Laparoscopic Intracorporeal Bowel Resection with Ultrasound versus Electrosurgical Dissection

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ABSTRACT

Background and Objectives: We assessed resection time and collateral thermal tissue damage of ultrasonically activated surgery (UAS) and high-frequency blade-enhanced bipolar electrosurgery (BE) in laparoscopic bowel surgery.

Methods: We compared UAS laparoscopic intracorporeal small bowel mesentery resection with an equivalent procedure performed with BE in a porcine model. Resection was defined as 12 end-arcade arteries supplying the intended bowel segment. Vessels were divided one cm off the bowel wall. Aside from shaft diameter, jaws gapping pattern, and cutting blade length, UAS and BE devices were well matched for handle ergonomics, jaws gapping extent, power setting, type of use, working shaft axial rotation, and length. A pathologist blind to the method used assessed the collateral thermal damage. Resections were allocated to either method by computer-generated block randomization. The study design was sequential triangular with a 5% significance level and 90% power.

Results: No significant differences occurred in intraoperative blood pressure and heart rate variations in pigs undergoing UAS or BE. Median operating time (measured after 10, 20, and 30 resections in each study arm) was significantly shorter in UAS than in BS (0.57 vs. 2.01 min \( P < 0.001 \)). Histology of small bowel wall specimens revealed no collateral thermal damage.

Conclusions: UAS laparoscopic bowel surgery offers reduced resection time as compared with its BE counterpart in a porcine model.

Key Words: Bipolar coagulation, Electrosurgery, Laparoscopy, Thermal damage, Ultrasonic dissection.

INTRODUCTION

Prolonged operating time is one of today’s limitations of laparoscopic surgery. In the case of colorectal surgery, dissection of bowel mesentery is one of the most time-consuming steps. Energy-based surgery has emerged as a technology aiming at shortening the duration of laparoscopic procedures by decreasing the need for tying knots or applying clips. The use of energy-based surgery in the laparoscopic setting raises questions about such issues as burst strength, costs, ergonomics, heat production, injuries, and generation of smoke or mist. As far as heat production is concerned, monopolar electrosurgery is associated with greater collateral thermal tissue damage and intraperitoneal temperature variations when compared with ultrasonically activated surgery (UAS) or bipolar electrosurgery (BE), respectively. The aim of the present study was to compare resection time and collateral thermal tissue damage in laparoscopic small bowel surgery performed in a porcine model either with UAS or BE.

MATERIALS AND METHODS

Domestic Norwegian pigs (weight 40 kg) were preanesthetized with intramuscular Ketamine (10 mg/kg) and ventilated with halothane via tracheostomy. Through the same neck incision, the right carotid artery was catheterized to allow monitoring of blood pressure and heart frequency. Pneumoperitoneum was induced insufflating carbon dioxide to a pressure of 10 mm Hg through a needle introduced into the infraumbilical skin. Five (three 5 mm, two 12 mm) ports and a 0° forward-viewing telescope were used. The optical angle (defined as the angle formed by the line of action determined by the working ports and the line of vision determined by the laparoscope) was 60° to the right and 60° to the left optimal 0° position. The extent of each mesenteric dissection included 12 end-arcade arteries supplying the intended segment of the small bowel. A two-handed technique was used during mesentery dissection, and 2 grasping forceps were used to hold the small intestine. Vessels were divided one at a time approximately one cm off the bowel wall. In case of bleeding, all time consumed to achieve hemostasis was included in the oper-
ating time, which was defined as the time elapsed from the division of the first to the twelfth artery. A UAS (Laparoscopic Coagulating Shears®, Ethicon Endo-Surgery, Cincinnati, OH) was compared with high-frequency bipolar electrosurgery forceps (BiCOAG®, Everest Medical Corporation, Minneapolis, MN) (Table 1). The sharp blade edge of the former device was used to divide the grasped tissue. The latter device was enhanced with a blade to speed up the division of the tissue after coagulation. Before animal sacrifice, laparotomy was performed and a full-thickness biopsy of mesentery and small bowel wall was obtained for each resection.

