

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

Nikica Družijanić, MD, PhD\*  
 Zenon Pogorelić, MD, PhD†  
 Zdravko Perko, MD, PhD\*  
 Ivana Mrklić, MD‡  
 Snježana Tomić, MD, PhD‡

From the Departments of \*Surgery,  
 †Pediatric Surgery and ‡Pathology, Split  
 University Hospital and Split University  
 School of Medicine, Split, Croatia

Accepted for publication  
 July 15, 2011

**Correspondence to:**  
 Z. Pogorelić  
 Department of Pediatric Surgery  
 Split University Hospital  
 Spinčićeva 1  
 21 000 Split  
 Croatia  
 zenon@vip.hr

DOI: 10.1503/cjs.000711

**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  $\mu\text{m}$ , 90.42  $\mu\text{m}$ , 127.48  $\mu\text{m}$  and 144.18  $\mu\text{m}$ , 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.

**Contexte :** On utilise souvent les nouvelles technologies hémostatiques lors de chirurgies ouvertes et laparoscopiques afin d'abrégier l'intervention et de prévenir les complications. La diathermie monopolaire, le scalpel Harmonic et le système LigaSure servent couramment lors des chirurgies ouvertes et laparoscopiques pour inciser et cautériser les tissus. Nous avons comparé les lésions thermiques latérales consécutives à l'application in vivo de ces 3 instruments d'usage courant.

**Méthodes :** Nous avons utilisé la diathermie monopolaire, le scalpel Harmonic et le système LigaSure pour cautériser et séparer le péritoine de patients soumis à une laparotomie médiane. Une fois les patients anesthésiés, la laparotomie supra-ombilicale médiane a été effectuée et le péritoine de chaque patient a été cautérisé à l'aide de différents instruments. Par microscopie optique et analyse morphométrique, nous avons mesuré la largeur des lésions thermiques latérales des tissus à partir du point d'incision du péritoine.

**Résultats :** Nous avons inclus 100 patients dans notre étude. Après l'incision du péritoine, les atteintes thermiques latérales moyennes associées à la diathermie monopolaire, au scalpel Harmonic (puissance 3), au scalpel Harmonic (puissance 5) et au système LigaSure ont été respectivement de 215,79  $\mu\text{m}$ ; 90,42  $\mu\text{m}$ ; 127,48  $\mu\text{m}$ ; et 144,18  $\mu\text{m}$ .

**Conclusion :** Le degré de propagation thermique latérale a varié selon le type d'instrument, sa puissance et sa durée d'application. Le système LigaSure et le scalpel Harmonic ont été les méthodes de cautérisation tissulaire les plus sécuritaires et efficaces. La diathermie monopolaire a donné lieu au degré le plus important de lésion tissulaire thermique.

**H**emostasis 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.<sup>1</sup> Minimizing thermal damage to surrounding

