



■ **TRAUMA**

Assisted closure of fasciotomy wounds

A DESCRIPTIVE SERIES AND CAUTION IN PATIENTS WITH VASCULAR INJURY

**J. R. Fowler,
M. T. Kleiner,
R. Das,
J. P. Gaughan,
S. Rehman**

From Temple University Hospital, Philadelphia, Pennsylvania, United States

Introduction

Negative pressure wound therapy (NPWT) and vessel loop assisted closure are two common methods used to assist with the closure of fasciotomy wounds. This retrospective review compares these two methods using a primary outcome measurement of skin graft requirement.

Methods

A retrospective search was performed to identify patients who underwent fasciotomy at our institution. Patient demographics, location of the fasciotomy, type of assisted closure, injury characteristics, need for skin graft, length of stay and evidence of infection within 90 days were recorded.

Results

A total of 56 patients met the inclusion criteria. Of these, 49 underwent vessel loop closure and seven underwent NPWT assisted closure. Patients who underwent NPWT assisted closure were at higher risk for requiring skin grafting than patients who underwent vessel loop closure, with an odds ratio of 5.9 (95% confidence interval 1.11 to 31.24). There was no difference in the rate of infection or length of stay between the two groups. Demographic factors such as age, gender, fracture mechanism, location of fasciotomy and presence of open fracture were not predictive of the need for skin grafting.

Conclusion

This retrospective descriptive case series demonstrates an increased risk of skin grafting in patients who underwent fasciotomy and were treated with NPWT assisted wound closure. In our series, vessel loop closure was protective against the need for skin grafting. Due to the small sample size in the NPWT group, caution should be taken when generalising these results. Further research is needed to determine if NPWT assisted closure of fasciotomy wounds truly leads to an increased requirement for skin grafting, or if the vascular injury is the main risk factor.

Keywords: Fasciotomy, Negative pressure wound therapy, NPWT, Vessel loop closure, Infection, Complications

Article focus

- Is the type of assisted closure technique for fasciotomy wounds predictive of the need for skin grafting to achieve definitive coverage?
- Is there a difference in the rate of infection or length of stay when comparing vessel loop assisted closure and negative pressure wound therapy (NPWT) assisted closure for treatment of fasciotomy wounds?

skin grafting than patients who underwent vessel loop closure, with an odds ratio of 5.9 (95% confidence interval 1.11 to 31.24)

- There was no difference in the rate of infection or length of stay between the two groups
- Demographic factors such as age, gender, fracture mechanism, location of fasciotomy, and presence of open fracture were not predictive of the need for skin grafting

Article summary

- Patients who underwent NPWT assisted closure were at higher risk for requiring

- J. R. Fowler, MD, Orthopaedic Resident
 - M. T. Kleiner, MD, Orthopaedic Resident
 - R. Das, MD, Orthopaedic Resident
 - J. P. Gaughan, PhD, Statistician
 - S. Rehman, MD, Associate Professor, Director of Orthopaedic Trauma
- Temple University Hospital, 3401 N Broad Street, Philadelphia, Pennsylvania 19140, USA.

Correspondence should be sent to Dr J. R. Fowler; e-mail: john.fowler@tuhs.temple.edu

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Strengths and limitations

- A major limitation of our study is the relatively small number of patients that underwent NPWT treatment and the large difference in numbers between groups
- The retrospective nature of this study introduces selection bias, although statistical analysis did not demonstrate any differences between the NPWT and vessel loop groups with regard to demographic, mechanism of injury or presence of open fracture. It is possible that patients with more severe injuries were selected to undergo NPWT and therefore this group had worse outcomes
- Continuous pressure monitoring was not employed, which several authors have suggested increases the false positive rate for the diagnosis of compartment syndrome

Introduction

The use of decompressive fasciotomy, in the setting of an acute compartment syndrome, is potentially a limb-saving procedure. Compartment syndrome, a situation where the compartment pressure is higher than perfusion pressure, occurs in both the upper and lower extremities and can result from insults such as fracture, ischemia, reperfusion, crush injury, burns and over-exertion.^{1,2} The sequelae from an untreated compartment syndrome are devastating. Therefore, early recognition and treatment via surgical decompression are paramount. However, the fasciotomy incisions can lead to large, unsightly, chronic wounds after surgical intervention.

