

Clinical Study

# Negative pressure wound therapy reduces incidence of postoperative wound infection and dehiscence after long-segment thoracolumbar spinal fusion: a single institutional experience

Owoicho Adogwa, MD, MPH<sup>a,\*</sup>, Parastou Fatemi, BS<sup>a</sup>, Edgar Perez, BS<sup>a</sup>,  
Jessica Moreno, RN, BSN<sup>a</sup>, Gustavo Chagoya Gazcon, BS<sup>a</sup>, Ziya L. Gokaslan, MD<sup>b</sup>,  
Joseph Cheng, MD, MS<sup>c</sup>, Oren Gottfried, MD<sup>a</sup>, Carlos A. Bagley, MD<sup>a</sup>

<sup>a</sup>Division of Neurosurgery, Duke University Medical Center, 3807, Durham, NC 27710, USA

<sup>b</sup>Department of Neurosurgery, Johns Hopkins University School of Medicine, 733 N. Broadway, Baltimore, MD, 21205, USA

<sup>c</sup>Department of Neurosurgery, Vanderbilt University Medical Center, 1211 Medical Center Dr, Nashville, TN 37232, USA

Received 8 October 2013; revised 24 March 2014; accepted 16 April 2014

## Abstract

**BACKGROUND CONTEXT:** Wound dehiscence and surgical site infections (SSIs) can have a profound impact on patients as they often require hospital readmission, additional surgical interventions, lengthy intravenous antibiotic administration, and delayed rehabilitation. Negative pressure wound therapy (NPWT) exposes the wound site to negative pressure, resulting in the improvement of blood supply, removal of excess fluid, and stimulation of cellular proliferation of granulation tissue.

**PURPOSE:** To assess the incidence of wound infection and dehiscence in patients undergoing long-segment thoracolumbar fusion before and after the routine use of NPWT.

**STUDY DESIGN:** Retrospective study.

**PATIENT SAMPLE:** One hundred sixty patients undergoing long-segment thoracolumbar spine fusions were included in this study.

**OUTCOME MEASURES:** Postoperative incidence of wound infection and dehiscence.

**METHODS:** All adult patients undergoing thoracolumbar fusion for spinal deformity over a 6-year period at Duke University Medical Center by the senior author (CB) were included in this study. In 2012, a categorical change was made by the senior author (CB) that included the postoperative routine use of incisional NPWT devices after primary wound closure in all long-segment spine fusions. Before 2012, NPWT was not used. After primary wound closure, a negative pressure device is contoured to the size of the incision and placed over the incision site for 3 postoperative days. We retrospectively review the first 46 cases in which NPWT was used and compared them with the immediately preceding 114 cases to assess the incidence of wound infection and dehiscence.

**RESULTS:** One hundred sixty (NPWT: 46 cases, non-NPWT: 114 cases) long-segment thoracolumbar spine fusions were performed for deformity correction. Baseline characteristics were similar between both cohorts. Compared with the non-NPWT cohort, a 50% decrease in the incidence of wound dehiscence was observed in the NPWT patient cohort (6.38% vs. 12.28%,  $p=.02$ ). Similarly, compared with the non-NPWT cohort, the incidence of postoperative SSIs was significantly decreased in the NPWT cohort (10.63% vs. 14.91%,  $p=.04$ ).

**CONCLUSIONS:** Routine use of incisional NPWT was associated with a significant reduction in the incidence of postoperative wound infection and dehiscence. © 2014 Elsevier Inc. All rights reserved.

FDA device/drug status: Not applicable.

Author disclosures: **OA:** Nothing to disclose. **PF:** Nothing to disclose.

**EP:** Nothing to disclose. **JM:** Nothing to disclose. **GCG:** Nothing to disclose. **ZLG:** Speaking/Teaching Arrangements: AO North America (E), AO Spine (E), NREF (E), DePuy (E); Stock Ownership: US Spine (A) and Spinal Kinetics (C); Honorarium: AO Foundation (A per diem); Board of Directors: JNS, Spine Journal, Journal of Spine Disorders, European

Spine Journal, Nature Review World Neurosurgery, Journal of Surgical Oncology; Trips/Travel: Visiting Professor (A); Travel/accommodation/s/meeting expenses unrelated to activities listed: AOSpine. **JC:** Nothing to disclose. **OG:** Nothing to disclose. **CAB:** Nothing to disclose.

\* Corresponding author. DUMC, Box 3807, Durham, NC 27710, USA. Tel.: (919) 668-6760; fax: (919) 668-1221.

