>Totalbilirubin (mg/dl)</td>
<td>T1</td>
<td>1.08±0.58</td>
<td>1.08±0.30</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>1.69±0.74</td>
<td>1.52±0.70</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>1.76±1.22</td>
<td>1.81±0.99</td>
<td>0.88</td>
</tr>
<tr>
<td>Albumin (g/dl)</td>
<td>T1</td>
<td>3.35±0.61</td>
<td>3.63±0.67</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>2.74±0.42</td>
<td>2.66±0.58</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>2.64±0.34</td>
<td>2.84±0.42</td>
<td>0.06</td>
</tr>
<tr>
<td>PA (%)</td>
<td>T1</td>
<td>79.04±10.03</td>
<td>77.40±11.06</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>68.72±9.68</td>
<td>64.52±13.00</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>66.40±7.11</td>
<td>65.04±14.27</td>
<td>0.67</td>
</tr>
<tr>
<td>Lactate (mg/dl)</td>
<td>T1</td>
<td>20.92±9.21</td>
<td>17.88±8.26</td>
<td>1.228</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>26.84±10.01</td>
<td>21.76±7.79</td>
<td>2.001</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>25.64±8.54</td>
<td>21.96±8.27</td>
<td>1.547</td>
</tr>
<tr>
<td>GST (IU/ml)</td>
<td>T1</td>
<td>0.0287±0.0016</td>
<td>0.029±0.0015</td>
<td>1.135</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>0.0460±0.0031</td>
<td>0.043±0.0020</td>
<td>4.044</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>0.0312±0.0016</td>
<td>0.031±0.0016</td>
<td>0.958</td>
</tr>
</tbody>
</table>

T1: preoperative; T2: immediately postoperative; T3: 48 hour postoperatively;
AST: aspartate aminotransferase; ALT: alanine aminotransferase; PA: prothrombin activity; GST: Glutathion-S-transferase.
Table 3
Renal function tests. Data is presented as mean±SD

<table>
<thead>
<tr>
<th>Variables</th>
<th>Time</th>
<th>Group S (n=25)</th>
<th>Group D (n=25)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea (mg/dL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T1</td>
<td>28.96±6.70</td>
<td>28.92±6.63</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>28.24±8.99</td>
<td>28.32±7.16</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>27.52±10.22</td>
<td>31.00±6.91</td>
<td>0.16</td>
</tr>
<tr>
<td>Creatinine (mg/dL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T1</td>
<td>0.76±0.22</td>
<td>0.82±0.19</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>0.78±0.30</td>
<td>0.81±0.25</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>0.84±0.26</td>
<td>0.96±0.30</td>
<td>0.14</td>
</tr>
<tr>
<td>Creatinine clearance (ml/min)</td>
<td>T1</td>
<td>132.64±32.48</td>
<td>113.40±26.12</td>
<td>0.02*</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>129.36±25.82</td>
<td>124.40±63.15</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>127.96±20.60</td>
<td>128.0±38.05</td>
<td>0.99</td>
</tr>
<tr>
<td>Microalbuminuria (µg/ml)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T1</td>
<td>9.04±2.49</td>
<td>7.32±3.56</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>14.24±8.65</td>
<td>14.76±3.95</td>
<td>0.78</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>8.20±2.54</td>
<td>7.28±3.34</td>
<td>0.28</td>
</tr>
</tbody>
</table>

T1: preoperative, T2: immediately postoperative, T3: 48 hour postoperatively.

Fig. 1
Box and Whisker plot of systemic vascular resistance (SVR) (dyn.sec.cm⁻⁵) in sevoflurane (Group S) and desflurane (Group D) groups.
Fig. 2
Box and Whisker plot of Stroke volume (SV) (ml) in sevoflurane (Group S) and desflurane (Group D) groups.

Fig. 3
Box and Whisker plot of Mean arterial blood pressure (mmHg) in sevoflurane (Group S) and desflurane (Group D) groups.
Blood loss in D group was 567.22±70.72 ml and in S group was 571.2±72.28 ml with no significant difference between both groups, \( P > 0.05 \). Blood transfusion requirements between both groups were comparable and minimal, 2 packed red blood cells units (PRBCs) were transfused for 4 patients in the D group and 3 in S group. No fresh frozen plasma units or cryoprecipitate were requested. Anaesthesia time was comparable between D and S groups (220±26.496 vs 222.60±10.32 minutes, \( P = 0.65 \)) with the same surgical and anaesthetic team.