A popular method of assisted closure of fasciotomy wounds uses a negative pressure environment created by negative pressure wound therapy (NPWT).³ NPWT dressings are a closed system whereby a vacuum applies sub-atmospheric pressure to a wound through a porous foam dressing, reducing extravascular pressure and oedema within the compartment, leading to improved circulation, granulation and approximation of wound edges, as well as less bacterial colonisation.³ Orthopaedic indications for NPWT include closure of fasciotomy wounds, degloving injuries and infectious wounds after debridement.^{4,5} It has been suggested that the use of the NPWT dressing leads to a higher rate of primary wound closure, less hospitalisation time and earlier rehabilitation than traditional wet-to-dry dressing changes.⁶ Other authors have shown that definitive closure of fasciotomy wounds, either primary or with split-thickness skin graft, is accelerated by the use of the NPWT^{7,8} and that it may help avoid the need for flap coverage.⁹

Dynamic wound closure using the vessel loop or shoelace technique has also been described as a viable management option (Fig. 1).¹⁰⁻¹⁶ This method entails approximation of wound edges using vessel loops anchored by skin staples and gradually tensioning them across the wound margins. Early versions of this technique used materials such as heavy nylon sutures and



Fig. 1

Photograph showing an example of vessel loop closure in a lower leg fasciotomy.

were claimed to lead to gradual closure of fasciotomy wounds without further need for surgery.¹⁶ As the technique has evolved, it has been suggested that vessel loop closure may avoid the need for split-thickness skin grafts, resulting in better cosmesis and avoidance of donor site morbidity.¹⁰⁻¹⁶ Vessel loop closure has been praised as cost-effective and simple due to the readily available materials needed for its execution.¹⁷ It may even have other applications such as the treatment of complex wounds associated with open fractures.¹⁸ Other commercially available devices for dermatotraction are available.^{19,20} Examples of these devices include the Dermaclose RC (Chanhassen, Minnesota) and the Sure-Closure skin-stretching system (Zimmer, Warsaw, Indiana). Despite this, the simplified vessel loop technique may be the cheapest and most readily available. Several modifications to the technique have been described, including the use of drains placed in the wound in order to prevent myonecrosis.²¹

The purpose of this study is to describe two commonly employed methods of fasciotomy closure and report on the need for skin graft, length of hospital stay and incidence of infection.

Patients and Methods

After obtaining Institutional Review Board approval, a retrospective search was performed of our orthopaedic database from January 2004 to July 2010 to identify patients who underwent fasciotomy at our level I trauma centre. Patients were included if the following criteria were met: 1) age between 18 and 89 years at the time of fasciotomy; 2) either NPWT or vessel loops were applied at the time of initial fasciotomy and at each subsequent debridement; 3) outpatient records were available for review. Patients were excluded if any of the following

Table I. Patient demographics and characteristics (NPWT, negative pressure wound therapy)

	Vessel loop (n = 49)	NPWT (n = 7)	p-value*
Mean age (yrs)	37.1 (18 to 82)	41.7 (19 to 72)	0.4†
Male (n, %)	40 (81.6)	6 (85.7)	1.00
Mean body mass index (kg/m ²)	27.9 (18.3 to 52.4)	28.9 (23.9 to 35.8)	0.6†
Diabetes (n, %)	4 (8.2)	1 (14.3)	0.50
Smoker (n, %)	11 (22.4)	1 (14.3)	1.00
White/Caucasian (n, %)	7 (14.3)	2 (28.6)	0.31
Mechanism (n, %)			
Gunshot wound	12 (24.5)	1 (14.3)	1.00
Blunt trauma	20 (40.8)	2 (28.6)	0.69
Automobile vs pedestrian	13 (26.5)	3 (42.9)	0.39
Other	4 (8.2)	1 (14.3)	-
Vascular injury (n, %)	6 (12.2)	2 (28.6)	0.26
Fracture (n, %)	44 (89.8)	7 (100)	1.00
Open fractures	18 (36.7)	1 (14.3)	0.40
Required skin graft (n, %)	9 (18.4)	4 (57.1)	0.04
Infection within 90 days (n, %)	3 (6.1)	2 (28.6)	0.11
Mean length of stay (days)	19.2 (3 to 113)	23.7 (6 to 75)	0.61†

* Fisher's exact test, unless otherwise stated

† t-test

criteria were met: 1) neither NPWT nor vessel loops were used at the initial fasciotomy or not used at one of the subsequent debridements; 2) outpatient charts were not available for review; 3) the method of assisted closure was unable to be determined from records; 4) fasciotomy was performed due to exertional compartment syndrome or burns. The Vacuum Assisted Closure device (KCI, San Antonio, Texas) was the NPWT device used in all cases.

