**Hypothesis:** Local wound management using a simple wound-probing protocol (WPP) reduces surgical site infection (SSI) in contaminated wounds, with less postoperative pain, shorter hospital stay, and improved patient satisfaction.

**Design:** Prospective randomized clinical trial.

**Setting:** Academic medical center.

**Patients:** Adult patients undergoing open appendectomy for perforated appendicitis were enrolled from January 1, 2007, through December 31, 2009.

**Interventions:** Study patients were randomized to the control arm (loose wound closure with staples every 2 cm) or the WPP arm (loosely stapled closure with daily probing between staples with a cotton-tipped applicator until the wound is impenetrable). Intravenous antibiotic therapy was initiated preoperatively and continued until resolution of fever and normalization of the white blood cell count. Follow-up was at 2 weeks and at 3 months.

**Outcome Measures:** Wound pain, SSI, length of hospital stay, other complications, and patient satisfaction.

**Results:** Seventy-six patients were enrolled (38 in the WPP arm and 38 in the control arm), and 49 (64%) completed the 3-month follow-up. The patients in the WPP arm had a significantly lower SSI rate (3% vs 19%; P =.03) and shorter hospital stays (5 vs 7 days; P =.049) with no increase in pain (P =.63). Other complications were similar (P =.63). On regression analysis, only WPP significantly affected SSI rates (P =.02). Age, wound length, body mass index, abdominal circumference, and diabetes mellitus had no effect on SSI. Patient satisfaction at 3 months was similar (P =.69).

**Conclusions:** Surgical site infection in contaminated wounds can be dramatically reduced by a simple daily WPP. This technique is not painful and can shorten the hospital stay. Its positive effect is independent of age, diabetes, body mass index, abdominal girth, and wound length. We recommend wound probing for management of contaminated abdominal wounds.

**Abbreviations:** WPP, wound-probing protocol; SSI, surgical site infection; WPP, wound-probing protocol; SSI, surgical site infection; LOS, length of hospital stay; CLASP, Center to Combat Surgical site Infections; CR, control; AL, alkaline; CAP, clindamycin and ampicillin; Bacteroides fragilis; Pseudomonas aeruginosa; MRSA, methicillin-resistant Staphylococcus aureus; VAP, ventilator-associated pneumonia; CR, control; AL, alkaline; CAP, clindamycin and ampicillin; Bacteroides fragilis; Pseudomonas aeruginosa; MRSA, methicillin-resistant Staphylococcus aureus; VAP, ventilator-associated pneumonia; CR, control; AL, alkaline; CAP, clindamycin and ampicillin; Bacteroides fragilis; Pseudomonas aeruginosa; MRSA, methicillin-resistant Staphylococcus aureus; VAP, ventilator-associated pneumonia.
Wound probing, a simple bedside technique that may reduce SSI in contaminated wounds, combines the benefits of primary (less labor for wound care and less pain) and secondary (lower rates of SSI) wound closure. The efficacy of wound probing was evaluated in only 1 retrospective study\(^2\) that involved pediatric patients undergoing an endorectal intestinal pull-through procedure for ulcerative colitis. The results showed a dramatic decrease in SSIs among patients who underwent wound probing (24.4% vs 4.3%). Some surgeons use this method with anecdotally good results.

We sought to prospectively validate wound probing in a prospective randomized clinical trial. The objective was to demonstrate the short- and long-term superiority of wound probing over primary closure in the management of contaminated wounds while quantifying the pain that may be attributed to this procedure.

### METHODS

We conducted a prospective, randomized, single-blind, single-institution controlled trial. Eligible patients included all adults with perforated appendicitis admitted to the Los Angeles County University of Southern California Medical Center's nontrauma Emergency Surgery Service who were scheduled for or who had undergone appendectomy for acute or gangrenous appendicitis alone were considered ineligible.