A computer-generated block randomization was used to generate the allocation schedule. Resections were randomly assigned to either the UAS or the ES groups. Allocation concealment was ensured giving identity numbers to the resections. Timing of assignment was just before the planned surgical task at the National Center for Advanced Laparoscopic Surgery, Trondheim, Norway. The generator of the assignment was separated from its executor. Version 2.1 of Planning and Evaluation of Sequential Trials was used in designing, monitoring, and analyzing the study. Before the study, the median operating time was estimated to be 2 min (standard deviation 48 sec), and a 15% reduction in operating time was considered of clinical relevance. With a 5% significance level and a study power of 90%, a sample size of 175 resections in each study arm would have been needed to detect significant differences in operating time. Thus, a sequential triangular design rather than a parallel design was chosen. The former is a statistical method where the sample size is not fixed in advance but a stopping rule is used. The data were inspected every 10 resections in each study arm. At each inspection, Z and V values were calculated. Positive and negative values of Z indicate superiority of ultrasonically activated surgery or bipolar electrosurgery, respectively. V is proportional to the sample size and is a measure of the variability of Z. If the scatterplot crosses the upper or lower boundaries, the trial will stop with a significant superiority of UAS or BE, respectively. If the vertical line between the upper and lower boundary is crossed, the trial is terminated showing no significant difference between UAS and BE (Figure 1). The pigs’ intraoperative blood pressure and heart rate variations in the two study arms were compared using Student’s t test with a significance level of \( P < 0.05 \).

| Table 1. Comparison of UAS and BE. |
|------------------------------------|
|                                   |
| UAS  | BE                |
|-------|-------------------|
| Active blade length, med mer  | 15  | 3.9  |
| Cutting blade blade             |     |      |
| Handle ergonomics pistol grip  | pistol grip | pistol grip |
| Jaws gaping Extend              | 45°  | 3.9 mm |
| Power setting 80 µm 30 watts   | No   | No   |
| Shaft axial rotation No         | No   | No   |
| Shaft diameter, med mer 10      | 10   | 5    |
| Use disposable disposable      |      |      |
| Working shaft length, cm 34     | 34   | 33   |

BE=bipolar electrosurgery; UAS=ultrasonically activated surgery.
RESULTS

No significant differences occurred in intraoperative blood pressure and heart rate variations in pigs undergoing UAS or BE (Table 2). A total of 60 small bowel resections were performed. All resections were carried out as allocated. Four withdrawals occurred resulting in 28 UAS and 28 BE resections. Median unbiased estimates of operating time were adjusted for the sequential nature of the study. At the third inspection, the scatterplot crossed the upper boundaries and the trial was terminated. The Christmas tree-shaped boundary (drawn within the original triangle) is an adjustment to the stopping rule for the gaps between the looks (Figure 1). Operation time was significantly shorter using UAS than BE (0.57 vs. 2.01 min \( P < 0.001 \)) (Table 3).

During surgery as well as at laparotomy, the macroscopic appearance of the approximately 1-cm-broad resected mesentery showed that charring was minimized by UAS as compared with BE. However, histology revealed no collateral thermal damage of the small bowel wall in the two study arms.

DISCUSSION

When exposed to pressures commonly found in living animals, arteries up to 3 mm in diameter occluded by UAS or BE are as unlikely to burst as in case of sealing accomplished by suture knots or clips.\(^8\)\(^9\) Arteries 3 to 7 mm in diameter sealed by UAS or BE can burst at pressures well within values found in living animals.\(^10\) The latter experimental data were confirmed in a clinical study reporting a mean bursting pressure of 213 mm Hg in colon mesentery arteries 4 to 6 mm in diameter sealed by BE.\(^11\) These findings are in support of a selective use of UAS or BE in laparoscopic dissection of bowel mesentery as most vessels encountered are indeed within 3 mm in diameter and may be therefore safely divided. However, the results of the present study strongly suggest that UAS is preferable to BE because the former offers significantly decreased operating time. The known inability of BE to produce the power density required to cut tissue was compensated by adding a blade. This enhancement made the UAS and BE devices used in the present study comparable.

Although BE minimizes the hazards of electrical current,\(^12\)\(^13\) heat production is still a source of concern for unintentional injuries that may occur whenever dissecting close to hollow viscera. BE forceps with an outer plastic layer insulating the metal jaws have been proposed to reduce collateral thermal tissue damage.\(^14\) It has long been known from data on the epidermis that collateral thermal tissue damage is definitively reduced by UAS as compared with electrosurgery.\(^15\) The findings of the present study suggest that mesentery dissection can be safely carried out by UAS or BE at a 1-cm distance from a hollow viscus as shown by the absence of microscopic thermal damage of the small bowel wall in the two study arms. Nevertheless, UAS should be preferred over BE because it minimizes macroscopic charring of the resected mesentery.