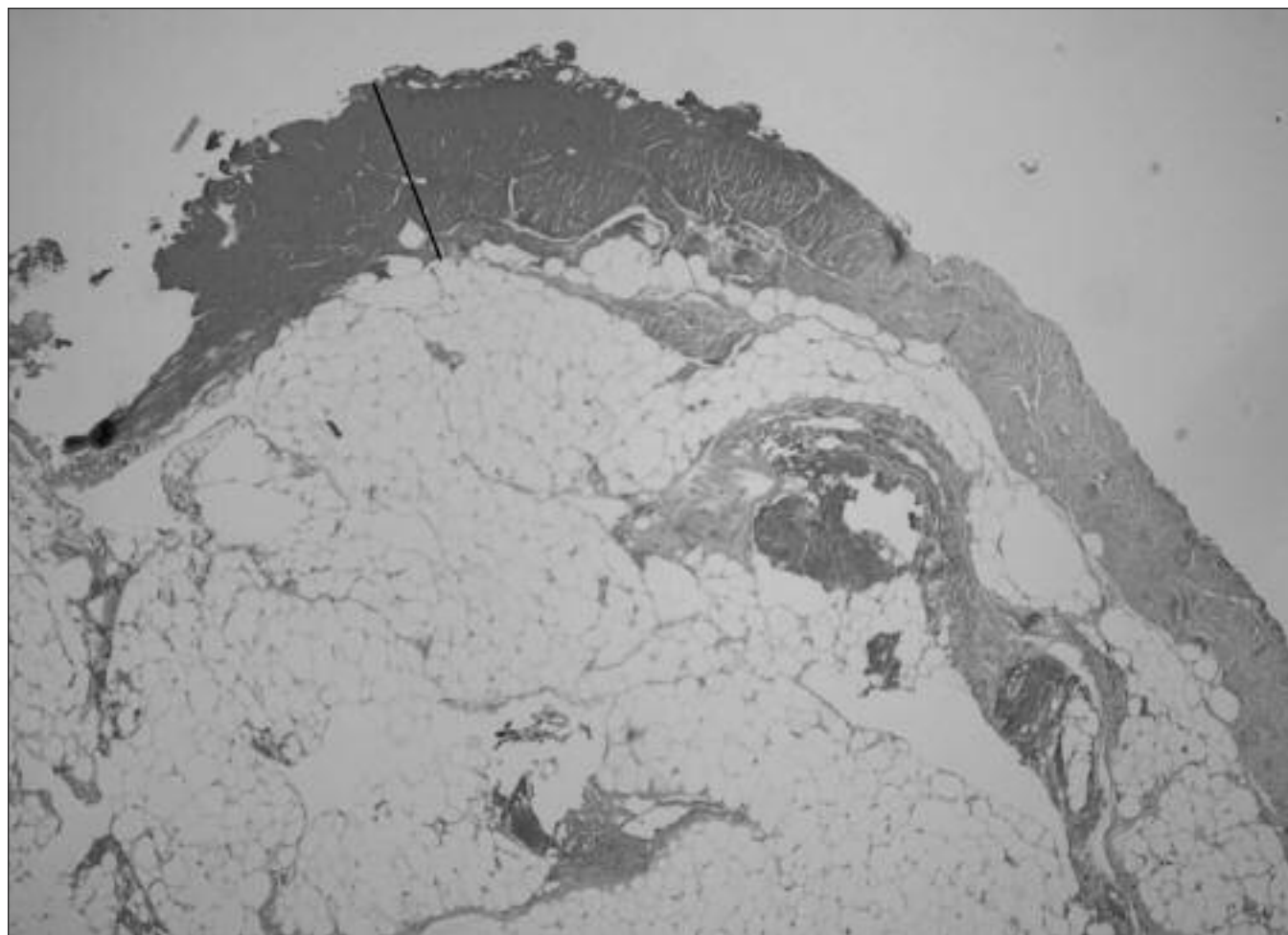
tissues and improving speed without compromising tissue integrity are of the great importance in open and laparoscopic surgery. Various devices have been introduced in clinical practice to achieve a safe and faster hemostasis. Newer instruments, such as the Harmonic scalpel and LigaSure, are thought to be safer than traditional diathermy.<sup>1-6</sup> 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.<sup>4,5</sup> 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.<sup>3,6</sup> 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.<sup>7-9</sup> The degree of lateral thermal spread depends on the type of

instrument, the power settings used and the duration of application.<sup>1,3-6</sup> 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 electro-surgical instruments: monopolar diathermy, Harmonic scalpel and LigaSure.

## METHODS

From January 2010 to September 2010, we used 3 different electro-surgical 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



**Fig. 1.** Histologic specimen illustrating lateral thermal damage of the peritoneum using hematoxylin and eosin staining,  $\times 40$  magnification. The black line represents the lateral damage around the instrument's jaw, measured by the pathologist using a morphometric computer imaging analysis.

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  $\mu\text{m}$  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)  $\mu\text{m}$ , 90.42 (75.12)  $\mu\text{m}$ , 127.48 (68.52)  $\mu\text{m}$  and 144.18 (103.44)  $\mu\text{m}$ , 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