E-mail address: [owoicho.adogwa@gmail.com](mailto:owoicho.adogwa@gmail.com) (O. Adogwa)

**Keywords:** Negative pressure wound therapy; Deformity; Wound dehiscence; Wound infection; Spine outcomes; Surgical site infections

## Introduction

Despite the use of prophylactic antibiotics, advances in surgical technique, and postoperative care, wound infections, and dehiscence after spine surgery remain a serious problem [1–6]. Numerous published studies have reported rates of wound complications ranging from 2% for simple discectomies to 15% after larger deformity correction procedures; with increased risk associated with spinal instrumentation [6–13]. The medical and financial sequelae of such complications can be devastating. The cost of medical care for postoperative spinal infection is greater than four times that of an uncomplicated case. In fact, the average “added cost” per patient with wound infectious complications has been reported to exceed \$100,000 [4].

Wound infections lead to tissue breakdown and ultimately wound dehiscence through interference with the normal cellular mechanisms of wound healing and devitalization of underlying tissue [4,14,15]. Aggressive tissue mobilization for wound closure without proper attention to preservation of skin blood supply can lead to dehiscence and infection as devitalized tissue is a nidus for bacterial infection. This is particularly true for larger wounds, where presumably, there may be potential spaces surrounded by devascularized tissue, often containing metallic hardware [5,16,17]. Additionally, longer operative times potentially allow more infectious agents to be introduced. Furthermore, prior operations, irradiated surgical beds, and concomitant steroid therapy dramatically increase the chance for wound dehiscence and infection.

Negative pressure closure dressings after elective surgery have been used in other surgical disciplines with good clinical outcomes [5,11,16,17]. Negative pressure closure dressings decrease fluid excess and edema around the wound site and facilitate arteriolar dilation. As a result, use of these devices improve microcirculation and reduce bacterial colonization [5,11,16,17]. Whether routine use of negative pressure closure devices reduce the incidence of wound infections and dehiscence and the duration of in-hospital stay remain unknown.

Although a growing number of studies have been performed on nonspinal applications of negative pressure wound therapy (NPWT), there remains a paucity of data on this type of closure for the spine. The aim of the present study is to assess the incidence of wound infection and dehiscence in deformity patients undergoing multilevel thoracolumbar fusion before and after the routine use of NPWT.

## Methods

### *Patient selection*

The primary aim of this study was to determine whether the routine use of NPWT in elective long-segment spine fusions would result in fewer postoperative wound infections and dehiscence. Long-segment fusions were defined as fusion constructs of four levels or greater. All adult patients undergoing thoracolumbar fusion for deformity correction at Duke University Medical Center over a 6-year period by senior author (CB) were enrolled in this study. The institutional review board approved this retrospective review.

A retrospective review of hospital records from January 2007 to January 2013 was performed of adult patients at our institution undergoing posterior thoracolumbar spinal fusion for deformity correction by senior author (CB). The inclusion criteria consisted of patients older than 18 years who had undergone multilevel (more than four vertebral levels) posterior spinal fusion using pedicle screws and rod instrumentation at any level in the thoracolumbar spine for deformity correction. The exclusion criteria included the history of infections at the surgical site, severe coexistent pathology that could confound the assessment of operative outcome (eg, rheumatoid arthritis, osteoarthritis, metabolic bone disease), history of immunosuppression or chronic systemic infection, and pregnancy.

Patient demographics, clinical presentation, comorbidities, radiologic studies, and all treatment variables were reviewed for each case.

### *Standard pre- and postoperative systemic prophylactic antibiotic regimen*

All patients received standard systemic antibiotic prophylaxis consisting of weight-based intravenous (IV) cefazolin within 1 hour of surgical incision, followed by IV cefazolin every 8 hours for 1 day. If the patient was allergic to penicillin, weight-based IV clindamycin was used instead. All patients were prepared with chlorhexidine. A standard midline incision and open approach was used in all cases. Fusion levels were determined based on the quality of bone and stability of the fracture. Before skin closure, irrigation with 3 L of normal saline by pulse lavage was performed.

### *Treatment and control cohorts*

In 2012, a categorical switch was made by the senior author (CB) that included the routine use of negative pressure

closure dressings in all long-segment spine fusions. Before 2012, negative pressure closure dressings were not used.

