Negative pressure wound therapy in resource-limited environments: Review and field guide

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ABSTRACT: Negative pressure wound therapy (NPWT) has emerged as a valuable tool in the management of traumatic soft tissue injuries. Negative pressure wound therapy alters the local wound environment through a variety of mechanisms at both the macroscopic and microscopic level to reduce edema, stimulate angiogenesis, decrease bacterial burden, and promote healing. In battlefield or disaster response settings, NPWT offers additional advantages including reductions in dressing changes and the skilled personnel required to complete them, as well as less exposure to the surrounding environment and associated infection risk. Despite these potential benefits, NPWT use in the austere environment can be limited by logistical and financial constraints associated with commercially available NPWT products. A variety of effective, low-cost NPWT systems have been devised to overcome these barriers. This review summarizes the existing literature on improvised NPWT systems. It also presents a detailed list of potential substitutions for the fundamental NPWT components, as well as techniques for troubleshooting and augments to consider in special scenarios. We aim to provide a concise and practical field guide for construction of an improvised NPWT system to facilitate delivery of evidenced-based wound care in austere environments with infrastructure constraints. (*J Trauma Acute Care Surg.* 2025;00: 00–00.

KEY WORDS: Negative pressure wound therapy; military; soft tissue; disaster; wound care.

Negative pressure wound therapy (NPWT) has become a fundamental technique in the management of chronic and acute extremity wounds.[1–3] Since it first became popularized for use in difficult-to-manage wounds, its indications have expanded to include bolstering partial thickness skin grafts and augmenting the healing of high-risk surgical incisions.[2,4,5] Negative pressure wound therapy enhances wound healing through multiple, well-described mechanisms. At the macroscopic level, it stabilizes the wound environment and causes wound contraction.[6] The semiocclusive drape prevents desiccation of the wound and provides thermal insulation, which can be especially relevant for physiologically unstable patients with large traumatic wounds.[6–8] Negative pressure wound therapy also minimizes skin and soft tissue retraction that can occur after traumatic or surgical disruption of soft tissue, resulting in improved approximation of wound edges and increased likelihood of primary wound closure.[6]

On a microscopic level, continuous evacuation of extracellular fluid leads to microdeformation of cells in the wound environment, which catalyzes increased cell proliferation, production of growth factors, and angiogenesis.[6,8–12] The architecture of sponge material also plays an important role at the molecular level by providing a scaffold for tissue ingrowth.[13] The various benefits of NPWT combine to accelerate wound healing, enhance blood flow in the wound and immediately surrounding tissues, optimize wound area for subsequent closure or coverage, and improve local biochemistry including reduction of bacterial burden.[14,15]

In an austere environment, NPWT offers several additional advantages. The high-energy trauma common in combat or disaster settings often results in wounds at high risk of infection due to contamination or secondary necrosis in areas of relative tissue ischemia.[16,17] These wounds are often managed with wide debridement, irrigation, and delayed closure to allow for a second-look procedure as the zone of injury evolves.[17] Wet-to-dry dressings, the traditional alternative to NPWT for this type of soft tissue injury, require dressing changes multiple times per day, creating a significant manpower challenge in settings with limited medical personnel.[14,18] In addition, every dressing change exposes the wound to the surrounding environment which increases the risk for contamination, especially in the field hospital setting.[17] In contrast, NPWT dressings can be changed every 3–4 days.[14,17,18] The decreased frequency of dressing changes not only reduces the total volume of wound care and manpower required for effective management, but it may also support the dressing change occurring in a sterile environment.[17] Finally, the expedited wound healing promoted by NPWT compared with alternatives may reduce the time to primary closure or soft tissue coverage. Due to the lack of skilled nursing facilities or home health in resource-limited settings, patients with ongoing wound care requirements often remain hospitalized to receive care.[14,17] In these cases, shorter time to definitive closure or coverage supported by NPWT improves medical resource utilization.