Study patients started perioperative intravenous antibiotic therapy per the standard appendectomy protocol at our hospital (ertapenem sodium, 1 g/d, or levofloxacin, 500 mg/d, plus metronidazole hydrochloride, 500 mg every 8 hours for patients with penicillin allergy). Antibiotic therapy was continued as a result of the probing was blotted dry. The wound was then covered with a dry dressing. This WPP procedure was performed only once in the morning and repeated every day until the wound was dry and no longer penetrable. This procedure was not repeated later in the day if there was continued fluid drainage.

On postoperative days 1, 3, and 5, quantitative bacterial cultures were obtained from the cotton-tipped applicators used to probe the wound in the WPP arm. If the wounds of control- or WPP-arm patients were deemed to be infected, cultures of the drainage from these wounds were also taken.

### ASSESSMENTS

During their hospitalization, patients underwent daily assessment of vital signs and white blood cell count. Wound assessment included daily monitoring based on the ASEPsis criteria for SSI (additional treatment; presence of serous discharge, erythema, purulent exudate, and separation of the deep tissues; isolation of bacteria; and duration of inpatient stay) (Table 2).\(^3\)

Patients with an ASEPsis score greater than 20 were considered to have an SSI. In cases of purulent drainage and an ASEPsis score less than 20, the wound was considered infected per the Centers for Disease Control and Prevention definition of nosocomial SSIs.\(^4\) If an SSI was diagnosed in patients in either arm of the study, the wound was opened and loosely packed with moist gauze. The gauze dressing was changed 3 times daily, allowing for healing by secondary intention.

### Table 1. Eligibility Criteria

<table>
<thead>
<tr>
<th>Inclusion Criteria</th>
<th>Exclusion Criteria</th>
</tr>
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<tbody>
<tr>
<td>Aged $\geq$ 18 y</td>
<td>Acute or gangrenous appendicitis</td>
</tr>
<tr>
<td>Open appendectomy via right lower quadrant incision, at the discretion of the primary surgical team</td>
<td>Pregnancy</td>
</tr>
<tr>
<td>Perforated appendicitis confirmed during surgery</td>
<td>Laparoscopic appendectomy</td>
</tr>
<tr>
<td>Intraoperative culture of pus</td>
<td>Laparotomy incision</td>
</tr>
<tr>
<td></td>
<td>Unable to consent</td>
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<tr>
<td></td>
<td>Critically ill, requiring monitored setting, and determined to be unable to tolerate wound sepsis</td>
</tr>
<tr>
<td></td>
<td>Neutropenia (WBC count $&lt;4000/\mu L$)</td>
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<tr>
<td></td>
<td>Immunosuppressive therapy (eg, daily corticosteroids) after recent chemotherapy or</td>
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<td></td>
<td>after transplantation</td>
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<td></td>
<td>History of prosthesis implantation, such as cardiac valve or hip replacement</td>
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</tbody>
</table>

Abbreviation: WBC, white blood cell.

SI conversion factor: To convert WBC count to 109 cells per liter, multiply by 0.001.

### INTERVENTIONS

Appendectomy was performed via standard right lower quadrant incision. Intraoperative cultures were taken. The wound was closed with staples placed at 2-cm intervals. Unblinded research staff performed the daily wound assessments and procedures. The patient’s primary surgical team was blinded to the randomization arm and was encouraged to treat the patient and manage the wound as they deemed appropriate.

Patients randomized to the control arm underwent daily swab of their closed appendectomy incision with povidone-iodine. Patients randomized to the WPP arm underwent standardized wound probing. Similar to the control condition, patients in the WPP arm underwent povidone-iodine solution swab of their incision. Next, a dry, sterile cotton-tipped applicator was used to penetrate the skin and soft tissue between the skin staples, reaching down to the external oblique fascia. Any fluid that extruded as a result of the probing was blotted dry. The wound was then covered with a dry dressing. This WPP procedure was performed only once in the morning and repeated every day until the wound was dry and no longer penetrable. This procedure was not repeated later in the day if there was continued fluid drainage.