Two cohorts were developed. The treatment group consisted of consecutive patients receiving NPWT after primary wound closure (January 2012 to January 2013); and the control group consisted of consecutive patients who received their operation before the categorical switch (January 2007 to January 2012). These patients underwent only primary wound closure with standard dressings of xeroform, gauze, and medopore tape. In all cases, the surgical approach involved an open midline posterior incision. Minimally-invasive cases were excluded.

#### *Wound closure and negative pressure device placement*

In all cases, surgical wounds were closed with absorbable suture in the fascia and subcutaneous layers and with staple or suture closure of the skin. After skin closure, incisions were cleaned again with chlorhexidine and a sterile dressing was applied.

Subfascial drains were used in all cases. Drains were kept in place until postoperative Day 2 or until drain outputs are less than 80 mL/24 hours.

In the treatment cohort, a negative pressure device was used in addition to primary wound closure. This system includes a small portable pump and dressing with fixation strips. This dressing is contoured to fit the size of the incision and placed over the incisional area. The fixation strip is applied over the incision and wound surroundings to make an airtight wound seal. A continuous negative pressure of  $-80$  mmHg generates uniform negative pressure over the entire incision and draws excess wound fluid from the wound into the dressing. The negative pressure device was left for 3 postoperative days.

#### *Diagnostic evaluation*

A deep surgical site infection (SSI) was principally suspected on clinical grounds from the clinical history, physical examination, and/or laboratory analysis and confirmed with radiologic studies. The definition of deep SSI developed by the Centers for Disease Control and Prevention (CDC) was used to make this diagnosis [18]. According to the CDC definitions, deep space incisional SSIs occur within 30 days after surgery. Additionally, they involve purulent drainage, isolation of organism, signs or symptoms of infection (such as pain or tenderness, localized swelling, and redness or heat) combined with positive culture results, and/or diagnosis by a surgeon or an attending physician. Thus, for this study, an SSI was defined as being diagnosed during the initial hospitalization or during a hospital readmission or postoperative clinic appointment within 30 days of the surgery.

All patients enrolled in this study had standard laboratory tests on admission to the hospital including erythrocyte sedimentation rate, peripheral white blood cell count, C-reactive protein, complete urine analysis, microbiology, and blood cultures. The erythrocyte sedimentation rates were determined by the Westergren method and was considered

## EVIDENCE & METHODS

### **Context**

There is increased interest in the use of incisional negative pressure wound therapy (NPWT) to decrease the risk of surgical site infection and wound-related complications in patients undergoing complex spine surgical interventions. The level of evidence supporting such techniques is admittedly poor. The authors sought to address this by performing a quasi-experiment using the practice discontinuity of a single surgeon.

### **Contribution**

The authors report that use of NPWT resulted in a 50% decrease in the incidence of wound dehiscence and an approximate 30% reduction in surgical site infections.

### **Implications**

The results of this study reinforce findings associated with the use of NPWT in other surgical disciplines. Nonetheless, this remains a retrospective analysis performed among a heterogeneous case series. While there was no significant difference between the cohorts based on the co-variables considered, the authors did not analyze and could not control for intrinsic differences in surgical technique, nursing management and postsurgical care. Furthermore, changes in the institutional culture (eg, implementation of keystone initiatives, etc) may have occurred over the time-period data was collected and further confounded the results. Moving forward, well-matched prospective studies using patients with specific indications should be performed to analyze the efficacy of incisional NPWT in spinal surgery.

—The Editors

abnormal if it was more than 15 mm/h. C-reactive protein was considered abnormal if it was greater than 5 mg/dL. Bacterial identification and susceptibility testing were performed according to the guidelines of the CDC.

#### *Immediate postoperative complications*

We assessed postoperative complications for each patient included in the study. Complications were divided into those likely or possibly associated with spine surgery (eg, incidental durotomy, nerve root injury, surgical site drainage or infection, and reoperation) and other complications known to be associated with lumbar spinal fusion surgery (eg, pulmonary embolism/deep vein thrombosis, hardware failure, nonunion, and adjacent segment disease).

#### *Clinical parameters*

Preoperative and intraoperative data for each patient were collected with use of patient charts and computerized medical records. Surgical infection risk factors were documented for

each patient, including body mass index, obesity, diabetes mellitus, insulin use, chronic steroid use, prior lumbar surgery, chronic obstructive pulmonary disease, tobacco use, and osteoporosis. Pertinent operative details were also collected, including number of levels instrumented, estimated blood loss, duration of anesthesia, intraoperative steroid use, blood transfusion, and dural tear. The number of days between surgery and diagnosis of infection was also recorded. Each cohort's baseline characteristics, operative data, and rates of wound infection were compared using the chi-square test for categorical variables and Student *t* test for continuous variables.