Despite a higher D consumption (73±17 vs 64±22 ml, \( P = 0.102 \)), the D cost in Egyptian pounds was lower than S (141.14 ± 32.90 vs 320.60 ± 114.01, \( P < 0.001 \)). Extubation time was significantly shorter with D (4.52±2 versus 7.72±2 min, \( P < 0.01 \)), but there was no difference (Days) in intensive care stay (1.40 ± 0.50 vs 1.64 ± 0.48, \( P = 0.09 \)) and in hospital stay (3.36 ± 0.90 vs 3.28 ± 0.89, \( P = 0.75 \)) between D and S.

**Discussion**

The current study reveals that the two inhalational agents used were well tolerated as far as routine hepatic and renal functions.

In a previous study comparing effects of Sevoflurane and Isoflurane on liver functions in cirrhotic patients undergoing hepatectomy, a significant increase was found in AST and ALT with Isoflurane compared to Sevoflurane\(^{17}\). In an earlier study comparing the effects of Desflurane and Isoflurane on hepatocellular function, a significant increase in α-GST concentration was observed only in the Isoflurane group\(^{18}\).
Desflurane, in particular, was expected to have the least effect due to its very little degradation and minimal excretion of organic or inorganic fluoride\textsuperscript{19,20}, in contrast to Sevoflurane which is known to be biotransformed and metabolized by the liver into compound A that requires the kidneys for excretion; however in the present study the effects of Sevoflurane compared to Desflurane on perioperative renal and hepatic functions appear to be relatively similar as reflected by both routine renal and liver functions, including the more specific renal tubular monitor microalbuminuria provided that hemodynamic stability is maintained. This is in agreement with several earlier studies\textsuperscript{21,22}.

GST is one of the most sensitive tests for detecting early hepatocellular damage. It offers significant clinical advantages over conventional aminotransferases for monitoring hepatocellular integrity. It has a short half-life of about 60 min, much shorter than the standard enzyme markers ALT (about 48 h) and AST (about 20 h). It is also predominantly found in the liver where it is uniformly distributed into the lobule in contrast with ALT and AST that are found mainly within the periportal area. Thus, substantial centrilobular necrosis can be accompanied by an increase in \( \alpha \)-GST without a concomitant increase in serum aminotransferases\textsuperscript{23,24}. In many studies, a disruption in the hepatocellular integrity with inhalation anaesthetic agents was observed only when the more specific hepatic marker, GST, was used\textsuperscript{25,26}.

The changes in GST concentrations observed in our study in both groups was in agreement with the above two studies reflecting a derangement of the hepatocellular integrity from the combined effects of anaesthesia and surgical stress, together with injury to the liver cells during the surgical excision of the tumor. It also showed a more significant affection with Sevoflurane than Desflurane immediately postoperative. This will need further extensive studies with more patients.