On postoperative days 1, 3, and 5, quantitative bacterial cultures were obtained from the cotton-tipped applicators used to probe the wound in the WPP arm. If the wounds of control- or WPP-arm patients were deemed to be infected, cultures of the drainage from these wounds were also taken.
Patients were queried daily for their pain score based on the Wong-Baker FACES visual analog scale. For those in the WPP arm, the pain score was recorded after the probing of their wound. Length of hospital stay was recorded along with any unexpected adverse events related or unrelated to treatment, which were reported to the institutional review board. Study participants were followed up as outpatients at 2 weeks and at 3 months after discharge. Wounds were assessed for infection, and pain scores were recorded. Each patient’s satisfaction with the operative result was recorded according to a 3-point scale (satisfied, somewhat satisfied, or not satisfied).

### MAIN OUTCOME MEASURES

The primary outcome measure was the rate of postoperative SSIs, which was objectively based on the daily ASEPSIS score for the wound and the daily assessment by the blinded surgical team. Secondary outcomes included length of hospital stay, pain score, and patient satisfaction with the surgical results at 2 weeks and at 3 months.

### OBJECTIVES

The purpose of this study was to evaluate the WPP for management of contaminated wounds. To our knowledge, this is the first prospective randomized controlled trial evaluating wound probing. The objective was to show superiority of the WPP compared with primary skin closure on the basis of reduced SSI and reduced hospital stay, without a significant increase in pain score.

### STATISTICAL CONSIDERATIONS

Our hospital has an approximately 25% SSI rate after open appendectomy for perforated appendicitis with primary wound closure. To detect a 50% reduction in SSI between the 2 procedures at the .05 level of significance and 80% power, we would need to randomize 336 patients. We perform 300 appendectomies annually, of which one-third are for perforated appendicitis. This is a pilot study randomizing 100 patients in a prospective controlled trial to evaluate the efficacy and feasibility of wound probing.

Statistical analysis included the 2-sample t test with equal variances, χ² test, and Fisher exact test for categorical variables, which are presented as mean (SD). For nonnormal numerical variables, the Wilcoxon rank sum test was performed, and data are presented as median and range.

### RESULTS

During a 2-year period, 76 patients were enrolled in the trial and equally distributed between the control and WPP arms. One patient in the control arm withdrew on postoperative day 2 (Figure). Patients in the 2 arms had similar characteristics, including age, sex, and race (Table 3). They were also similar with respect to factors and comorbidities that may affect wound healing or SSI after open appendectomy, including diabetes mellitus, body mass index, and abdominal girth.

Postoperatively, patients had similar incisional lengths (mean, 8 cm). Patients were febrile, with a normal heart rate and normalization of their white blood cell count.

### Table 2. Simplified ASEPSIS Score Method for Wound Assessment for Infection

<table>
<thead>
<tr>
<th>Score, Proportion of Wound Affected</th>
<th>0%</th>
<th>&lt;20%</th>
<th>20%-39%</th>
<th>40%-59%</th>
<th>60%-79%</th>
<th>≥80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serous exudate</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Erythema</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Purulent exudate</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Separation of deep tissues</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
</tbody>
</table>

*The original ASEPSIS score also includes the following points: 10 for need for antibiotics; 5 to 10 for need for drainage of pus; 10 for isolation of bacteria; and 5 for inpatient stay longer than 14 days. A total score of greater than 20 is considered an infected wound.

### Table 3. Patient Demographics

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Control (n=37)</th>
<th>WPP (n=38)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic</td>
<td>Control</td>
<td>WPP</td>
<td></td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>34 (11)</td>
<td>32 (12)</td>
<td>.39</td>
</tr>
<tr>
<td>Male sex</td>
<td>28 (76)</td>
<td>30 (79)</td>
<td>.79</td>
</tr>
<tr>
<td>Hispanic race</td>
<td>34 (92)</td>
<td>34 (89)</td>
<td>.71</td>
</tr>
<tr>
<td>Comorbidities, any</td>
<td>10 (27)</td>
<td>9 (24)</td>
<td>.80</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>5 (14)</td>
<td>1 (3)</td>
<td>.11</td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>27 (5)</td>
<td>26 (4)</td>
<td>.15</td>
</tr>
<tr>
<td>Abdominal circumference, mean (SD), cm</td>
<td>100 (16)</td>
<td>94 (16)</td>
<td>.14</td>
</tr>
</tbody>
</table>

*Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); WPP, wound-probing protocol.