We also considered long-term complications including SSI and wound dehiscence, for which we extended the review period to 90 days. Other outcome measures included 30-day readmission rate and return to operating room (OR).

### Statistical analysis

The primary aim of this study was to determine whether the routine use of NPWT in elective long-segment spine fusions results in fewer postoperative wound infections and dehiscence. Parametric data were expressed as the mean  $\pm$  standard deviation (SD) and were compared using the Student *t* test. Nonparametric data are expressed as the median [interquartile range] and were compared using the Mann Whitney *U* test. Nominal data were compared with the chi-square test. Time to wound infection and dehiscence were graphically represented as estimated Kaplan-Meier plots and compared via the log-rank test. A *p* value  $<.05$  was considered statistically significant.

## Results

We identified a consecutive series of patients undergoing elective thoracolumbar surgery for idiopathic scoliosis

performed by senior author (CB) between January 1, 2007 and January 1, 2013 at Duke University Medical Center. All outpatient surgeries were excluded.

One hundred sixty (NPWT: 46 cases, non-NPWT: 114 cases) long-segment thoracolumbar spine fusions were performed for deformity correction. Ninety-one percent of patients in the NPWT cohort had fusion constructs that extended to the pelvis compared with 75% in non-NPWT cohort. The overall mean  $\pm$  SD age was  $63.87 \pm 13.34$  years (NPWT:  $65.31 \pm 11.19$  years vs. non-NPWT:  $63.28 \pm 14.14$  years, *p* = .33), of which 48 were men and 112 were women. Seventy-six (46.91%) patients smoked, 110 (67.9%) had hypertension, 28 (17.28%) had diabetes, 3 (1.85%) had end-stage renal disease, 4 (2.46%) had acute kidney injury, 37 (22.83%) had coronary artery disease, 17 (10.49%) had a myocardial infarction, and 14 (8.64%) had congestive heart failure. Overall mean ( $\pm$ SD) body mass index (BMI) was  $28.58 (\pm 6.51 \text{ Kg/m}^2)$  (NPWT:  $28.44 \pm 5.72 \text{ Kg/m}^2$  vs. non-NPWT:  $28.64 \pm 6.84 \text{ Kg/m}^2$ , *p* = .85). Both cohorts of patients were similar at baseline without significant differences. A summary of baseline characteristics is provided in Table 1.

The mean duration of surgery was similar between both cohorts (NPWT:  $317.17 \pm 78.73$  minutes vs. non-NPWT:  $339.59 \pm 86.59$  minutes, *p* = .11). The mean  $\pm$  SD estimated blood loss was less on untreated cohort (NPWT:  $2,288 \pm 2,336$  mL vs. non-NPWT:  $1,915 \pm 1,429.61$  mL, *p* = .11). The median [interquartile range] number of levels fused was similar between both cohorts, *p* = .47.

### Postoperative complications

There were no significant differences in postoperative complication rates between NPWT and non-NPWT cohorts in terms of spinal cord/nerve root injury (2.12% vs. 1.75%, *p* = .88), durotomy (12.76% vs. 19.29%, *p* = .28), CSF leak (8.51% vs. 3.51%, *p* = .27), pulmonary embolism/deep vein

Table 1

Comparison of demographic and comorbidity data in deformity patients undergoing thoracolumbar and lumbar fusion before and after the introduction of NPWT

Variables	Combined cohort (n=160)	NPWT cohort (n=46)	Non-NPWT cohort (n=114)	<i>p</i>
Mean age (y)	63.87 $\pm$ 13.34	65.31 $\pm$ 11.19	63.28 $\pm$ 14.14	.33
Male (%)	29.62	34.04	28.07	.46
BMI (Kg/m <sup>2</sup> )	28.58 $\pm$ 6.51	28.44 $\pm$ 5.72	28.64 $\pm$ 6.84	.85
Smoker (%)	46.91	42.55	49.12	.42
Hypertension (%)	67.90	76.59	64.91	.15
Diabetes (%)	17.28	19.14	16.66	.73
ESRD (%)	1.85	8.51	1.75	.12
AKI (%)	2.46	14.89	7.89	.25
CAD (%)	22.83	34.04	18.42	.05
AFib (%)	9.87	6.38	11.40	.27
MI (%)	10.49	8.51	11.40	.53
CHF (%)	8.64	10.63	7.89	.60

NPWT, negative pressure wound therapy; BMI, body mass index; ESRD, end-stage renal disease; CAD, coronary artery disease; AFib, atrial fibrillation; AKI, acute kidney injury; MI, myocardial infarction; CHF, congestive heart failure; SD, standard deviation.