Patient demographics including age, gender, race, body mass index (BMI), history of diabetes and history of smoking were recorded. The location of the fasciotomy, type of assisted closure, mechanism of injury, presence of fracture, bone(s) fractured, presence of vascular injury, number of debridements before final closure/graft, need for skin graft, length of stay, evidence of infection within 90 days and time to infection were recorded. Compartment syndrome was diagnosed based on clinical findings and confirmed intra-operatively using a handheld compartment pressure measurement device (Stryker, Kalamazoo, Michigan), with a threshold of a compartment pressure within 30 mm Hg of the diastolic blood pressure declared positive for compartment syndrome. Patients were indicated for skin grafting if the attending surgeon determined that their fasciotomy wound could not be closed primarily. This decision was most commonly made after three debridements and/or NPWT changes. Time to infection was defined as the time from injury to initiation of antibiotics and/or operative debridement.

Statistical analysis. Baseline, demographic and clinical variables were tested for group differences using *t*-tests for continuous variables and Fisher's exact test for categorical variables. The analysis of binary outcomes (skin graft, infection) was carried out using univariate logistic regression. The odds ratios with 95% confidence intervals (CI) were calculated for each predictor. Analysis of variance (ANOVA) was used to determine if there was a

significant difference when three or more groups were present. Time to event data (time to infection) was analysed using univariate and multivariate Cox proportional hazards regression. Hazard ratios with 95% CI were calculated for each predictor. Differences between groups (rejection of the null hypothesis) and regression effects were considered significant if the probability of chance occurrence was ≤ 0.05 using two-tailed tests.

Results

The retrospective medical record search identified 72 patients who underwent fasciotomy over the study period. A total of 16 patients were excluded; two of whom received both NPWT and vessel loops during their course and 14 who did not have treatment with NPWT or vessel loops to assist with closure. Of the remaining 56 patients, 49 underwent vessel loop closure and seven underwent NPWT assisted closure. The two groups (NPWT and vessel loop) were statistically similar in regards to age, race, gender, mechanism of injury, presence of vascular injury, open fracture, infection and length of stay (Table I). Patients who underwent NPWT assisted closure were at higher risk for requiring skin grafting than patients who underwent vessel loop closure, with an odds ratio of 5.9 (95% CI 1.11 to 31.24). Patients treated with vessel loop assisted closure were found to be protected from requiring a skin graft in this series, with an odds ratio of 0.17 (95% CI 0.03 to 0.89). Patients treated with vessel loop assisted closure had a mean length of stay of 19.2 days (3 to 113) while patients treated with NPWT assisted closure had a mean length of stay of 23.7 days (6 to 75), which was not statistically significant ($p = 0.61$). There was no difference in the frequency of infection between the patients treated with NPWT and those treated with vessel loop closure ($p = 0.11$). Location and mechanism of injury were not predictive of skin graft

Table II. Comparison of patients who had a skin graft *versus* those who did not

	No skin graft (n = 42)	Skin graft (n = 14)	Odds ratio (95% CI)
Mean age (yrs)	38.3 (18 to 82)	35.6 (19 to 72)	0.99 (0.94 to 1.03)
Male (n, %)	34 (81.0)	12 (85.7)	3.18 (0.36 to 27.76)
Mean body mass index (kg/m ²)	28.2 (18.3 to 52.4)	27.7 (23.5 to 34.4)	0.99 (0.92 to 1.05)
Diabetes (n, %)	3 (7.1)	2 (14.3)	2.42 (0.36 to 16.36)
Smoker (n, %)	9 (21.4)	3 (21.4)	1.13 (0.26 to 5.0)
White/Caucasian (n, %)	7 (16.7)	2 (14.3)	0.94 (0.17 to 5.17)
NPWT* (n, %)	3 (7.1)	4 (28.6)	5.93 (1.11 to 31.24)
Vessel loop (n, %)	40 (95.2)	9 (64.3)	0.17 (0.03 to 0.89)
Location (n, %)			
Forearm	7 (16.7)	5 (35.7)	3.21 (0.81 to 12.77)
Lower leg	30 (71.4)	9 (64.3)	0.69 (0.19 to 2.53)
Thigh	6 (14.3)	0 (0)	-
Mechanism (n, %)			
Gunshot wound	11 (26.2)	2 (14.3)	0.53 (0.10 to 2.76)
Blunt trauma	16 (38.1)	6 (42.9)	1.44 (0.41 to 5.07)
Automobile vs pedestrian	12 (28.6)	4 (28.6)	1.15 (0.30 to 4.44)
Other	3 (7.1)	2 (14.3)	-
Vascular injury (n, %)	4 (9.5)	4 (28.6)	4.33 (0.9 to 20.7)
Fracture (n, %)	38 (90.5)	14 (100)	-
Open fractures	14 (33.3)	5 (35.7)	1.30 (0.36 to 4.69)
Infection (n, %)	4 (9.5)	1 (7.1)	1.1 (0.87 to 1.24)
Mean length of stay (days)	17 (3 to 87)	28 (8 to 113)	-

