

# Surgical Site Infection after Primary Closure of High-Risk Surgical Wounds in Emergency General Surgery Laparotomy and Closed Negative-Pressure Wound Therapy

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- BACKGROUND:** We hypothesized that the universal adoption of closed wounds with negative pressure wound therapy (NPWT) in emergency general surgery patients would result in low superficial surgical infection (SSI) rates.
- STUDY DESIGN:** We performed a retrospective observational study using primary wound closure with external NPWT, from May 2017 to May 2018. Patients with active soft tissue infection of the abdominal wall were excluded. Data were analyzed by Fisher's exact tests and Wilcoxon-Mann-Whitney tests, with significance is set at a value of  $p < 0.05$ .
- RESULTS:** Eighty-five patients (53% female) with a median age of 65 years (range 19 to 98 years) underwent laparotomies. Four patients were excluded for active soft tissue infection. Wounds were classified as dirty ( $n = 18$ ), contaminated ( $n = 52$ ), and clean contaminated ( $n = 11$ ). Median BMI was  $27 \text{ kg/m}^2$  (interquartile range [IQR]  $23.4$  to  $33.0 \text{ kg/m}^2$ ). Median antibiotic therapy was 4 days (IQR 1 to 7 days). Twenty-six patients had open abdomen management. Patient follow-up was a median of 20 days (range 14 to 120 days). Six patients (7%) developed superficial SSI requiring conversion to open wound management. No patients developed fascial dehiscence. There were no statistically significant associations between SSI and wound class ( $p = 0.072$ ), antibiotic duration ( $p = 0.702$ ), open abdomen management, or preoperative risk factors ( $p < 0.1$ ). Overall morbidity was 38% and mortality was 6%.
- CONCLUSIONS:** Primary closure of high risk incisions combined with NPWT is associated with acceptably low SSI rates. Due to the low morbidity and decreased cost associated with this technique, primary closure with NPWT should replace open wound management in the emergency general surgery population. (J Am Coll Surg 2019;228:393–397. © 2018 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Negative pressure wound therapy (NPWT) was introduced in 1997 and has become a widely accepted practice among a variety of surgical specialties.<sup>1</sup> For open wounds, NPWT

is associated with improved patient comfort and faster healing compared with traditional open wound management with wet to dry dressing changes.<sup>2</sup> The use of NPWT on closed surgical incisions has been proposed to decrease infection in high risk wounds and avoid the morbidity of an open wound. A recent meta-analysis concluded that the use of NPWT on closed wounds (closed-NPWT) significantly reduces the rate of wound infections and seromas.<sup>3</sup>

Many studies involving NPWT are limited to clean or clean-contaminated wounds. Management of contaminated and dirty wounds has traditionally involved open wound management with healing by secondary intention or delayed primary closure (DPC).<sup>4</sup>

Closed-NPWT for contaminated and dirty surgical wounds has not been widely adopted due to the 10% to

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**Abbreviations and Acronyms**

DPC	= delayed primary closure
EGS	= emergency general surgery
IQR	= interquartile range
NPWT	= negative pressure wound therapy
PC	= primary closure
SSI	= surgical site infection

30% risk of wound infections in this patient population. The incidence of superficial surgical site infection (SSI) in emergency general surgery (EGS) cases is significant. Scarborough and colleagues<sup>5</sup> reported that the incidence of incisional SSI was 6.7% in a large cross-section of EGS patients. Surgical site infection is associated with a significant financial burden.<sup>6</sup> A recent study in the Veterans Affairs surgical population demonstrated that SSI increases patient care cost by an estimated \$7,003 per event.<sup>7</sup> In colorectal surgical populations, SSI increases postoperative care costs by 35.5% and length of stay by 71.7%.<sup>8</sup> These studies highlight the importance of developing effective, cost-conscious wound management strategies to minimize superficial SSI without sacrificing wound healing.

We have previously demonstrated, in a prospective, randomized pilot study, that contaminated and dirty surgical wounds benefit from closed-NPWT, with significantly faster healing rates and similar wound complications compared with open-NPWT.<sup>9</sup> Because this pilot study included only 24 patients in the closed-NPWT arm with contaminated or dirty wounds, we expanded our clinical use of closed-NPWT to include all EGS laparotomies and ostomy site closures. We hypothesized that primary wound closure with NPWT would result in similar superficial SSIs compared with open-NPWT for EGS operations with wound classifications of contaminated or dirty.

