Negative-pressure wound therapy in pediatric extremity trauma: a single-institution experience

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Received 19 February 2017
Accepted 27 March 2017

The Egyptian Journal of Surgery
2017, 36:260–264

Background
The value of negative-pressure wound therapy as a bridge to definitive closure of traumatic extremity wounds has been established in adults. Negative-pressure wound therapy has been used to assist granulation tissue formation and promote closure of wounds. In this study, we evaluated our experience with negative-pressure wound therapy for pediatric extremity wounds requiring delayed closure.
Patients and methods
A prospective study was conducted on 20 pediatric patients presenting with extremity injuries involving soft-tissue defects not suitable for immediate primary closure. Initial evaluation of the traumatized patient, wound irrigation, debridement, and antibiotic therapy were carried out and a plan for each case was outlined. Negative-pressure wound therapy was established using the vacuum-assisted closure system and dressings were changed every 3 days before definitive closure either by skin graft, Integra dermal matrix followed by skin graft, or local flaps.
Results
Granulation tissue was noted in all wounds by day 3. The mean duration of vacuum therapy was 12±3.3 days in patients whose wounds were closed by local flap advancement (n=4), 9±3.6 days in patients whose wounds were closed by skin grafts (n=8), and 6±4.8 days in patients whose wounds were closed by Integra dermal matrix (n=8). There was no incidence of skin graft or Integra losses. All local flaps healed completely. The mean follow-up period was 18±6.8 months, during which no complications were noted.
Conclusion
As a relatively atraumatic wound care technique with little complications, negative-pressure wound therapy provides a highly effective option as a bridge for soft-tissue management of extremity trauma in pediatric patients.

Keywords:
extremity, negative-pressure wound therapy, vacuum-assisted wound closure

Egyptian J Surgery 36:260–264

1110-1121

Introduction

Pediatric extremity trauma is associated with unique challenges to wound management. The visual and emotional experience of a tragic injury demands an approach that lessens the daily trauma of wound care to the child. Soft-tissue management must be as atraumatic as possible with adequate pain management, especially in wounds that will heal by delayed primary or secondary intention requiring multiple and often painful dressing changes that add great anxiety to the pediatric patient's experience. Alternative methods for soft-tissue management are needed to promote wound healing before closure and to ensure patient comfort and minimize anxiety [1,2].

Negative-pressure wound therapy has been used to manage difficult wounds since 1985 and has focused the use of this tool to assist in the management of children with complex traumatic wounds since 2000. The application of negative pressure to wounds has been practiced for some time; however, the benefits of negative-pressure wound therapy were outlined in a series of clinical studies in Russia in the 1980s [3–6] and later in Europe [7–9]. In recent times, negative-pressure wound therapy has re-emerged as a way of removing exudate, cell debris, inflammatory factors, and microbes from the wound while maintaining a moist environment that supports granulation tissue formation. Negative-pressure wound therapy has been gaining acceptance in the USA, and has been used in a variety of patients and wound types. The utility of negative-pressure wound therapy specifically in the pediatric population has been described by several groups [10–12]. Negative-pressure wound therapy using the vacuum-assisted closure (VAC)

system has been described for the temporary treatment of open fractures in both adults [13] and children [11], to promote granulation tissue formation before definitive closure by flaps or grafts. In this study, we evaluated our experience with negative-pressure wound therapy for pediatric extremity wounds requiring delayed closure.

Patients and methods

A prospective study of 20 patients who presented with extremity injuries to Adan Hospital, Kuwait, between 2013 and 2015 was performed. This study was approved by the ethical committee of our institutions. Patient demographics are shown in Table 1. The study included patients with injuries that involved the loss of soft tissue that was contaminated or traumatized and was not suitable for immediate primary closure. We recorded the injury site, presence of fracture, duration of vacuum therapy, time to formation of a granulating wound bed, and method of closure. After initial debridement and antibiotic therapy, negative-pressure wound therapy was applied using the VAC system (Kinetic Concepts Inc., San Antonio, Texas, USA) [1]. The dressings were changed every 3 days in the operating room when debridement was required or at the bedside with conscious sedation when indicated. Methods of wound closure included skin grafts, Integra dermal matrix followed by skin graft, and local flaps.

Results

Negative-pressure wound therapy was used on 20 children. The ages of the patients ranged from 4 to 16 years. The mean age was 6.5±3.9 years. Twelve patients were treated for upper-extremity injuries, and eight were treated for lower-extremity injuries. Granulation tissue was noted in all wounds by day 3. The mean number of dressing change was 4.7±1.2.