AST and ALT present in hepatocytes can leak into the blood during the resection process. Unlike the present study, Suttner SW et al\textsuperscript{27} and KoJS et al\textsuperscript{15} were able to demonstrate minimal effects when patients in both studies were exposed to Desflurane. In Suttner S et al study the patients were elderly patients undergoing non-hepatic surgery and in the second study by KoJS et al, the patients enrolled in his study where healthy donors undergo liver resection for living liver transplantation donation. Few studies monitored the effect of Desflurane in cirrhotic patients undergoing liver resection. Tao KM et al study\textsuperscript{28} is one of these studies among cirrhotic patients, they stated that hepatic inflow occlusion during the liver surgery may result in a transient ischemia period followed by reperfusion, and may initiate liver injury. In cirrhotic patients, the tolerance time to ischemia is much shorter and the outcome would hence be worse. In our study and in contrast to Tao KM et al study, we were able to perform all the liver resections with no occlusion of the hepatic and portal blood flow (Pringle Maneuver) which could explain in part why there was no difference between both groups in our study as they were able to sustain the hepatic blood flow to the liver cells by maintaining a haemodynamic status of stability throughout the procedure. It is not only the anaesthetic choice that plays an important role in reducing the liver dysfunction but the surgical technique adopted by the surgeons also plays an important role together with haemodynamic stability. Our results support the importance of a combined and mutual understanding between the anaesthesia management and the adopted surgical technique to achieve the appropriate level of protection to both the liver and kidneys. Avoiding the Pringle maneuver during the surgical procedure (no ischaemic reperfusion injury) and the preservation of the middle hepatic vein in all the patients contributed to a minimal perioperative blood transfusion requirements, this lead to no haemodynamic supportive therapy used and allowed for the use of less invasive techniques for monitoring as the trans-oesophageal doppler adopted in the current study. Selective vascular occlusion of hepatic inflow was not adopted by the surgeons in our study, but instead the anterior parenchymal resection was used and this technique did not require significant reduction in the CVP\textsuperscript{6,29,30}.

The haemodynamic changes demonstrated in the results section were found to be in favour with Desflurane compared to Sevoflurane based anaesthesia, this could be due to the better preservation of the systemic vascular resistance with desflurane when used to maintain the general anaesthetic status in contrast to Sevoflurane. Cirrhotic patients are known to be peripherally vasodilated as a result of their liver
disease, which necessitates the use of an anaesthetic technique with the least effect on their vascular tone. Sevoflurane resulted in a sustained decrease in SVR and this was associated with a decrease in MABP.

In a previous study by El Sharkawy O et al\(^6\) designed to monitor the haemodynamic changes among cirrhotic patients undergoing liver resection with TED, the authors were able to present data demonstrating significant haemodynamic changes that associate liver resection procedure itself, particularly in the immediate post-resection. Reporting an increase in SV and cardiac output as monitored by TED, together with an associated decrease in calculated SVR despite stable and normal readings of both central venous pressure (CVP) and corrected flow time (FT\(c\)).

The present study demonstrated similar changes in SVR and SV in both groups but with cardiac output increase only demonstrated with Desflurane. Similar changes were previously described also by Niemann et al\(^3\) in patients with healthy livers undergoing the same procedure (major hepatic resection) for living donor liver transplantation with inhalation anaesthetic agent. In Niemann et al study they had to inject Indocyanine green and measure plasma levels with a pulse dye densitometry, not usually available in the operating theaters and which is still considered as a research tool. In contrast, the TED was used in our current study and was found to be easy to use and less invasive with the possible availability in operating suites.

The haemodynamic changes observed in this current study after hepatotomy could be due to the possible reduction in portal blood flow\(^3\) or to the release of various splanchnic mediators such as endotoxin, during liver surgery\(^3\) and changes in the levels of nitric oxide, a potent vasodilator, which could be elevated in response to endotoxin and cytokine release\(^4\). Boermeester, et al., found that these haemodynamic changes improved after the administration of endotoxin-neutralizing protein\(^5\).

The extubation time in this current study was enhanced by Desflurane as demonstrated by other similar studies, this may be due to the peculiar nature of Desflurane which enjoys a low blood/gas solubility coefficient and low metabolic rate which can reach to 0.02% of administered Desflurane that will definitely shorten and enhance recovery\(^3\).\(^6\)\(^7\).

One of the limitations of this study was the small number of the patients included, this may be attributed to the restricted inclusion of only major liver resection procedures performed for cirrhotic patients of Child A.

Another limitation observed when the liver was mobilized during resection of hepatic tumors was the frequent requirement to reposition the Doppler probe. This can be considered as an important weak point in the TED monitoring system which needs frequent attention from the anaesthetist.

The inability to continue monitoring in this study with the TED post-extubation as it needs to be left nasally which is uncomfortable with a nasogatric tube in place in the other nostril and finally TED traces were also affected during the periods of diathermy application from temporary interferences.

