Comparison of lateral thermal damage of the human peritoneum using monopolar diathermy, Harmonic scalpel and LigaSure

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Background: New hemostatic technologies are often employed in open and laparoscopic surgery to reduce duration of surgery and complications. Monopolar diathermy, Harmonic scalpel and LigaSure are routinely used in open and laparoscopic surgery for tissue cutting and hemostasis. We compared lateral thermal damage following in vivo application of 3 commonly used instruments.

Methods: We used monopolar diathermy, Harmonic scalpel and LigaSure to coagulate and divide the peritoneum of patients who underwent median laparotomy. After anesthesia, median supraumbilical laparotomy was performed, and the peritoneum of each patient was coagulated using different devices. Using light microscopy and morphometric imaging analysis, the width of tissue lateral thermal damage was measured from the point of the peritoneal incision.

Results: We included 100 patients in our study. After a peritoneal incision, the mean lateral thermal damage of monopolar diathermy, Harmonic scalpel (output power 3), Harmonic scalpel (output power 5) and LigaSure were 215.79 μm, 90.42 μm, 127.48 μm and 144.18 μm, respectively.

Conclusion: The degree of lateral thermal spread varied by instrument type, power setting and application time. LigaSure and Harmonic scalpel were the safest and most efficient methods of tissue coagulation. Monopolar diathermy resulted in the greatest degree of thermal damage in tissues.

Hemostasis is extremely important in open and laparoscopic surgery to avoid postoperative complications, but it requires a meticulous technique and is very often time-consuming. Traditionally used monopolar electrosurgery is associated with well-known risks and can cause substantial thermal injury to surrounding tissues. Minimizing thermal damage to surrounding...
tissues and improving speed without compromising tissue integrity are of the great importance in open and laparoscopic surgery. Various devices have been introduced in clinical practice to achieve a safe and faster hemostasis. Newer instruments, such as the Harmonic scalpel and LigaSure, are thought to be safer than traditional diathermy.\(^1\)\(^{-}\)\(^6\) The Harmonic scalpel incorporates piezoelectric transducers that induce a vibration frequency at the functional tip and transduces a lower amount of energy to the tissue than high-frequency current or laser techniques, resulting in reduced lateral thermal damage and penetration depth owing to lower temperatures.\(^4\)\(^{-}\)\(^5\) Ultrasonic energy controls bleeding through the process of coaptive coagulation. LigaSure uses a combination of pressure and current to melt the collagen and elastin contained within blood vessel walls, thereby sealing the vessels.\(^3\)\(^{-}\)\(^6\) However, there is evidence that these advanced and electronically controlled devices may lead to inadvertent damage to nearby structures through the lateral spread of thermal energy, and this could result in delayed injuries to surrounding structures.\(^7\)\(^{-}\)\(^9\) The degree of lateral thermal spread depends on the type of instrument, the power settings used and the duration of application.\(^1\)\(^{-}\)\(^6\) The present study attempts to investigate the degree of lateral thermal injury on the human peritoneum following in vivo application of the most commonly used electrosurgical instruments: monopolar diathermy, Harmonic scalpel and LigaSure.

**METHODS**

From January 2010 to September 2010, we used 3 different electrosurgical devices to coagulate and divide the peritoneum of patients undergoing supraumbilical median laparotomy at the Department of Surgery, Split University Hospital. We obtained informed consent from the patients, and the Ethical Committee of Split University Hospital approved our study protocol.

After administering anesthesia, median supraumbilical laparotomy was performed, and the peritoneum of each patient was coagulated using each of the following instruments: monopolar diathermy with the Erbe VIO 300D (Erbe), Harmonic scalpel (Ethicon Endosurgery) and
LigaSure (Valleylab). The coagulated tissue of the peritoneum was removed, divided and categorized into 4 groups based on the instrument used: monopolar diathermy at maximum power; the 5 mm Harmonic Ace forceps Harmonic scalpel at output levels of 3 and 5, respectively; and the LigaSure V 5 mm forceps at maximum power. The application time for all groups was 5 seconds. The parts of the removed peritoneum were fixed in 4% buffered formalin for 24 hours. The preparations were dehydrated in growing concentrations of alcohol, clarified in xylol and embedded in paraffin. The paraffin blocks were cut in 5 μm slides and stained with hematoxylin and eosin. We could clearly see the width of lateral thermal damage from the point of instrument application to the margins of unchanged nearby tissue (Fig. 1). Using an Olympus BX41 light microscope and morphometric computer imaging analysis (Soft Imaging System), the width of the lateral thermal damage was measured at the application area.

Statistical analysis

The data were analyzed using the Student $t$ test, Excel version 11.0 for Windows (Microsoft) and Statistica version 14.0 for Windows (Statsoft).

Results

We included 100 patients (52 men, 48 women) in our study. Patients were well matched for age, sex, pathology and weight (all $p > 0.05$). The mean age was 64 (range 34–86) years, and the mean weight was 75.8 (range 61–112) kg. According to the pathology, the reason for surgery was colorectal cancer in 53% of the patients and benign conditions in the remaining 47%.

The levels of lateral thermal damage to the peritoneum are presented in Figure 2 and Table 1. Following a peritoneal incision at the highest power setting, the means (and standard deviation [SD]) lateral thermal damage of monopolar diathermy, Harmonic scalpel with an output power of 3, Harmonic scalpel with an output power of 5 and LigaSure were 215.79 (121.06) μm, 90.42 (75.12) μm, 127.48 (68.52) μm and 144.18 (103.44) μm, respectively (Table 1).