CONCLUSIONS

UAS laparoscopic mesentery division offers reduced resection time and no differences in thermal bowel wall damage (1 cm off the bowel wall) as compared with its blade-enhanced BE counterpart in a porcine model.

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### Table 2. Intraoperative data on pigs allocated to UAS or BE.*

|            | UAS     | BE      | \( P \) |
|------------|---------|---------|---------|
| Blood pressure |         |         |         |
| Systolic    | 125.6 (2.3) | 124.6 (2.4) | NS     |
| Diastolic   | 85.7 (2.1)  | 85.8 (2.4)  | NS     |
| Heart rate  | 105.1 (2.2) | 103.2 (2.5) | NS     |

*Values are median (standard deviation)

NS=not significant; BE=bipolar electrosurgery; UAS=ultrasonically activated surgery.

### Table 3. Comparison of operating time (minutes).*

| Resections # | UAS     | BE      |
|-------------|---------|---------|
| 20          | 1.19 (0.45) | 2.05 (0.54) |
| 40          | 1.08 (0.35) | 2.04 (0.46) |
| 56          | 1.03 (0.34) | 1.56 (0.43) |

*Values are median (standard deviation)

BE=bipolar electrosurgery. UAS=ultrasonically activated surgery.
References:

1. Gossot D, Buess G, Cuschieri A, et al. Ultrasonic dissection for endoscopic surgery. Surg Endosc. 1999;13:412-417.

2. Kinoshita T, Kanehira E, Omura K, Kawakami K, Watanabe Y. Experimental study on heat production by a 23.5-kHz ultrasonically activated device for endoscopic surgery. Surg Endosc. 1999;13:621-625.

3. Barrat C, Capelluto E, Champault G. Intraperitoneal thermal variations during laparoscopic surgery. Surg Endosc. 1999;13:136-138.

4. Meng WCS, Kwok SPY, Leung KL, Chung CC, Lau WY, Li AKC. Optimal position of working ports in laparoscopic surgery: an in vitro study. Surg Laparosc Endosc. 1999;6:278-281.

5. Begg C, Cho M, Eastwood S, et al. Improving the quality of reporting of randomized controlled trials: the CONSORT statement. JAMA. 1996;276:637-639.

6. Whitehead J, Brunier H. Planning and Evaluation of Sequential Trials. Department of Applied Statistics, University of Reading, UK: Pest project; 1989.

7. Whitehead J. The Design and Analysis of Sequential Clinical Trials. 2nd ed. Chicester: Ellis Horwood; 1991.

8. Spivak H, Richardson WS, Hunter JG. The use of bipolar cautery, laparoscopic co-agulating shears, and vascular clips for hemostasis of small and medium-sized vessels. Surg Endosc. 1998;12:183-185.

9. Kanehira E, Omura K, Kinoshita T, Kawakami K, Watanabe Y. How secure are arteries occluded by a newly developed ultrasonically activated device? Surg Endosc. 1999;13:340-342.

10. Kennedy JS, Stranahan PL, Taylor KD, Chandler JG. High-burst-strength, feedback-controlled bipolar vessel sealing. Surg Endosc. 1998;12:876-878.

11. Kusunoki M, Shoji Y, Yanagi H, Yamamura T. Usefulness of bipolar scissors for total colectomy. Dis Colon Rectum. 1998;41:1197-1200.

12. Tucker RD. Laparoscopic electrosurgical injuries: survey results and their applications. Surg Endosc. 1995;5:311-317.

13. Wu MP, Ou CS, Chen SL, Yen EYT, Rowbotham R. Complications and recommended practices for electrosurgery in laparoscopy. Am J Surg. 2000;179:67-73.

14. Remorgida V. Tissue thermal damage caused by bipolar forceps can be reduced with a combination of plastic and metal. Surg Endosc. 1998;12:936-939.

15. Hambley R, Hebda PA, Abell E, Cohen BA, Jegasothy BV. Wound healing of skin incisions produced by ultrasonically vibrating knife, scalpel, electrosurgery, and carbon dioxide laser. J Dermatol Surg Oncol. 1988;14:1213-1217.

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