**METHODS**

We performed an IRB-approved, retrospective observational study of a prospective protocol using primary wound closure with closed-NPWT in consecutive EGS patients, from May 2017 to May 2018. All patients underwent surgery on the acute care surgery service by 1 of 7 physicians. Patients with active soft tissue infections of the abdominal wall were excluded from the study. Patients were analyzed for demographics, risk factors for wound complications, surgical indication, wound class, open abdomen management, and duration of antibiotic therapy. The primary outcome under investigation was incidence of superficial SSI requiring intervention. Secondary outcomes included overall morbidity and in-hospital mortality.

Wounds were managed with a Prevena (KCI). This device is designed to provide NPWT to wounds that have been sutured or stapled closed. All wounds in the study were stapled closed. The Prevena dressing was placed at the time of closure and remained in place until discharge, or a maximum of 7 days. The device was then removed and the wound was left open to air. For open abdomen cases, the Prevena was placed on the same day as fascial closure. Wounds were counted as superficial SSIs if they met any of the following conditions: they demonstrated purulent drainage, localized fever and/or spreading erythema requiring treatment with antibiotics, or needed to be opened or debrided. Infected wounds were then converted to open wound management with wet-to-dry dressings or open-NPWT. Wound observation time was calculated as the number of days from skin closure to the patient's last clinic visit or death.

Sample characteristics used descriptive statistics. Frequencies and percentages were used to describe categorical variables. Means and standard deviations (or medians and ranges where appropriate) were used to describe continuous variables. Fisher's exact tests were used to assess associations in bivariate comparisons of categorical variables. Wilcoxon-Mann-Whitney tests were used to test group differences of continuous variables. Statistical significance was set at a value of  $p < 0.05$ .

**RESULTS**

Eighty-five consecutive patients were considered for closed-NPWT in the postoperative management of their wound. Four patients were excluded from the study due to the presence of skin or soft tissue infection at the time of surgery, leaving 81 patients for analysis. Median age was 65 years old (interquartile range [IQR] 52 to 74 years old), median BMI was 26.5 kg/m<sup>2</sup> (IQR 23.4 to 33.0 kg/m<sup>2</sup>), and 43 patients were female (53.1%). The prevalence of comorbidities in our patient population that may contribute to SSI are shown in [Table 1](#).

Operative indications and wound classifications are shown in [Table 2](#). For patients who had open abdomen management, wounds were categorized at the time of initial operation. Sixteen of the 18 cases categorized as clean contaminated represented wound closures at ostomy sites for ostomy reversal procedures. Colon pathology was the indication for operating in 46 patients (57%). Twenty-six (32.1%) patients were managed with an open abdomen. Indications for open abdomen management included extensive contamination (9 patients), hemodynamic compromise (8 patients), or bowel ischemia requiring a second look (9 patients). Twelve of these patients (48%) obtained fascial closure on the second

**Table 1.** Patient Demographics

Characteristic	Data
Total n	81
Female, n (%)	43 (53.1)
Coronary artery disease, n (%)	18 (22.2)
Congestive heart failure, n (%)	16 (19.8)
COPD, n (%)	19 (23.5)
Renal failure, n (%)	18 (22.2)
Cirrhosis, n (%)	3 (3.7)
Smoking history, n (%)	32 (39.5)
Diabetes, n (%)	19 (23.5)
Immunosuppression medication, n (%)	5 (6.2)
Previous surgical site infection, n (%)	2 (2.5)
Age, y, median (IQR)	65 (52–74)
BMI, kg/m <sup>2</sup> , median (IQR)	26.5 (23.4–33.0)

IQR, interquartile range.

operation, 20 patients (80%) by the third operation, and 26 (100%) by the fourth operation. Postoperatively, antibiotics were continued for a median of 4 days after the initial surgery (IQR 1 to 7 days).

Wounds were observed for a median of 20.0 days (IQR 14.0 to 30.0 days). Superficial SSI requiring antibiotics or reopening of the wound occurred in 6 patients (7.4%). One SSI was due to the development of a postoperative enterocutaneous fistula that drained via the midline wound from an anastomotic leak. Patients with an SSI had a significantly longer wound observation time compared with patients without an SSI: median of 56 days to 19 days, respectively ( $p = 0.03$ ). This was related to longer wound healing time. All wounds resulted in complete closure at the end of the observation time. Results of the bivariate analysis comparing preoperative variables to SSI are shown in Table 3. No variable had a significant impact

**Table 2.** Operative Indications and Wound Class

Variable	n	%
Pathology		
Abdominal abscess	1	1.2
Bowel obstruction	13	16.0
Diverticulitis	17	21.0
Gastrointestinal bleeding	1	1.2
Malignancy	7	8.6
Mesenteric ischemia	6	7.4
Ostomy reversal	10	12.3
Perforated viscus	20	24.7
Trauma	6	7.4
Wound class		
Clean-contaminated	18	22.2
Contaminated	43	53.1
Dirty	20	24.7

**Table 3.** Results of Bivariate Analysis

Variable	n	SSI, yes	SSI, no	p Value
Total	81			
Sex				
Female	43	3	40	
Male	38	3	35	
Colon pathology	48	4	44	1.00
Open abdomen	26	2	24	1.00
Antibiotic duration	81	6	75	0.70
Wound class				
Clean-contaminated	18	0	18	
Contaminated	43	6	37	
Dirty	20	0	20	
BMI	81	6	75	0.09
Coronary artery disease	18	1	17	1.00
Congestive heart failure	16	2	14	0.34
COPD	19	2	17	0.62
Renal failure	18	3	15	0.12
Cirrhosis	3	0	3	1.00
Smoking history	32	1	31	0.40
Diabetes	19	3	16	0.14
Immunosuppression medication	5	1	4	0.33
Prior SSI	2	0	2	1.00

SSI, surgical site infection.

on the incidence of wound infection in this study. All wound infections occurred in contaminated cases. Patients with an SSI had an average body mass index (BMI) of 33 kg/m<sup>2</sup> compared with 28 kg/m<sup>2</sup> in patients without SSI; however, this was not statistically significant.

The overall morbidity and mortality rates for patients in the study were 38% and 6%, respectively. Nonwound complications by organ system included cardiac (9 patients), gastrointestinal (6 patients), infectious (3 patients), and pulmonary (14 patients). In-hospital mortality occurred in 5 patients and were not related to SSI or other wound complications.

## DISCUSSION

As a follow-up to our previously published prospective, randomized clinical trial, this study demonstrated that closed-NPWT can be used in high risk surgical wounds with improved rates of SSI. Our previous study demonstrated a wound infection rate of 8% (2 of 24 patients), similar to the SSI rate of 7% shown in this study.<sup>9</sup> Historical data have shown that class II, III, and IV wounds are associated with SSI rates of 3% to 11%, 10% to 17%, and more than 27%, respectively, with traditional wound management strategies.<sup>6</sup> Novel wound management systems, such as the closed-NPWT device used in this study,

help reduce the rate of SSI without the morbidity and patient discomfort of an open abdominal wound. Similar results using closed-NPWT have been demonstrated at other institutions. O'Leary and colleagues<sup>10</sup> demonstrated that closed-NPWT decreased superficial SSI rates from 32% to 8% in patients undergoing open abdominal surgery. In their study, the use of closed-NPWT was also associated with a significant reduction in length of stay compared to that with traditional wound dressings.<sup>10</sup> The use of closed-NPWT in other surgical specialties is also widely supported in the literature. Two meta-analyses have recently demonstrated that closed-NPWT is associated with a decrease in SSI, wound dehiscence, and length of stay.<sup>3,11</sup>

Dayama and associates<sup>12</sup> performed an analysis of the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) for class IV wounds in emergency colon surgery. For wounds closed primarily, they showed an incidence of superficial SSI at 10.3%. They did not comment on the use of NPWT, and their study did not distinguish between laparoscopic and open operations. Therefore, this study has the potential to introduce significant bias due to lack of details regarding type of operative approach, postoperative wound management, and an inability to match groups for comparison based on factors that were not available in the database. Most surgeons and the literature would agree that primary closure of contaminated and dirty wounds without NPWT is associated with the highest rate of SSI. Open wound management remains an option to minimize wound infections. Seamon and co-workers<sup>13</sup> demonstrated, in patients undergoing trauma laparotomies, that superficial SSI and fascial dehiscence rates could be decreased to 9.8% and 2.5%, respectively, with open wound management, compared with 31% and 8% of patients who underwent loose or complete skin closure. This study suggests open wound management is an effective way to minimize SSI; however, the authors do not comment on the time to wound closure. Open-NPWT cuts wound healing rates in half compared with wet-to-dry dressing changes.<sup>2</sup> Although open wound management is associated with similar SSI rates compared with primary closure with NPWT, the rate of closure and morbidity of frequent dressing changes must be considered. Furthermore, open wound management also carries a significant financial burden. In a 2004 study, Smith and colleagues<sup>14</sup> estimated that colorectal surgery patients who developed an SSI accumulated \$6,200/patient in-home health care costs required for management of their open wounds.