Note: Both cohorts of patients were similar at baseline.

Data expressed as mean  $\pm$  SD or number (%). Values significant at the *p*  $<.05$  level are in bold.

Table 2  
Total and cohort-specific postoperative complication rates

Variables	Combined cohort (n=160)	NPWT cohort (n=46)	Non-NPWT cohort (n=114)	p
Spinal cord/nerve root injury (%)	3 (1.83)	1 (2.12)	2 (1.75)	.88
Durotomy (%)	28 (17.28)	6 (12.76)	22 (19.29)	.28
CSF leak (%)	8 (4.93)	4 (8.51)	4 (3.51)	.27
PE/DVT (%)	7 (4.32)	4 (8.51)	3 (2.63)	.18
UTI (%)	30 (18.51)	10 (21.27)	20 (17.54)	.74
Pneumonia (%)	3 (1.85)	0 (0.00)	3 (2.63)	<b>.08</b>
SSI (%)	22 (13.58)	5 (10.63)	17 (14.91)	<b>.04</b>
Wound dehiscence (%)	17 (10.49)	3 (6.38)	14 (12.28)	<b>.02</b>
Return to OR (%)	18 (11.11)	6 (12.76)	12 (10.52)	<b>.07</b>
30-d readmission rate (%)	30 (18.51)	9 (19.14)	21 (18.42)	.48

NPWT, negative pressure wound therapy; CSF, cerebrospinal fluid; PE, pulmonary embolism; DVT, deep venous thrombosis; UTI, urinary tract infection; SSI, surgical site infection; OR, operating room.

Note: When compared with the NPWT cohort, patients undergoing thoracolumbar fusions had a higher postoperative complication rate.

Values significant at the  $p < .05$  level are in bold.

thrombosis (8.51% vs. 2.63%,  $p = .18$ ), or UTI (21.27% vs. 17.54%,  $p = .74$ ), Table 2. There was a statistical trend toward a higher rate of pneumonia in the non-NPWT cohort ( $p = .08$ ); however, postoperative pneumonia is not commonly affected by use of NPWT and occurred in less than three patients (<3%) in the control group.

#### Microbial isolates

The causative pathogens were determined from intraoperative sampling. The most common organism isolated in 12 cases was *Staphylococcus aureus* (methicillin resistant in six cases and methicillin sensitive in six cases), followed by *Pseudomonas aeruginosa* in 4 cases, and coagulase-negative *Staphylococcus* species in 2 cases. Other causative agents included *Escherichia coli* (one case), *Proteus mirabilis* (two cases), and *Enterococcus* (two cases). One patient presented with mixed bacterial infection. The causative organism was unknown in three patients. We observed a higher percentage of gram-negative organisms in the non-NPWT cohort compared with the NPWT cohort. The reasons for this observed difference is not entirely known.

#### Clinical follow-up

Compared with the NPWT cohort, the incidence of postoperative SSIs was significantly higher in the non-NPWT cohort (10.63% vs. 14.91%,  $p = .04$ ), Table 2. Similarly, compared with the non-NPWT cohort, a 50% decrease in the incidence of wound dehiscence was observed in the NPWT patient cohort (6.38% vs. 12.28%,  $p = .02$ ). The median time interval to wound dehiscence was longer in the NPWT cohort (40 days vs. 14 days,  $p = .07$ ), Fig. 1. No patient in the NPWT cohort was lost to follow-up.

There was no significant difference in the length of hospital stay between both cohorts (NPWT:  $7.29 \pm 4.26$  days vs. non-NPWT:  $8.08 \pm 7.00$  days,  $p = .16$ ), Fig. 2. The 30-day hospital readmission rates were similar between both cohorts (19.14% vs. 18.42%,  $p = .48$ ), Table 2. The most common reason for readmission was infection (13.58%) and wound dehiscence (10.49%). A small number of patients in the NPWT cohort were readmitted for reasons other than wound infection or dehiscence.

Eighteen (11.11%) patients returned to the OR (non-NPWT: 12.76% vs. NPWT: 10.52%,  $p = .07$ ). The most common reason for reoperation was postoperative wound

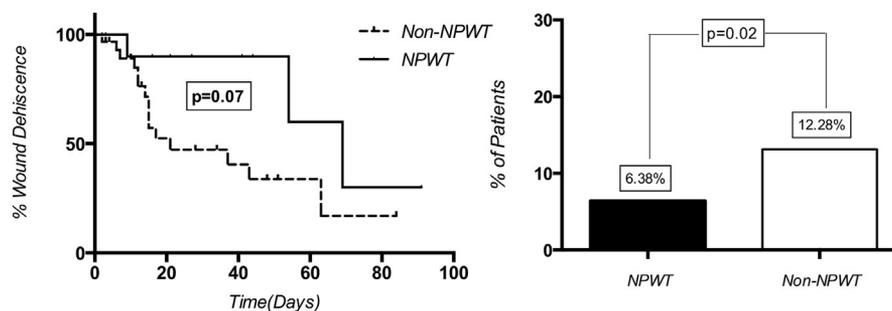


Fig. 1. (Left) Kaplan-Meier plot depicting the difference in the time to wound dehiscence in deformity patients undergoing long-segment thoracolumbar fusion before and after the introduction of NPWT. The median time to wound dehiscence was longer in the NPWT cohort (40 days vs. 14 days,  $p = .07$ ). (Right) The incidence of wound dehiscence was twofold higher in the non-NPWT cohort (12.28% vs. 6.38%,  $p = .02$ ). NPWT, negative pressure wound therapy.

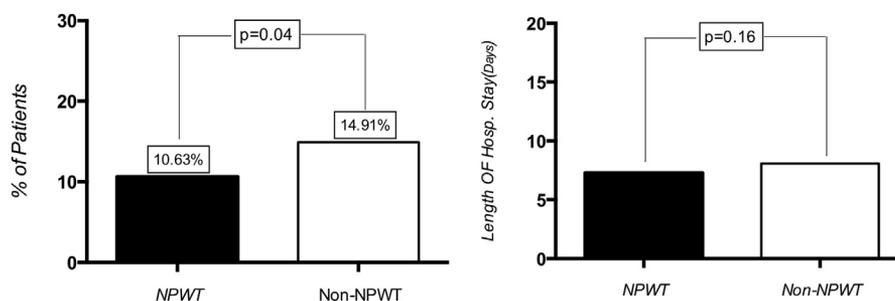


Fig. 2. (Left) Difference in the incidence of surgical site infections in deformity patients undergoing long-segment thoracolumbar fusion before and after the introduction of NPWT (14.91% vs. 10.63%,  $p=0.04$ ). (Right) Both cohorts had similar postoperative lengths of in-hosp stay ( $p=0.16$ ). NPWT, negative pressure wound therapy; hosp, hospital.

infection (41.66%), wound dehiscence (37.50%), hardware failure (16.66%), and malposition (4.16%).

## Discussion

In this longitudinal cohort study, we observed that the routine use of negative pressure devices in addition to primary wound closure resulted in a significant reduction in the incidence of postoperative wound infections ( $p=0.04$ ). Furthermore, the use of negative pressure devices was associated with a 50% reduction in the incidence of wound dehiscence (6.38% vs. 12.28%,  $p=0.02$ ) and fewer reoperations. This study demonstrates that routine use of negative pressure devices after elective thoracolumbar spine fusion for deformity correction resulted in a significant reduction in the incidence of postoperative wound infections, dehiscence, and reoperation rates.

Negative pressure closure dressings as a technique for reduction of dead space and wound conditioning has several merits: it increases local blood perfusion, reduces bacterial colonization, removes interstitial fluid, and facilitates control and accurate monitoring of wound fluid egress [2,4,19,20]. The removal of excess interstitial fluid from the vicinity of the wound improves lymphatic and microvascular drainage, increases oxygen and nutrient delivery, and facilitates removal of metabolic byproducts [2,4,19,20]. Additionally, it enhances neovascularization, increases granulation tissue formation, and ultimately accelerates wound healing. Morykwas et al. [5,16] demonstrated in a porcine model that removal of excess interstitial fluid resulted in a 400% increase in local blood flow to the wound, an increase in granulation tissue, and a significant reduction in bacterial colonization. A 98.65% of patients in the aforementioned study responded favorably with a pronounced rate of granulation tissue formation. The authors noted that acute wounds (<12 hours) healed most rapidly; subacute wounds (>12 hours, <1 week) healed slightly more slowly, and chronic wounds (>1 week) healed most slowly. In our series, we left the negative pressure device in place for 3 postoperative days, theoretically maximizing the proliferative response.

The association between formation of granulation tissue and accelerated wound healing has been previously

published. In a prospective randomized control study of 162 diabetic foot amputation sites, Armstrong and Lavery [21] demonstrated a strong association between a significant increase in granulation tissue and a superior rate of wound closure in the negative pressure device cohort compared with the control cohort using standard wound care. Blume et al. [22] demonstrated that granulation tissue covered a wound site more quickly in patients treated with a negative therapy device, resulting in faster wound closure. Similarly, Vuerstaek et al. [23] in a prospective randomized trial of lower extremity ulcerations, demonstrated accelerated wound healing in patients with a negative pressure device (25 days vs. 45 days). In this study, wound dehiscence was used as a proxy for the formation of granulation tissue. The incidence of wound dehiscence was 50% less in the negative pressure therapy cohort (12.28% vs. 6.38%), suggesting that even a limited exposure to NPWT yielded significant clinical benefit.

Changes in bacterial burden have been demonstrated with the routine use of negative pressure therapy. Moues et al. [24] in a randomized prospective study demonstrated a significant reduction in bacterial load in the cohort of patients assigned to the NPWT cohort compared with a control cohort using standard wound care. Similarly, Morykwas et al. [5,17] demonstrated a decrease in bacterial burden using negative pressure therapy in experimental pigs. The mechanisms behind these observations are not entirely clear, although presumably there may be several factors that influence the total bacterial burden of any wound, such as direct removal of bacteria and alterations in blood flow. Analogous to these aforementioned studies, we observed a significant reduction in the incidence of wound infections in the NPWT cohort.

The rate of SSIs reported in our series fall within the previously reported ranges. Generally, postspinal fusion SSI rates are highly variable in the literature, ranging from 1% to well above 10%. The variability may be partly attributed to different patient exclusion criteria. Some studies considered only infections below the fascia (deep) and/or infections that necessitated the patient to return to the OR. Here, we defined SSI broadly as any postoperative wound that required antibiotic treatment and/or surgical

incision and drainage. This definition most closely resembles that of Gunne et al., who recently evaluated incidence of SSI after adult spinal deformity surgery, similar to patients in our cohort.<sup>i</sup> Although the overall SSI rate in that study was 5.5%, obesity (BMI>30) significantly increased the risk of SSI and was associated with 13% SSI rate. Our patient population on average had much higher BMIs: 31% were obese (compared with 7.9% in Gunne et al.). It has been proposed that increased retraction forces required during surgery in obese persons leads to tissue necrosis and increased SSI risk. Obesity thus contributes, at least in part, to our SSI rate. Age may be another influencing factor. Schuster et al. recently conducted a systematic review of infection rates after spine surgery and confirmed age greater than 60 years as a preoperative risk factor for SSI.<sup>ii</sup> Kurtz et al. evaluated SSI after spinal fusion in the Medicare population and reported SSI rate of 8.5% in primary procedures and 12.2% in revisions.<sup>iii</sup> Thus, with a mean age of 64 years and 31% obesity, our patient population was at an increased risk for SSI as appropriately reflected in our rate.

Although this study demonstrated encouraging results with the routine use of negative pressure therapy after primary wound closure, it had inherent limitations that have implications for its interpretation. First, the initiation of the study occurred after patients underwent surgery. Although pre- and perioperative variables were recorded into an electronic medical record system at the time of surgery, these variables were assessed post hoc at the time of the study's initiation and may have introduced bias. Despite these limitations, the present study clearly demonstrated that the use of NPWT is associated with significant reduction in the rates of wound infection, dehiscence, and return to OR, all of which have beneficial clinical and socioeconomic implications. Future randomized controlled trials assessing the incidence of wound infection, dehiscence, and return to OR will be needed to further corroborate these results.

## Conclusion

For patients undergoing long-segment thoracolumbar fusion, routine use of NPWT was associated with a significant reduction in the incidence of postoperative wound infection and dehiscence.