The differences in thermal damage between monopolar diathermy and Harmonic scalpel or LigaSure were significant ($p < 0.001$, Table 1). The difference in thermal damage between Harmonic scalpel at output power 3 and Harmonic scalpel at output power 5 was also significant ($p = 0.001$, Table 1). There was no significant difference in

![Fig. 2: Mean (and standard deviation) thermal tissue damage in micrometres by instrument type.](image)

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<th>Table 1. Between-group comparison of thermal damage caused by the hemostatic technologies</th>
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<td>Group comparison</td>
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<td>Monopolar diathermy v. Harmonic scalpel (output power 3)</td>
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thermal damage between Harmonic scalpel and LigaSure at maximum output power ($p = 0.39$, Table 1).

**DISCUSSION**

Electrosurgery has facilitated the development of advanced laparoscopic surgery by allowing rapid division of the vascular structures. Electrosurgical instruments are unsafe in abdominal surgery since their lateral thermal spread may easily damage vital structures. Harmonic scalpel and LigaSure have been used in laparoscopic and open surgery for several years and have changed the way we operate. Both technologically advanced, they have been suggested to have excellent results and minimal lateral thermal injury.

The Harmonic scalpel controls bleeding by tamponading the vessel and sealing it with a protein coagulum at temperatures ranging from 50°C to 100°C. The Harmonic scalpel works at lower temperatures than electrosurgical devices, since it denatures proteins by mechanically breaking the hydrogen bounds in protein molecules when the blade vibrates at 55.5 kHz, thus generating much less heat from tissue friction. The Harmonic scalpel has been proven to be a safe and useful device in both open and endoscopic surgery. Compared with a standard electric scalpel, the Harmonic scalpel leads to a shorter duration of surgery, less lateral thermal spread, no smoke and no electric energy passage through the patient’s body.

The LigaSure vessel sealing system is a bipolar feedback controlled sealing system that effectively seals vessels up to 7 mm in diameter with a minimal thermal spread. The device applies a precise amount of mechanical pressure and radiofrequency energy to tissue, causing fusion of the opposing layers by creating a seal of denatured collagen, which can then be transected. The superiority of LigaSure over bipolar electrocautery is that the tissue fusion is created by the denaturation of proteins, thus forming a true seal rather than creating a proximal thrombus. Its lateral thermal spread is reported to be less than 1 mm. Given that electrosurgical instruments are commonly used for dissection and hemostasis, it is surprising that there is a paucity of literature on the lateral spread of energy and tissue temperature changes.

Previous studies have correlated the degree of thermal injury with lateral thermal spread. Thermal injury after monopolar diathermy application has been described in many studies. Side thermal injury is likely to occur after every method of coagulation. The ideal technique would be one that provides excellent hemostatic results and allows no thermal energy to escape from the area where it has been strictly applied. In our study, thermal injury of the surrounding tissue was much more evident after monopolar diathermy than after LigaSure or Harmonic scalpel. Other investigators have reached the same conclusions.

Thermal spread caused by LigaSure and Harmonic scalpel is limited to areas less than 1.5 mm and 1.6 mm beyond the tissue bundle or vessel, respectively.

Ultrasonic energy delivered through a harmonic scalpel has been shown to be safe and to produce minimal damage to the surrounding tissues. On the other hand, high-power ultrasonic dissection may result in considerable heat production and collateral tissue damage, especially when the activation time exceeds 10 seconds. In previous studies, we demonstrated that harmonic scalpel application times of more than 5 seconds presented a risk of lateral thermal damage, especially near sensitive tissues or organs such as the common bile duct or ureter. The findings of these studies suggest that after 5 seconds of application, a 5-second pause should be made, followed by an additional 5 seconds if necessary.

Lateral thermal damage produced by the Harmonic scalpel at an output power of 5 was greater than that at an output power of 3. In our previous research on rats and pigs, we obtained the same results.

At the highest power setting, we found slightly less thermal injury caused by the Harmonic scalpel (127.48 μm) than LigaSure (144.18 μm), but that difference was nonsignificant. Contrary to our findings, Diamantis and colleagues in their studies, found that LigaSure (197.79 μm) might cause less thermal injury than Harmonic scalpel (205.61 μm); that difference was nonsignificant. Sutton and colleagues found a little difference in generated temperatures between the LigaSure and Harmonic scalpel. They found that LigaSure produced the smallest increase in temperature. Sartori and colleagues found that the only real advantage between LigaSure and Harmonic scalpel was a shorter duration of surgery with the Harmonic scalpel, probably owing to its ability to coagulate and cut at the same time.

**CONCLUSION**

Our findings suggest that LigaSure and Harmonic scalpel are both useful and widely used hemostatic and dissecting devices. They are much safer and more effective than the older monopolar diathermy. LigaSure is considerably slower than Harmonic scalpel, as it cannot achieve coagulation and cutting at the same time. Although Harmonic scalpel might cause slightly less thermal injury than LigaSure, the clinical implications of this need to be investigated further.

**Competing interests:** None declared.

**Contributors:** N. Družijačić and Z. Perko designed the study. Z. Pogorelić acquired the data, which he, I. Mrklič and S. Tomić analyzed. Z. Pogorelić and I. Mrklič wrote the article, which N. Družijačić, Z. Perko and S. Tomić reviewed. All authors approved its publication.

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