

# 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.<sup>1</sup> In fact, the major cause of bowel obstruction in female patients is adhesion formation after abdominal hysterectomy.<sup>2,3</sup> 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.<sup>1</sup> 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).<sup>4</sup> 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-

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riod, 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).<sup>5,6</sup> 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.**

Clinical Adhesion Scoring System

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)

**Table 2.**  
Pathologic Adhesion Scoring System

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

**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 electro-surgery 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

**Table 3.**  
Clinical Scoring

	0	1	2	3	4
Monopolar <sup>a</sup>	8 rabbits	4 rabbits	3 rabbits	1 rabbit	1 rabbit
Harmonic <sup>a</sup>	8 rabbits	3 rabbits	6 rabbits	0 rabbits	0 rabbits

<sup>a</sup> $P = .71$ .

**Table 4.**  
Pathologic Scoring

	1	2	3	4
Monopolar <sup>a</sup>	9 rabbits	3 rabbits	2 rabbits	3 rabbits
Harmonic <sup>a</sup>	13 rabbits	2 rabbits	1 rabbits	1 rabbits

<sup>a</sup> $P = .30$

compared with laparotomy.<sup>7</sup> 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.<sup>8,9</sup> 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 electro-surgery 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. Thermal change by resistive heating is also significantly linked to the application time of energy, or dwell time.<sup>8</sup> The tissue effects obtained with monopolar electro-surgery include vaporization, transection, fulguration, desiccation, and small vessel coaptation.<sup>9</sup>

Several studies, both animal and human, have examined postoperative adhesion formation caused by different energy sources.<sup>10–12</sup> Hirota et al<sup>11</sup> examined monopolar electro-surgery, 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-

est adhesion formation score. Sasi<sup>10</sup> performed a meta-analysis and examined perioperative outcomes after laparoscopic cholecystectomy comparing monopolar energy dissection with ultrasonic energy. Perioperative data, such as operating time, postoperative pain, length of stay, and time to return to work, were found to be significantly superior when ultrasonic energy, as opposed to monopolar energy, was used. One might speculate that less operative inflammation might result in lower postoperative adhesion rates. In a study by Brokelman et al,<sup>13</sup> ultrasonic scalpel dissection was associated with statistically significantly lower peritoneal total and active transforming growth factor  $\beta$ 1 levels compared with electrosurgery, at the end of the procedure, suggesting a reduced risk of formation of peritoneal adhesions with the ultrasonic scalpel. On the basis of the premise that peritoneal tissue ischemia is associated with postoperative pain, abdominal distention, and adhesion formation, ten Broek et al<sup>12</sup> compared electrosurgery and ultrasonic dissection in mice in terms of peritoneal tissue ischemia measured by microdialysis. They concluded that electrosurgery causes more ischemic peritoneal damage than ultrasonic dissection. Diamond et al<sup>14</sup> performed a study of patients who underwent second-look laparoscopy within 90 days of laparoscopic adhesiolysis. Adhesions were lysed using a number of techniques, including sharp dissection, electrosurgery, carbon dioxide, argon, or potassium-titanyl-phosphate (KTP) laser. They did not use any adjuvants or barrier methods to minimize adhesion formation. Ninety-seven percent of patients showed a recurrence of approximately 66% of their adhesions. However, de novo adhesions occurred in only 12% of patients.

In our previous study, although no clinical benefit was shown by performing surgical dissection with monopolar scissors compared with ultrasonic shears, there was a marked decrease in histologic indicators of tissue inflammation and necrosis in the early postoperative period with the ultrasonic shears.<sup>4</sup> At the time, this finding was postulated as a benefit and thought to become evident if the animals were examined in the late postoperative period. However, the results of our current study were not able to duplicate the histologic findings found in the early postoperative period, indicating that there is no clear superiority regarding adhesion formation between the use of the Harmonic scalpel and monopolar energy. One might argue that the confounding factor between our two studies is the addition of sterile saline solution used to cover all the treated surfaces in the former study. Furthermore, in

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 electro-surgical 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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