* NPWT, negative pressure wound therapy

requirement (Table II). Vascular injury demonstrated a trend for increased risk of skin graft, odds ratio 4.33 (95% CI 0.9 to 20.7), but the confidence interval crossed unity and was therefore found to be non-significant. ANOVA was used to determine that there was no difference in rate of skin graft between groups (forearm, lower leg, thigh) ($p = 0.12$).

Discussion

Fasciotomy is a limb saving procedure that can carry significant morbidity. Although our series clearly suffers from an imbalance in the number of patients in each group, it demonstrates that NPWT assisted closure of fasciotomy wounds may lead to an increased risk of skin grafting, while vessel loop closure may be protective against patients requiring skin graft. Demographic and patient factors such as BMI, fracture mechanism, age, gender, and presence of open fracture did not affect the rate of skin graft. Patients with vascular injury demonstrated a trend toward skin grafting after use of a NPWT. The mechanism of this association is unclear, however, the negative pressure environment created by the NPWT may lead to increased soft-tissue oedema due to the 'leakiness' of cell basement membranes created during ischemia. NPWT has been purported to decrease bacterial counts in soft-tissue wounds, theoretically decreasing the rate of infection.⁶ The potential benefit of NPWT therapy in decreasing infection rates is not reflected in the data from our study.

Zannis et al⁶ compared wet-dry saline dressings with NPWT assisted closure, and found that NPWT significantly

increased the rate of primary closure and reduced the time to closure. While NPWT increased the rate of primary closure in their series, the rate of skin grafting was similar for upper extremity fasciotomies treated with NPWT (42.6%) and those treated with saline dressings (47.3%).⁶ The percentage of patients requiring skin grafting for lower extremity fasciotomy was also similar (16.5% vs 20.4% in the saline dressing group), although significance values were not provided.

Forearm fasciotomy wounds were treated exclusively with vessel loop closure in our series, resulting in no infections, but a 42% rate of skin grafting. The high rate of skin grafting may be reflective of the minimal amount of redundant skin in this location. A series of patients randomised to either NPWT or vessel loop closure will be needed to determine the optimal closure method for upper extremity fasciotomy wounds.

A major limitation of our study is the relatively small number of patients that underwent NPWT treatment. This likely stems from anecdotal experience in our department that fasciotomy wounds treated with NPWT tended to require skin grafting, therefore surgeons were less inclined to employ NPWT for this use. The retrospective nature of this study also introduces selection bias, although statistical analysis did not demonstrate any differences between the NPWT and vessel loop groups with regard to demographic, mechanism of injury, or presence of open fracture. It is possible that patients with more severe injuries were selected to undergo NPWT and therefore this group had worse outcomes. Another potential weakness is the use of clinical findings and a single

compartment measurement for diagnosis of compartment syndrome. Several authors have found a high rate of false positives in using a single compartment measurement, as opposed to trending pressures with continuous monitoring, meaning that some of the patients in our series may have had an 'unnecessary' fasciotomy.²²⁻²⁴ Given the potential for false positives, our groups could have a different number of true positive compartment syndromes, possibly affecting the rate of skin grafting given that patients with a false positive compartment syndrome would theoretically have a higher change of delayed primary closure. It would have been better to trend compartment measurements and record absolute values to determine the severity of the compartment syndromes and determine if pressure correlates with need for skin graft.

In conclusion, this retrospective descriptive case series demonstrates an increased risk of skin grafting in patients who underwent fasciotomy and were treated with NPWT assisted wound closure. In our series, vessel loop closure was protective against the need for skin grafting. Due to the small sample size in the NPWT group, caution should be taken when generalising these results. Further research is needed to determine if NPWT assisted closure of fasciotomy wounds truly leads to an increased requirement for skin grafting, or if the vascular injury is the main risk factor.

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- J. R. Fowler: Study design, Data collection, Writing and proofreading the paper
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- R. Das: Data collection, Writing and proofreading the paper
- J. P. Gaughan: Data analysis, Writing and proofreading the paper
- S. Rehman: Data analysis, Writing and proofreading the paper

ICMJE Conflict of Interest:

- None declared

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