In conclusion, Desflurane was found to offer better haemodynamic parameters, shorter and enhanced recovery at a lower cost when compared to Sevoflurane, but neither is clinically superior to the other with respect to their effects on liver and kidneys. Both Desflurane and Sevoflurane can be used safely during liver surgery in cirrhotic patients. The statistical difference in GST between both groups remains to be investigated further on a larger scale for more evidence based support and may be at different clinical scenarios as in association with major blood loss in cirrhotic patients when a difference could be of clinical importance. TED was able to present significant hemodynamic changes in association with the major liver resection procedure; however the use of the less invasive TED monitoring and the development of TED guided fluid management protocols for this population need to be further studied, particularly in comparison to the routinely used standard central venous catheter monitoring and fluid management protocols with special emphasis during and after major liver surgery.

**Acknowledgement**

I would like to express my thanks to Dr. El-sayed Amr for his assistance in statistics.
References


35. BOERMEESTER MA, HOUDEIK AP, STRAATBURG IH, VAN NOORDEN CJ,


BRIDION—for **optimal neuromuscular blockade management** and improved recovery

**Predictable and complete reversal**
- 98% of BRIDION patients recovered to a TOF® ratio of 0.9 from reappearance of T\textsubscript{2} \superscript{+} within 5 minutes\textsuperscript{2}
- 97% of BRIDION patients recovered to a TOF® ratio of 0.9 from 1 to 2 PTCs \superscript{+} within 5 minutes\textsuperscript{3}

**Rapid reversal**
- BRIDION rapidly reversed patients from reappearance of T\textsubscript{2} \superscript{+} in 1.4 minutes\textsuperscript{2}
- BRIDION rapidly reversed patients from 1 to 2 PTCs \superscript{+} in 2.7 minutes\textsuperscript{3}

BRIDION is indicated for the reversal of neuromuscular blockade induced by rocuronium or vecuronium. In children and adolescents (aged 2-17 years), BRIDION is only recommended for routine reversal of moderate rocuronium-induced neuromuscular blockade.\textsuperscript{1}

**Important safety information**
BRIDION is not recommended in patients with severe renal impairment. Studies in patients with hepatic impairment have not been conducted and, therefore, patients with severe hepatic impairment should be treated with great caution. Caution should be exercised when administering BRIDION to pregnant women as no clinical data on exposed pregnancies are available.

BRIDION has not been investigated in patients receiving rocuronium or vecuronium in the Intensive Care Unit (ICU) setting.

If neuromuscular blockade is required within 24 hours of BRIDION administration, a non-neuromuscular blocking agent should be used instead of rocuronium or vecuronium. The most commonly reported adverse reactions were dysgeusia (metal or bitter taste) and anesthetic complications (movement, coughing, grimacing, or suddent on the endotracheal tube). In patients treated with BRIDION, a few cases of awareness were reported. The relation to BRIDION was uncertain. In a few individuals, allergic-like reactions (ie, flushing, erythematous rash) following BRIDION were reported. Clinicians should be prepared for the possibility of allergic reactions and take the necessary precautions. In a trial of patients with a history of pulmonary complications, bronchospasm was reported in 2 patients and a causal relationship could not be fully excluded.

Volunteer studies have demonstrated a slight (17%-22%) and transient (<30 minutes) prolongation of the prothrombin time activated partial thromboplastin time (PT/ aPTT) with BRIDION; however, clinical studies have demonstrated no clinically relevant effect on peri- or postoperative bleeding complications with BRIDION alone or in combination with anticoagulants. As BRIDION has demonstrated an in vitro pharmacodynamic interaction with anticoagulants, caution should be exercised in patients on anticoagulation for a pre-existing or concomitant condition. This pharmacodynamic interaction is not clinically relevant for patients receiving routine postoperative prophylactic anticoagulation. Although formal interaction studies have not been conducted, no drug interactions were observed in clinical trials. Preclinical data suggest that clinically significant drug interactions are unlikely with the possible exceptions of toremifene, fusidic acid, and hormonal contraceptives.

\textsuperscript{1} Train-of-four  
\textsuperscript{2} Post tetanic counts  
\textsuperscript{3} Second twitch

**REFERENCES**
1. BRIDION Summary of Product Characteristics (SPC).

Please see summary of product characteristics for full prescribing information.

MSD
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References: