Postoperative Adhesion Formation in a Rabbit Model: Monopolar Electrosurgery Versus Ultrasonic Scalpel

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ABSTRACT

Background and Objectives: To determine if surgery using ultrasonic energy for dissection results in less adhesion formation than monopolar electrosurgical energy in the late (8 weeks) postoperative period.

Methods: Injuries were induced in rabbits by using ultrasonic energy on one uterine horn and the adjacent pelvic sidewall and using monopolar energy on the opposite side. Eight weeks postoperatively, the rabbits underwent autopsy and clinical and pathologic scoring of adhesions was performed by blinded investigators.

Results: There was no significant difference in clinical adhesion scores between the two modalities. The mean clinical score for monopolar cautery was 1.00 versus 0.88 for the Harmonic device (Ethicon Endo-Surgery, Cincinnati, Ohio) ($P = .71$). Furthermore, there was no significant difference found in the pathologic adhesion scores between the ultrasonic scalpel and monopolar energy. The mean pathologic score for monopolar electrosurgery was 4.35 versus 3.65 for the Harmonic scalpel ($P = .30$).

Conclusion: Neither monopolar electrosurgery nor ultrasonic dissection is superior in the prevention of adhesion formation in the late postoperative period.

Key Words: Adhesions, Energy sources, Laparoscopy, Monopolar electrosurgery, Ultrasonic dissection.

INTRODUCTION

Adhesions are abnormal fibrous connections that form between adjacent organs after pelvic surgery or pelvic infection or inflammation that results in tissue damage. Pelvic and abdominal adhesions have been associated with infertility, chronic pelvic pain, small bowel obstruction, and difficulty with surgical access or surgical complications. Although adhesions are formed as a physiological healing response to tissue injury and despite research and the availability of multiple adhesion barriers, they remain a persistent problem.1 In fact, the major cause of bowel obstruction in female patients is adhesion formation after abdominal hysterectomy.2,3 Several strategies have been developed to minimize or prevent postoperative adhesions in pelvic and abdominal surgery. Meticulous hemostasis, gentle tissue handling, and minimally invasive techniques are integral in reducing adhesion formation. Furthermore, various pharmacologic agents have been marketed as means of preventing adhesions, with mixed results.1 Electrosurgery is the main energy form used during laparoscopic surgery, with ultrasonic energy and monopolar energy sources being two of the most commonly used instruments.

The purpose of this study is to determine if surgery using ultrasonic energy for dissection results in less adhesion formation than monopolar electrosurgical energy in the late (8 weeks) postoperative period. Our recent previous study showed no clinical difference in adhesion scores between the two modalities during the early postoperative period (21–23 days).4 However, there was a highly significant difference in the histologic markers of inflammation and tissue necrosis in the tissues dissected with monopolar energy compared with those operated on with ultrasonic shears. This finding suggests that as the tissue changes evolve, a significant clinical difference favoring ultrasonic energy over monopolar electrosurgery may be evident in the late postoperative period. The late postoperative pe-
period, defined in this article as 8 weeks, should allow for full pathologic and clinical maturation of adhesions. These two energy sources are the most commonly used instruments for surgical dissection during laparoscopic surgery. To our knowledge, there have been no previous studies comparing the potential for adhesion formation, in the late postoperative period, between these two energy sources after minimally invasive surgery.

MATERIALS AND METHODS

The study was approved by the Winthrop University Hospital Institutional Animal and Utilization Committee. Eighteen sexually mature New Zealand albino rabbits (Oryctolagus cuniculus) underwent laparoscopy after preoperative sedation. One uterine horn and the adjacent pelvic sidewall were operated on with monopolar energy, and the opposite horn underwent an identical procedure using the ultrasonic scalpel Harmonic ACE Shears (Ethicon Endo-Surgery, Cincinnati, Ohio). The animals were housed for 8 weeks, after which they were euthanized and underwent autopsy. They received a standard scientific diet supplemented with additional fresh vegetables. They were premedicated with ketamine, 35 mg/kg; xylazine, 5 mg/kg; and butorphanol, 0.1 mg/kg, subcutaneously before augmentation of anesthesia with isoflurane at 1% to 3%. They also received gentamicin, 5 mg/kg, prophylactically within 1 hour before surgery and continued once daily for 5 days postoperatively.