Delayed primary closure (DPC) is an alternative method to wound management that involves packing the wound with saline-moistened gauze for a minimum

of 3 to 4 days and closing the wound with adhesive strips or suture if the wound appears healthy. This management strategy was popularized in a prospective, randomized controlled trial comparing DPC to primary closure (PC) in patients with dirty laparotomy wounds.<sup>15</sup> Surgical site infections occurred in 12% of patients (3 of 26) undergoing DPC and 48% (11 of 23) undergoing PC. A more recent randomized trial comparing DPC with PC at a tertiary referral center in India demonstrated a 2.7% SSI rate in patients undergoing DPC compared with 42.5% in PC patients.<sup>4</sup> These authors preferred to perform DPC with interrupted suture in the operating room when the wound appeared acceptable for closure. These studies suggest DPC of dirty wounds is associated with acceptable closure rates; however, this method does require multiple interventions throughout the patient's hospital stay with wet-to-dry dressing changes and a procedure for final wound closure.

Our study analyzed the results of consecutive patients on an acute care surgery service. Most patients had contaminated or dirty wounds. We opted to include ostomy wounds in our analysis because they have been associated with a higher risk of SSI. The incidence of wound infection at stoma sites ranges from 5% to 40%.<sup>16,17</sup> Sixteen of the wounds classified as clean contaminated represented ostomy wound closures, and none developed SSI. This is a subset of patients that deserves future analysis, but this appears promising based on this initial evaluation. It is also interesting that all the SSIs occurred only in the contaminated wound category and none in the dirty category. Eighteen of the 20 patients in the dirty category were managed with open abdomens. During the time of open abdomen management, the wounds are treated with open NPWT. At the time of fascial closure, the wounds have had an opportunity to form a granulation base before wound closure and application of closed NPWT. One could hypothesize that the open abdomen management resulted in the advantages seen in delayed primary closure.

In today's health care market, the cost of any new treatment or therapy must be strongly considered before being universally adopted. For the purposes of this manuscript, KCI provided 2017 retail cost data for the Prevena closed-NPWT system compared with traditional open-NPWT. The estimated cost for 1 week of inpatient open-NPWT is \$1,273, which includes the wound VAC, canister, and 3 medium-sized black foam dressings. Two weeks of outpatient open-NPWT would add an additional \$1,750 for VAC therapy and supplies. This does not include the cost of home health nursing for dressing changes. The Prevena device provides 7 days of closed-NPWT for a 1-time cost of \$544. These prices may vary depending on contracted prices with individual health

care organizations; however, it is clear that closed-NPWT is economically justifiable compared with open-NPWT.

Our study limitations include its retrospective observational design. We included high-risk wounds in the clean contaminated category that are associated with a high incidence of SSI. We recognize the closed-NPWT has not resulted in decreased SSI rates in all patient populations. Shen and associates<sup>16</sup> demonstrated, in a randomized trial, that closed-NPWT did not result in decreased SSI rates compared with standard laparotomy dressings in patients with gastrointestinal malignancies. In their study, NPWT was discontinued on postoperative day 4, but it is unknown whether or not this contributes to the difference in outcomes. Patients in our protocol were not risk-stratified because we wanted to establish a universal protocol for all EGS patients at our institution. There are numerous preoperative and operative variables that are associated with SSI, such as age, nutritional status, operation performed, and wound classification.<sup>17</sup> We attempted to study numerous variables that may contribute to wound healing and the development of SSI, but none showed significance in analysis. We also ended our analysis at the point of complete wound closure and have no data on long-term incidence of postoperative hernia. Finally, it is important to recognize that SSI will develop in a portion of this population even with closed-NPWT, and that early recognition and treatment are necessary to prevent more the serious complications of soft tissue infection and potential fascial dehiscence.

## CONCLUSIONS

Closed-NPWT is a viable alternative to open wound management with acceptable surgical site infection rates in EGS patients. This wound management strategy should replace delayed primary closure and open-NPWT for contaminated and dirty wounds.

## Author Contributions

Study conception and design: Hall, Regner, Abernathy, C Isbell, T Isbell, Kurek, Smith, Frazee

Acquisition of data: Hall, Frazee

Analysis and interpretation of data: Hall, Regner, Abernathy, C Isbell, T Isbell, Kurek, Smith, Frazee

Drafting of manuscript: Hall, Frazee

Critical revision: Hall, Regner, Abernathy, C Isbell, T Isbell, Kurek, Smith, Frazee

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