## References

- [1] Chaudhary SB, Vives MJ, Basra SK, Reiter MF. Postoperative spinal wound infections and postprocedural diskitis. *J Spinal Cord Med* 2007;30:441–51.
- [2] Bertran J, Farrell M, Fitzpatrick N. Successful wound healing over exposed metal implants using vacuum-assisted wound closure in a dog. *J Small Anim Pract* 2013;54:381–5.
- [3] Capen DA, Calderone RR, Green A. Perioperative risk factors for wound infections after lower back fusions. *Orthop Clin North Am* 1996;27:83–6.
- [4] Calderone RR, Garland DE, Capen DA, Oster H. Cost of medical care for postoperative spinal infections. *Orthop Clin North Am* 1996;27:171–82.
- [5] Morykwas MJ, Simpson J, Punger K, et al. Vacuum-assisted closure: state of basic research and physiologic foundation. *Plast Reconstr Surg* 2006;117(7 Suppl):121S–6S.
- [6] Labler L, Keel M, Trentz O, Heinzelmann M. Wound conditioning by vacuum assisted closure (V.A.C.) in postoperative infections after dorsal spine surgery. *Eur Spine J* 2006;15:1388–96.
- [7] Black P. Cerebrospinal fluid leaks following spinal surgery: use of fat grafts for prevention and repair. Technical note. *J Neurosurg* 2002;96(2 Suppl):250–2.
- [8] Bosacco SJ, Gardner MJ, Guille JT. Evaluation and treatment of dural tears in lumbar spine surgery: a review. *Clin Orthop Relat Res* 2001;238–47.
- [9] Cammisa FP Jr, Girardi FP, Sangani PK, et al. Incidental durotomy in spine surgery. *Spine* 2000;25:2663–7.
- [10] Deyo RA, Cherkin DC, Loeser JD, et al. Morbidity and mortality in association with operations on the lumbar spine. The influence of age, diagnosis, and procedure. *J Bone Joint Surg Am* 1992;74:536–43.
- [11] Malahias M, Hindocha S, Saedi F, McArthur P. Topical negative pressure therapy: current concepts and practice. *J Perioper Pract* 2012;22:328–32.
- [12] McMahon P, Dididze M, Levi AD. Incidental durotomy after spinal surgery: a prospective study in an academic institution. *J Neurosurg Spine* 2012;17:30–6.
- [13] Saxler G, Kramer J, Barden B, et al. The long-term clinical sequelae of incidental durotomy in lumbar disc surgery. *Spine* 2005;30:2298–302.
- [14] Finnegan WJ, Fenlin JM, Marvel JP, et al. Results of surgical intervention in the symptomatic multiply-operated back patient. Analysis of sixty-seven cases followed for three to seven years. *J Bone Joint Surg Am* 1979;61:1077–82.
- [15] Jones AA, Stambough JL, Balderston RA, et al. Long-term results of lumbar spine surgery complicated by unintended incidental durotomy. *Spine* 1989;14:443–6.
- [16] Morykwas MJ, Argenta LC. Nonsurgical modalities to enhance healing and care of soft tissue wounds. *J South Orthop Assoc* 1997;6:279–88.
- [17] Morykwas MJ, Faler BJ, Pearce DJ, Argenta LC. Effects of varying levels of subatmospheric pressure on the rate of granulation tissue formation in experimental wounds in swine. *Ann Plast Surg* 2001;47:547–51.
- [18] Mangram AJ, Horan TC, Pearson ML, et al. Guideline for prevention of surgical site infection, 1999. Hospital Infection Control Practices Advisory Committee. *Infect Control Hosp Epidemiol* 1999;20:250–78. quiz 279–80.
- [19] Argenta LC, Morykwas MJ. Vacuum-assisted closure: a new method for wound control and treatment: clinical experience. *Ann Plast Surg* 1997;38:563–76; discussion 577.
- [20] Jones GA, Butler J, Lieberman I, Schlenk R. Negative-pressure wound therapy in the treatment of complex postoperative spinal wound infections: complications and lessons learned using vacuum-assisted closure. *J Neurosurg Spine* 2007;6:407–11.
- [21] Armstrong DG, Lavery LA. Negative pressure wound therapy after partial diabetic foot amputation: a multicentre, randomised controlled trial. *Lancet* 2005;366:1704–10.
- [22] Blume PA, Walters J, Payne W, et al. Comparison of negative pressure wound therapy using vacuum-assisted closure with advanced moist wound therapy in the treatment of diabetic foot ulcers: a multicenter randomized controlled trial. *Diabetes Care* 2008;31:631–6.
- [23] Vuerstaek JD, Vainas T, Wuite J, et al. State-of-the-art treatment of chronic leg ulcers: a randomized controlled trial comparing vacuum-assisted closure (V.A.C.) with modern wound dressings. *J Vasc Surg* 2006;44:1029–37; discussion 1038.
- [24] Moues CM, Vos MC, van den Bemd GJ, et al. Bacterial load in relation to vacuum-assisted closure wound therapy: a prospective randomized trial. *Wound Repair Regen* 2004;12:11–7.