Adhesions were graded by 2 investigators blinded to the energy source used on each of the 2 uterine horns and sidewalls. Each horn, as well as the attached sidewall, was then submitted to pathologic examination for microscopic grading of adhesions. The pathologists were also blinded to the type of energy used on the individual tissues examined.

After induction of general anesthesia and abdominal shaving, the abdomen was prepared and draped in the usual sterile fashion. The surgeon used an open laparoscopic entry technique, by first making a 12-mm midline vertical incision just above the umbilicus with a knife. The incision was carried down to the fascia sharply. The rectus muscles were separated in the midline, and the peritoneum was grasped with 2 hemostats. The peritoneum was then entered, and a 10- to 12-mm trocar sleeve was inserted. The abdomen was insufflated with carbon dioxide gas. A 10-mm video laparoscope was used. Two 5-mm accessory trocars, one in each lower quadrant, were placed through 5-mm skin incisions under direct laparoscopic visualization. By use of the Harmonic scalpel on one side and the monopolar energy scissors on the opposite side, the antimesenteric serosal surfaces of both uterine horns were cauterized along a 2 × 2–cm area of adjacent pelvic sidewall peritoneum. The monopolar energy was set at a cutting power of 35 W and was applied for 1 to 2 seconds at each point from the uterine bifurcation up to the tubouterine junction until visible blanching and contraction of the serosa were noted. The tip of the Harmonic scalpel was used to supply energy for 5 seconds at each serosal point, at a generator power level of 3, in a similar manner on the opposite horn. The power level and application time were chosen because they represent the amount of energy required to coagulate a 5-mm artery.

Postoperatively, the animals were allowed to recover for 8 weeks, after which they were euthanized by injection of pentobarbital. They underwent autopsy through a midline vertical abdominal incision, and biopsy specimens were taken by removing each horn and adjacent sidewall peritoneum with underlying muscle. Clinical grading of adhesions was performed using a score from 0 to 4 (Table 1), whereas a score of 1 to 4 was used for pathologic adhesion grading (Table 2). Both the investigators performing the autopsies and the examining pathologists were blinded to the specifics of the surgical procedure and the type of energy source used in the animals.

Statistical analysis to compare surgical methods with respect to clinical and pathologic adhesion scores was performed using the paired t test. P ≤ .05 was considered statistically significant. This study (N = 18) was originally powered to detect a clinically relevant difference in scores between monopolar electrosurgery and ultrasonic dissection of 1.0 (SD, 1.3; effect size, 0.75) with 80% power at the .05 level of significance.

Table 1.

| Grade | Description                                      |
|-------|-------------------------------------------------|
| 0     | No adhesions                                    |
| 1     | Thin or narrow, easily separable adhesions       |
| 2     | Thick adhesions, limited to 1 area               |
| 3     | Thick and widespread adhesions                   |
| 4     | Thick and widespread adhesions plus adhesions of viscera to anterior or posterior abdominal wall (or both) |
RESULTS
Of the 18 rabbits undergoing the laparoscopic procedures, 17 survived for the entire study period. There was 1 major surgical complication, resulting in 1 death that occurred on postoperative day 3 as a result of sepsis due to visceral injury.

Adhesions were measured on an ordinal (ranked) scale. We expected that the Harmonic scalpel would be associated with fewer adhesions.

Analysis of the data did not show a statistically significant difference in the clinical adhesion scores. The mean clinical score for monopolar energy was 1.00 versus 0.88 for the Harmonic device, with \( P = .71 \) (mean difference, 0.12; 95% confidence interval, –0.53 to –0.77) (Table 3). Furthermore, there was no statistically significant difference in the pathologic adhesion scores. The mean pathologic score for monopolar electrosurgery was 4.35 versus 3.65 for the Harmonic scalpel, with \( P = .30 \) (mean difference, 0.71; 95% confidence interval, –0.69 to 2.10) (Table 4).