### Figure

Trial enrollment. *Patient requested withdrawal from the study on postoperative day 2.
within a similar postoperative period (Table 4). Patients in the control arm reached a wound ASEPSIS score of 0 significantly earlier than those in the WPP arm (2.0 vs 4.0 days; P= .007); however, the range of scores was much wider among the control patients (0-20 vs 0-7 days). Those in the WPP arm had a significantly shorter hospital stay (5 vs 7 days; P=.049).

Follow-up visits at 2 weeks were attended by 34 of 37 control-arm patients (92%) and 37 of 38 WPP-arm patients (97%). At 3 postoperative months, follow-up visits were attended by 25 of 37 control-arm patients (92%) and 37 of 38 WPP-arm patients (97%). At 3 postoperative months, follow-up included the pain score, wound ASEPSIS score, and patient satisfaction. The patients had similar long-term outcomes at 2 weeks and 3 months postoperatively (Table 6).

Wound probing is a simple daily technique that can be applied to contaminated abdominal wounds to significantly reduce SSIs without increasing pain. In our study, we standardized all patients to open appendectomy via right lower quadrant wounds. The wounds were probed daily until the wound was closed and no longer draining, which took approximately 3 days and rarely as long as 5 days. The patients who underwent wound probing had a significantly lower SSI incidence (19% vs 3%) and did not report increases in pain from the probing technique. Patients who had SSIs required an opening of the wound and packing with saline-soaked gauze 3 times a day. By reducing SSI, there was a significantly shorter hospital stay (7 vs 5 days) and also a reduction in time spent by the health care providers attending to wound care.

Surgical practice varies with regard to wound management. Even for a procedure as common as open appendectomy, there is little consensus concerning optimal wound management for perforated appendicitis. Primary closure is a common choice and results in failure in 7% to 50% of patients.11 When primary closure fails or is deemed inappropriate, the wound is opened and allowed to close by secondary intention (ie, packing an open wound multiple times a day). Closure by secondary intention can be painful to the patient, can be labor intensive, and has a poor cosmetic outcome. Nevertheless, it is the most widely used closure technique in adults with contaminated wounds. To avoid these problems, some surgeons prefer to delay primary closure (ie, packing an open wound for 4 days followed by primary closure).11 Compared with closure by secondary intention, delayed primary closure offers improved cosmetic outcome and reduction in morbidity and wound care costs once closed. However, the morbidity and costs of packing the wound for the first 4 days are
similar to those of closure by secondary intention. In obese patients, all 3 methods can result in amplification of the morbidities.

Based on our results, we recommend that wound probing be practiced for contaminated wounds due to open appendectomy for perforated appendicitis. We believe that our results can also be extrapolated to other contaminated abdominal wounds regardless of their incisional length. Wound probing for all contaminated laparotomy wounds has been a common practice of one of us (S.T.) and of other surgeons, with anecdotal results until now. The favorable results from our prospective randomized study have strengthened our belief in this technique.

The method by which wound probing reduces SSIs is not clearly understood at this time. We surmise that this technique allows for drainage of contaminated fluid within the soft tissue, thus reducing the bacterial count while maintaining a moist wound for improved healing. We are currently analyzing the bacteriology data gathered from this study to gain insight into the process by which wound probing helps in wound healing in the face of contamination.

We recommend that wound probing be practiced in the first-line management of incisions after open surgery, such as bowel resection, in the face of contamination. Use of this technique will reduce SSI and decrease hospital stay, both of which may result in improved long-term outcomes such as fascial dehiscence and incisional hernias, reduced labor for wound care by nursing staff and physicians, improved cosmetic outcome with primary closure, and possibly reduced overall cost.

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REFERENCES