The advantages of using NPWT for managing high-energy trauma in a resource-limited setting are demonstrated by experiences with NPWT at military hospitals during the

Submitted: March 26, 2025, Accepted: May 14, 2025, Published online: June 19, 2025.

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Supplemental digital content is available for this article. Direct URL citations appear in the printed text, and links to the digital files are provided in the HTML text of this article on the journal's Web site (www.jtrauma.com).

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DOI: 10.1097/TA.0000000000004708

Iraq war. Machen et al. developed a NPWT protocol at a combat support hospital in Iraq that involved an initial debridement and NPWT application, a repeat debridement and NPWT application on postoperative day one, followed by NPWT dressing changes every 3 days to 4 days. In their series of more than 50 patients, they observed that NPWT rapidly reduced edema, decreased wound size, and promoted granulation tissue formation.[18] Leininger et al. experienced similar success in managing combat-related injuries with NPWT at the 332nd Air Force Theater Hospital in Balad, Iraq.[17] They observed a 0% infection rate and 0% overall complication rate utilizing NPWT in a series of 88 high-energy soft tissue injuries. In both series, patients underwent early surgical debridement followed by repeat surgical debridements as needed. Importantly, NPWT was utilized as an adjunct in the management of their injuries but did not eliminate the need for thorough operative debridement and resection of nonviable tissue. The patients in these series were primarily host-nation citizens making their results applicable for patients undergoing definitive management of high-energy injuries in resource-limited settings including civilian casualties of military conflicts, natural disaster victims, and orthopedic trauma patients in low-income countries.[19–22] For military personnel rapidly evacuated to a higher echelon of care after initial stabilization, prior studies have demonstrated the safety of NPWT during transport, but the existing literature is limited to commercial NPWT devices with approval for in-flight use.[23,24] In addition, casualty evacuation timelines in future wars may be longer than those experienced during recent conflicts in Iraq and Afghanistan. Further research is needed to explore the use of improvised NPWT for military members undergoing medical evacuation and to understand what role it could play in the management of complex wounds during the prolonged field care expected in large scale combat operations.

The need for medical care delivery in disaster response settings is expected to increase in tandem with more frequent and intense extreme weather events. In addition, military doctrine is shifting away from larger field hospitals, which can be vulnerable targets, in favor of delivering medical care in smaller, de-centralized teams. Despite the important role NPWT can play in these austere environments, financial and supply constraints often prevent the use of commercially available NPWT. A variety of improvised NPWT systems have been developed in response, but to our knowledge, the existing literature on NPWT in resource-limited environments is limited to single-technique case reports and series. The aims of this study are to provide a detailed review of options for NPWT components and present a practical field guide for NPWT delivery in logistically challenging settings.

FUNDAMENTAL COMPONENTS OF AN NPWT SYSTEM AND ALTERNATIVES FOR THE AUSTERE ENVIRONMENT

A traditional NPWT system is comprised of four primary components: an open-pore reticulated sponge or foam, a semiocclusive drape, tubing, and a suction device with a cannister.

Open-pore Sponge or Foam

Open-pore foam allows for the negative pressure created by the suction device connected to the surface of the foam to be transferred across the entire foam-wound interface. Polyurethane ether foam is commonly utilized in commercial NPWT because its relatively larger pore size allows for maximal fibrovascular ingrowth.[6,8,13,25] In settings where tissue ingrowth is not desired— such as exposed tendons, nerves, or viscera— foam with smaller pore size like saline-soaked polyvinyl alcohol is utilized.[8,26,27] If applying NPWT to an area with at-risk structures in a resource-limited environment, one option is to transpose the structures out of the wound bed or rotate healthy soft tissue to cover them. Alternatively, a sheet of nonadherent dressing can be used to provide a barrier between the wound and the sponge.[21]