Table 1 Patient demographics

Number of patients	20
Male : female	12 : 8
Lower-limb : upper limb	12 : 8
Age (mean±SD) (years)	6.5±3.9
Follow-up period (mean±SD) (months)	18±6.8
Number of dressing changes (mean±SD)	4.7±1.2

Table 2 Duration of negative-pressure therapy according to type of closure

	Local flap group (4 patients)	Skin graft group (8 patients)	Integra group (8 patients)
Duration of negative-pressure therapy (mean±SD) (days)	12±3.3	9±3.6	6±4.8

The mean duration of vacuum therapy was 12±3.3 days in patients whose wounds were closed by local flap advancement (n=4), 9±3.6 days in patients whose wounds were closed by skin grafts (n=8), and 6±4.8 days in patients whose wounds were closed by Integra dermal matrix (n=8) (Table 2). There was no incidence of skin graft or Integra losses. All local flaps healed completely. All patients were managed as inpatients and the wounds were closed at the time of discharge. The mean follow-up period was 18±6.8 months, during which no complications were noted.

Two cases selected from this study are described in Figs 1 and 2.

Discussion

The use of vacuum dressing in the management of complex upper-extremity and lower-extremity injuries in the adult population has been clearly documented and is an effective tool in the management of open fractures complicated by soft-tissue loss [13–17]. Negative-pressure wound therapy is considered a bridge technique for soft-tissue management of traumatic extremity wounds, meaning that it is used to promote wound healing before closure, either by secondary intention or by grafting or flap placement [13–17].

Our protocol for closing traumatic extremity wounds are started at the initial operation. Once the wound is debrided, local flaps are used to decrease the wound size and to gain tension-free coverage of any exposed neurovascular structures, tendons, or bone. Once local flap coverage has been maximized, the wound is covered with the negative-pressure wound therapy dressing. This process is repeated at 3-day intervals until it is clear that all nonviable tissue has been removed. Once it is clear that further debridement is no longer needed, dressing changes can be performed at the bedside with conscious sedation. Once evidence of granulation tissue appears, wound closure can be performed.

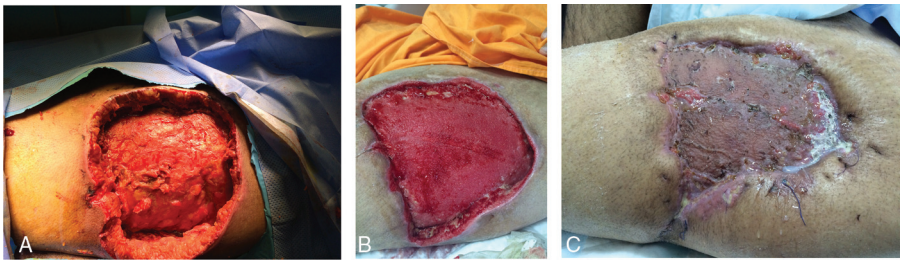
In the present study, negative-pressure wound therapy was used as a means of preparing the wound for definitive closure in 20 pediatric patients with upper-extremity and lower-extremity injuries.

Studies on the role of vacuum therapy in adult and pediatric traumatic extremity wounds are infrequent. In pediatric patients, Mooney *et al.* [18] conducted a small retrospective study of 27 patients treated with VAC for various soft-tissue defects (11 of which were acute

Figure 1

Crushed forearm in a 10-year-old child.

Figure 2



Crushing injury to the thigh in a 14-year-old child.

extremity wounds secondary to trauma). There was a 56% closure rate after an average of 4.8 dressing changes performed approximately every 3 days [18]. Notably, no patients required free tissue transfer for definitive closure [18]. The authors described infrequent complications, which were primarily related to bleeding caused by disruption of the granulation tissue during dressing changes [18].

Another study has evaluated the efficacy of vacuum therapy in pediatric patients, specifically for traumatic extremity wounds [11]. Fifteen patients with type III open tibial shaft fractures underwent VAC with an average of 3.6 dressing changes before definitive wound closure or coverage, with only one patient requiring free tissue transfer [11].

Chariker *et al.* [2] have performed a retrospective review of 24 pediatric patients presenting with extremity injuries involving soft-tissue defects not amenable to immediate primary closure. They evaluated the efficacy of gauze-based negative-pressure wound therapy using the Chariker–Jeter technique. Granulation tissue was noted in all

wounds by day 4. The duration of vacuum therapy averaged 10 days in patients whose wounds were closed primarily (n=19) and 17 days in patients who were allowed to heal by secondary intention (n=5). Nine patients' wounds were closed with skin grafts and local flaps, eight were closed with local flaps only, and three were closed with free tissue transfer. There was no incidence of skin graft loss or flap failure. Follow-up evaluation of the wounds averaged 24 months, during which no complications were noted [2].

Notably, our study of negative-pressure wound therapy confirmed the major conclusion of these previous studies: that vacuum therapy allows the possibility of traumatic wound closure by secondary intention or with local flaps or grafts in extremity wounds that otherwise would require more complex microvascular procedures.