DISCUSSION
Postoperative abdominal and pelvic adhesions have important consequences to patients and surgeons. With the advent of operative laparoscopy, surgeons noted a decrease in the frequency of postoperative adhesions, as well as formation of de novo adhesions, with laparoscopy compared with laparotomy.7 Furthermore, appropriate selection of surgical instruments, based on knowledge of their unique characteristics and tissue effects, is of paramount importance in adhesion prevention.

The Harmonic scalpel technology uses ultrasonic energy for both cutting and controlled coagulation. This is achieved by converting electrical to mechanical to thermal energy without the passage of electrical current through the tissue. The tips vibrate at 55 500 Hz; this causes protein denaturation, forming a coagulum that seals small vessels.8,9 When the effect is prolonged, secondary heat is produced that seals larger vessels. Cutting is also possible without generating either smoke or char. The vibration of the ultrasonic scalpel is thought to generate low heat at the incision site. On the other hand, monopolar electrosurgery delivers an electrical current via an active electrode that is conducted via a multiplicity of tissue pathways to the dispersive electrode. The rate of heat production or burn in living tissue is primarily governed by the current density.8 The tissue effects obtained with monopolar electrosurgery include vaporization, transection, fulguration, desiccation, and small vessel coaptation.9

Several studies, both animal and human, have examined postoperative adhesion formation caused by different energy sources.10–12 Hirota et al11 examined monopolar electrosurgery, LigaSure (Valley Lab, Boulder, Colorado), ultrasonic shears, Loop Tie (U.S. Surgical, Norwalk, Connecticut), and Endo GIA stapler (U.S. Surgical), as well as the degree of postoperative adhesion formation associated with these instruments, after uterine horn resection in a porcine model. They performed a second-look laparotomy at 14 days postoperatively and graded adhesion formation by visual inspection. They found the advanced bipolar instrument (LigaSure) to have the lowest adhesion formation score, whereas the monopolar energy device had the highest. The ultrasonic shears were found to have the second high-

### Table 2.

| Score | Polymorphonuclear Cells or Lymphocytes | Giant Cells | Collagen Necrosis |
|-------|--------------------------------------|-------------|------------------|
| 1     | None                                 | None        | None             |
| 2     | 1–5 per section                      | Difficult to find | Mild            |
| 3     | 6–10 per section                    | Easy to find | Moderate         |
| 4     | >10 per section                     | Many        | Severe           |

### Table 3.

|       | 0 | 1   | 2 | 3 | 4 |
|-------|---|-----|---|---|---|
| Monopolar\(^a\) | 8 rabbits | 4 rabbits | 3 rabbits | 1 rabbit | 1 rabbit |
| Harmonic\(^a\) | 8 rabbits | 3 rabbits | 6 rabbits | 0 rabbits | 0 rabbits |

\(^aP = .71\).

### Table 4.

|       | 1 | 2 | 3 | 4 |
|-------|---|---|---|---|
| Monopolar\(^a\) | 9 rabbits | 3 rabbits | 2 rabbits | 3 rabbits |
| Harmonic\(^a\) | 13 rabbits | 2 rabbits | 1 rabbit | 1 rabbit |

\(^aP = .30\)
the current study, the number of rabbits accrued was small and the study was underpowered to detect a significant difference in adhesion formation between the two energy sources.

**CONCLUSION**

Good surgical technique is of paramount importance to minimize tissue damage and therefore the possibility of adhesion formation. Furthermore, the type of electrosurgical instrument used may affect the risk of adhesion formation even further. In this study, two of the more commonly used instruments for dissection, ultrasonic shears and monopolar energy, were evaluated for the degree of postoperative adhesion formation. We found no statistical difference in the degree or severity of adhesions between these two instruments, in this model, after a 2-month postoperative period. In this study, as in our operative cases, we took care to minimize the amount of dwell time when using monopolar electrosurgery to avoid the generation of high temperatures resulting in wide thermal spread and increased tissue damage. We believe that this may be a major factor in explaining our results, as well as a major point to be stressed in training novice surgeons. Moreover, surgeons who prefer one instrument over the other can feel confident that both instruments are equally safe and effective when used properly.

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