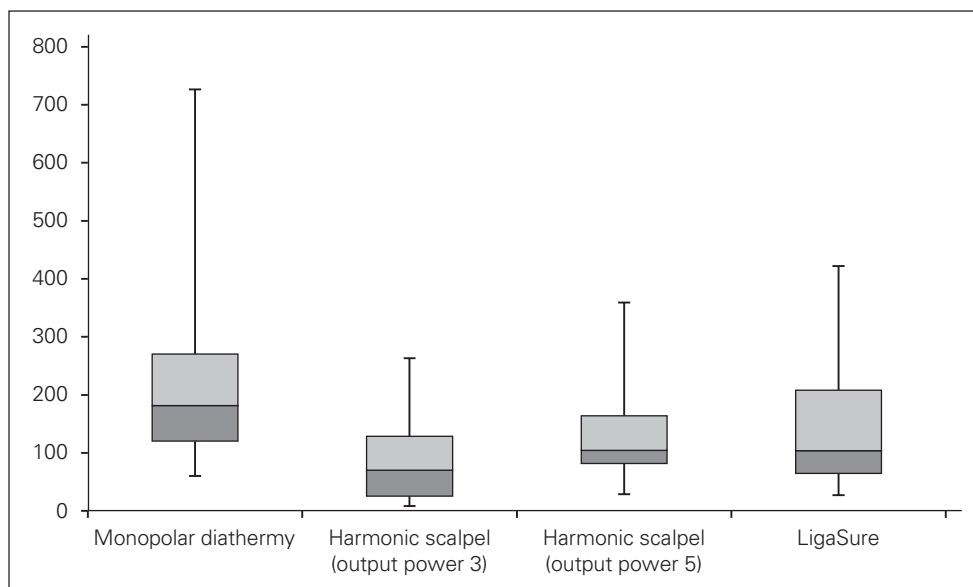


Fig. 2: Mean (and standard deviation) thermal tissue damage in micrometres by instrument type.

Table 1. Between-group comparison of thermal damage caused by the hemostatic technologies

Group comparison	Mean value A, $\mu\text{m}$	Mean value B, $\mu\text{m}$	<i>p</i> value
Monopolar diathermy v. Harmonic scalpel (output power 3)	215.79	90.42	< 0.001
Monopolar diathermy v. Harmonic scalpel (output power 5)	215.79	127.48	< 0.001
Monopolar diathermy v. LigaSure	215.79	144.18	< 0.001
Harmonic scalpel (output power 3) v. Harmonic scalpel (output power 5)	90.42	127.48	0.001
Harmonic scalpel (output power 3) v. LigaSure	90.42	144.18	< 0.001
Harmonic scalpel (output power 5) v. LigaSure	127.48	144.18	0.39

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.<sup>10,11</sup> Electrosurgical instruments are unsafe in abdominal surgery since their lateral thermal spread may easily damage vital structures.<sup>4,5,11</sup> 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.<sup>1-6,10,12,13</sup>

The Harmonic scalpel controls bleeding by tamponating 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 bonds in protein molecules when the blade vibrates at 55.5 kHz, thus generating much less heat from tissue friction.<sup>4,5</sup> The Harmonic scalpel has been proven to be a safe and useful device in both open and endoscopic surgery.<sup>4,5,9,10,13</sup> 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.<sup>4,5,9,13</sup>

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.<sup>14,15</sup> 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.<sup>10</sup> 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.<sup>1,3,6,16</sup> 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.<sup>1,3,6,10-12</sup> 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.<sup>4,5,17,18</sup>

Ultrasonic energy delivered through a harmonic scalpel has been shown to be safe and to produce minimal damage to the surrounding tissues.<sup>4,5,9</sup> 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.<sup>4,5,9</sup> 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.<sup>4,5</sup>

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.<sup>4,5</sup>

At the highest power setting, we found slightly less thermal injury caused by the Harmonic scalpel (127.48  $\mu\text{m}$ ) than LigaSure (144.18  $\mu\text{m}$ ), but that difference was nonsignificant. Contrary to our findings, Diamantis and colleagues,<sup>16</sup> in their studies, found that LigaSure (197.79  $\mu\text{m}$ ) might cause less thermal injury than Harmonic scalpel (205.61  $\mu\text{m}$ ); that difference was nonsignificant. Sutton and colleagues<sup>3</sup> 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<sup>10</sup> 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. Družijanić and Z. Perko designed the study. Z. Pogorelić acquired the data, which he, I. Mrklić and S. Tomić analyzed. Z. Pogorelić and I. Mrklić wrote the article, which N. Družijanić, Z. Perko and S. Tomić reviewed. All authors approved its publication.

## References

1. Diamantis T, Gialikaris S, Kontos M, et al. Comparison of safety and efficacy of ultrasonic and bipolar thermal energy: an experimental study. *Surg Laparosc Endosc Percutan Tech* 2008;18:384-90.