A similar conclusion was reached by the authors of five studies of VAC used to treat traumatic open-extremity wounds in adults [13–17]. In a series of 75 patients with open wounds of the lower extremity (of which 49 were the result of trauma), granulation tissue was present by day 4 of vacuum therapy, with decreased edema and bacterial counts [16]. No patients required free tissue transfer, and wound closures remained stable through a 6-year follow-up [16]. Another group reported their results in 21 consecutive patients with high-energy soft-tissue wounds who underwent vacuum therapy for an average of 19.3 days (4.1 dressing changes) [15]. Fifty-seven percent of wounds healed by secondary intention or were closed with a split-thickness skin graft, and 43% required free tissue transfer [15]. A similar study in 49 patients with grade III open tibia fractures found that vacuum therapy applied for an average of 12.7 days (2.9 dressing changes) was sufficient for wound closure or definitive coverage [13]. Only three patients required free tissue transfer, and 14 wounds were closed with rotational pedicled muscle flaps [13]. Bollero *et al.* [14] likewise reported rapid granulation tissue formation in 35 patients with lower-limb traumatic wounds who underwent vacuum therapy. After an average treatment time of 22 days, two-thirds of the wounds were able to be covered by split-thickness skin grafts, and 76% of patients had stable soft-tissue reconstruction after an average follow-up of 265 days [14]. The efficacy of intermittent vacuum therapy was assessed in a subset of patients with grade III tibia fractures whose wounds could not undergo immediate closure (within 7 days after trauma) [17]. Patients were treated with either subatmospheric pressure dressing therapy (n=17) or wet-to-dry gauze or a moist occlusive dressing (n=38) [17]. The average duration of subatmospheric pressure dressing therapy was 5.91 days [17]. Patients who received vacuum therapy had statistically significantly lower complication rates (35 vs. 53%; P=0.05) and decreased time to bony union (4.9 vs. 7.2 months; P=0.05) than those who did not receive vacuum therapy [17]. Furthermore, these complication and union rates were comparable to those of patients who were able to undergo free tissue transfer within the first 7 days after injury, suggesting that vacuum therapy is an effective option for extending the 'acute' period of traumatic wounds that cannot undergo immediate closure [17].

Our study findings in pediatric patients using negative-pressure wound therapy are thus highly consistent with the existing literature in that they support the use of subatmospheric pressure therapy as a 'bridging' wound care technique in traumatic extremity wounds that are not amenable to immediate closure. In others' and our studies, application of vacuum therapy decreased the need for more complex wound closure procedures, with many wounds able to be covered with grafts or local flaps or healed by delayed secondary intention.

Soft-tissue management in extremity wounds may be particularly challenging in pediatric patients, who may experience intensified anxiety regarding traumatic wounds and who may have a lower threshold for tolerating wound-associated pain and complications. Pediatric extremity trauma thus presents a unique constellation of challenges – anxiety management, pain management, consistent wound care, restorative reconstruction, and post-traumatic stress management – that must be addressed to ensure optimal outcomes [19]. Prevention of wound infection, moist wound care, and wound closure strategies must be both time efficient and relatively painless. The psychological and physical pain management of children requires a team approach involving nurses, anesthesiologists, physical therapists, and family support staff [19].

It is believed that negative-pressure wound therapy enables wound healing by at least three mechanisms. The first is by enabling moist wound healing with an occlusive dressing. Use of an occlusive dressing alone has been shown to increase epithelialization, increase granulation rates, and promote wound healing [20]. The second mechanism is wound drainage. The vacuum effect created under this occlusive dressing creates a highly effective drainage system whereby the products of cell turnover, bacteria, destructive

proteases, and harmful wound factors, and the alkaline drainage of a chronic wound or the acidic drainage of an enteric fistula, are removed [5]. This drainage facilitates the movement of a chronic wound along a dynamic healing curve of an acute wound. The third mechanism is the soft-tissue mechanical stress applied by the vacuum. Urschel *et al*. [21,22] estimated that mechanical stress leads to an upregulation of wound healing through increased cellular nutrition.

Conclusion

In conclusion, this study supports the efficacy of negative-pressure wound therapy as a relatively atraumatic temporary bridging technique to manage soft-tissue defects in complex extremity wounds in pediatric patients. The success of negative-pressure wound therapy depends on a comprehensive clinical judgment and an appropriate wound care regimen once granulation tissue has formed and negative-pressure wound therapy is stopped. More clinical trials are needed to confirm the clinical evidence base needed for this powerful wound care technique.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 V.A.C. therapy clinical guidelines: a reference source for clinicians. Available at: http://www.kci-medical.com.au/AU-ENG/npt-brochures-videos.