2. Newcomb WL, Hope WW, Schmelzer TM, et al. Comparison of blood vessel sealing among new electro-surgical and ultrasonic devices. *Surg Endosc* 2009;23:90-6.
3. Sutton PA, Awad S, Perkins AC, et al. Comparison of lateral thermal spread using monopolar and bipolar diathermy, the Harmonic Scalpel and the Ligasure. *Br J Surg* 2010;97:428-33.
4. Pogorelič Z, Perko Z, Družijanić N, et al. How to prevent lateral thermal damage to tissue using the harmonic scalpel: experimental study on pig small intestine and abdominal wall. *Eur Surg Res* 2009;43:235-40.
5. Perko Z, Pogorelič Z, Bilan K, et al. Lateral thermal damage to rat abdominal wall after harmonic scalpel application. *Surg Endosc* 2006;20:322-4.
6. Diamantis T, Kontos M, Arvelakis A, et al. Comparison of monopolar electrocoagulation, bipolar electrocoagulation, Ultracision, and Ligasure. *Surg Today* 2006;36:908-13.
7. Humes DJ, Ahmed I, Lobo DN. The pedicle effect and direct coupling: delayed thermal injuries to the bile duct after laparoscopic cholecystectomy. *Arch Surg* 2010;145:96-8.
8. Kadesky KM, Schopf B, Blair GK. Proximity injury by the ultrasonically activated scalpel during dissection. *J Pediatr Surg* 1997;32:878-9.
9. Emam TA, Cuschieri A. How safe is high-power ultrasonic dissection. *Ann Surg* 2003;237:186-91.
10. Sartori PV, De Fina S, Colombo G, et al. Ligasure versus Ultracision in thyroid surgery: a prospective randomized study. *Langenbecks Arch Surg* 2008;393:655-8.
11. Gözen AS, Teber D, Rassweiler JJ. Principles and initial experience of a new device for dissection and hemostasis. *Minim Invasive Ther Allied Technol* 2007;16:58-65.
12. Kwok A, Nevell D, Ferrier A, et al. Comparison of tissue injury between laparoscopic coagulating shears and electro-surgical scissors in the sheep model. *J Am Assoc Gynecol Laparosc* 2001;8:378-84.
13. Družijanić N, Perko Z, Kraljević D, et al. Harmonic scalpel in transanal microsurgery. *Hepatogastroenterology* 2008;55:356-8.
14. Smulders JF, de Hingh IH, Stavast J, et al. Exploring new technologies to facilitate laparoscopic surgery: creating intestinal anastomoses without sutures or staples, using a radio-frequency-energy-driven bipolar fusion device. *Surg Endosc* 2007;21:2105-9.
15. Elemen L, Yazir Y, Tugay M, et al. LigaSure compared with ligatures and endoclips in experimental appendectomy: How safe is it? *Pediatr Surg Int* 2010;26:539-45.
16. Lantis JC II, Durville FM, Connolly R, et al. Comparison of coagulation modalities in surgery. *J Laparoendosc Adv Surg Tech A* 1998;8:381-94.
17. Kennedy JS, Stranahan PL, Taylor KD, et al. High-burststrength, feedback-controlled bipolar vessel sealing. *Surg Endosc* 1998;12:876-8.
18. Hoening DM, Chrostec CA, Amaral JF. Laparoscopic coagulation shears: alternative methods of hemostatic control of unsupported tissue. *J Endourol* 1996;10:431-3.

## CJS's top articles\*

1. **Research questions, hypotheses and objectives**  
Farrugia et al.  
*Can J Surg* 2010;53(4):278-81
2. **Tracheostomy: from insertion to decannulation**  
Engels et al.  
*Can J Surg* 2009;52(5):427-33
3. **The history of women in surgery**  
Wirtzfeld  
*Can J Surg* 2009;52(4):317-20
4. **Adhesive small bowel obstruction: epidemiology, biology and prevention**  
Attard and MacLean  
*Can J Surg* 2007;50(4):291-300
5. **The efficacy and risks of using povidone-iodine irrigation to prevent surgical site infection: an evidence-based review**  
Chundamala and Wright  
*Can J Surg* 2007;50(6):473-81
6. **Chest tube complications: How well are we training our residents?**  
Ball et al.  
*Can J Surg* 2007;50(6):450-8
7. **Topical nifedipine with lidocaine ointment versus active control for pain after hemorrhoidectomy: results of a multicentre, prospective, randomized, double-blind study**  
Perrotti et al.  
*Can J Surg* 2010;53(1):17-24
8. **Antibiotics versus appendectomy in the management of acute appendicitis: a review of the current evidence**  
Fitzmaurice et al.  
*Can J Surg* 2011;54(5):307-14
9. **Combined large HillSachs and bony Bankart lesions treated by Latarjet and partial humeral head resurfacing: a report of 2 cases**  
Grondin and Leith  
*Can J Surg* 2009;52(3):249-54
10. **Soft-tissue nail-fold excision: a definitive treatment for ingrown toenails**  
Chapeskie and Kovac  
*Can J Surg* 2010;53(4):282-6

\* Based on page views on PubMed Central of research, reviews, commentaries and continuing medical education articles. Updated Sept.13, 2012.