2 Chariker ME, Gerstle TL, Morrison CS. An algorithmic approach to the use of gauze-based negative-pressure wound therapy as a bridge to closure in pediatric extremity trauma. Plast Reconstr Surg 2009; 123: 1510.

3 Kostiuchenok BM, Kolker II, Karlov VA, Ignatenko SN, Muzykant LI. Vacuum treatment in the surgical management of suppurative wounds (in Russian). Vestn Khir Im I I Grek 1986; 137:18–21.

4 Davydov Iu A, Malafeeva EV, Smirnov AP, Flegontov VB. Vacuum therapy in the treatment of suppurative lactation mastitis (in Russian). Vestn Khir Im I I Grek 1986; 137:66–70.

5 Davydov Iu A, Larichev AB, Men'kov KG. Bacteriologic and cytologic evaluation of vacuum therapy of suppurative wounds (in Russian). Vestn Khir Im I I Grek 1988; 141:48–52.

6 Iusupov IN, Epifanov MV. Active drainage of a wound (in Russian). Vestn Khir Im I I Grek 1987; 138:42–46.

7 Fleischmann W, Lang E, Kinzl L. Vacuum assisted wound closure after dermatofasciotomy of the lower extremity (in German). Unfallchirurg 1996; 99:283–287.

8 Fleischmann W, Russ M, Marquardt C. Closure of defect wounds by combined vacuum sealing with instrumental skin expansion (in German). Unfallchirurg 1996; 99:970–974.

9 Fleischmann W, Strecker W, Bombelli M, Kinzl L. Vacuum sealing as treatment of soft tissue damage in open fractures (in German). Unfallchirurg 1993; 96:488–492.

10 Baharestani MM. Use of negative pressure wound therapy in the treatment of neonatal and pediatric wounds: a retrospective examination of clinical outcomes. Ostomy Wound Manage 2007; 53:75–85.

11 Dedmond BT, Kortesis B, Punger K, Simpson J, Argenta J, Kulp B, *et al.* Subatmospheric pressure dressings in the temporary treatment of soft tissue injuries associated with type III open tibial shaft fractures in children. J Pediatr Orthop 2006; 26:728–732.

12 Fleck T, Simon P, Burda G, Wolner E, Wollenek G. Vacuum assisted closure therapy for the treatment of sternal wound infections in neonates and small infants. Interact Cardiovasc Thorac Surg 2006; 5:285–288.

13 Caniano DA, Ruth B, Teich S. Wound management with vacuum-assisted closure: experience in 51 pediatric patients. J Pediatr Surg 2005; 40: 128–132.

14 Mooney JF III, Argenta LC, Marks MW, Morykwas MJ, DeFranzo AJ. Treatment of soft tissue defects in pediatric patients using the V.A.C. system. Clin Orthop Relat Res 2000; 376:26–31.

15 Dedmond BT, Kortesis B, Punger K, Simpson J, Argenta J, Kulp B, *et al.* The use of negative-pressure wound therapy (NPWT) in the temporary treatment of soft-tissue injuries associated with high-energy open tibial shaft fractures. J Orthop Trauma 2007; 21:11–17.

16 Bollero D, Carnino R, Risso D, Gangemi EN, Stella M. Acute complex traumas of the lower limbs: a modern reconstructive approach with negative pressure therapy. Wound Repair Regen 2007; 15:589–594.

17 Herscovici D Jr, Sanders RW, Scaduto JM, Infante A, DiPasquale T. Vacuum-assisted wound closure (VAC therapy) for the management of patients with high-energy soft tissue injuries. J Orthop Trauma 2003; 17:683–688.

18 DeFranzo AJ, Argenta LC, Marks MW, Molnar JA, David LR, Webb LX, *et al.* The use of vacuum-assisted closure therapy for the treatment of lower extremity wounds with exposed bone. Plast Reconstr Surg 2001; 108: 1184–1191.

19 Rinker B, Amspacher JC, Wilson PC, Vasconez HC. Subatmospheric pressure dressing as a bridge to free tissue transfer in the treatment of open tibia fractures. Plast Reconstr Surg 2008; 121:1664–1673.

20 Ziegler MF, Greenwald MH, DeGuzman MA, Simon HK. Posttraumatic stress responses in children: awareness and practice among a sample of pediatric emergency care providers. Pediatrics 2005; 115:1261–1267.

21 Vogt PM, Andree C, Breuing K, Liu PY, Slama J, Helo G, Eriksson E. Dry, moist, and wet skin wound repair. Ann Plast Surg 1995; 34:493–499. discussion 499–500.

22 Urschel JD, Scott PG, Williams HT. The effect of mechanical stress on soft and hard tissue repair: a review. Br J Plast Surg 1988; 41:182–186.