A variety of materials have been successfully substituted for commercially available foam in the austere setting. Sterile gauze or lap sponges and surgical scrub brush sponges are the most commonly reported foam alternatives.[18,19,22,28–34] These items have the advantage of being inexpensive, sterilized, portable, and readily available. Notably, nonadherent, sterile gauze was also utilized as the wound filler in earlier iterations of commercial NPWT devices.[35] Alternatively, Chaudhary et al. describe repurposing foam packaging from a hemiarthroplasty implant as a NPWT.[36] While this exact option may be difficult to apply given the scarcity of orthopedic implants in many austere settings, it highlights the opportunity to sterilize and repurpose foam commonly used as packaging for other medical supplies or devices. Both autoclave and submersion in boiling water have been described as methods for sterilizing foam and sponge.[21,36] It is important to confirm the safety of the sterilization method and its compatibility with the chosen sponge or foam material. One potential hazard of using multiple sponges or pieces of foam compared with larger commercial sheets of foam is the increased risk of a retained sponge, which is a known cause of complication with NPWT.[37] For a foam/sponge alternative generated from multiple pieces, a standardized protocol should be used to account for all of the components.[1]

Semiocclusive Drape

After application of the sponge to the wound bed, a semiocclusive dressing is applied over top of the sponge. This semipermeable membrane prevents protein loss and desiccation, protects the wound from environmental contamination, and creates a vacuum seal.[8] Commercial NPWT kits come with specialized drape created for this purpose. Semiocclusive dressings utilized in improvised NPWT included iodophor-impregnated operating room drape, transparent sterile adhesive bandages, plastic food wrap, and sterile glove material.[18,21,29–31,33,34,38] The use of sterile gloves can be particularly advantageous for wounds on the hands or feet where it is difficult to achieve a seal with strips of drape due to the irregular contours.[32,39] Hemmanur et al. describe a method leveraging the long arms commonly found on gynecological gloves to cover larger wounds by overlapping the arm portion of the glove in a telescopic fashion.[32]

Impervious stockinet is a viable option for larger areas that present challenges in efficiently obtaining and maintaining a seal, such as residual limbs or complex multifocal extremity

wounds. After the cotton liner is removed, the plastic stockinet can be placed over the limb and secured proximally with an adhesive bandage or elastic dressing to quickly create a reliable seal over a large, irregular area.[38] In areas where it is difficult to create a seal with an adhesive drape, such as near the perineum or around external fixation pins, ultrasound gel can be used to create an air-tight barrier and then covered with plastic wrap.[21,27,40] Finally, for the special case of using improvised NPWT to manage an open abdomen, Faulconer et al. describe a successful technique that calls for placing the abdominal contents in a perforated bowel bag and then packing the surrounding area with sterilized lap sponges.[29]

Tubing

After a semiocclusive drape has been applied, tubing is used to connect the sealed sponge within the wound bed to a device that creates a negative pressure gradient. Commercial NPWT tubing attaches to the drape via a landing pad with prefashioned holes that allow it to communicate with the foam material. To create the same effect in an improvised system, the selected tubing should either be fenestrated on one end or modified with a scalpel or rongeur. The fenestrated end is then situated such that all of its openings are in direct contact with sponge material and the nonfenestrated end is attached to the suction device. Previously described options for tubing in a resource-limited setting include a standard suction catheter, a nasogastric tube, Foley catheter tubing, surgical drain tubing, and a chest tube.[18–22,29,31–34,36]

Suction Device

Wall suction and portable suction machines are the two primary options available for creating a negative pressure gradient. Portable suction machines allow for increased patient mobility and continuation of care during patient transport.[18,19] Despite these advantages, the limited availability of portable suction machines in far-forward settings and the feasibility of running them continuously in high ambient temperatures has led to more widespread use of wall suction.[18,30,34,36] The production of low-cost, locally produced portable suction machines based on aquarium aerator pumps is a promising area of development that may expand the feasibility of NPWT in resource-poor settings. Barau et al. describe one example, the Turtle vacuum-assisted closure (VAC), a device that costs roughly $60 to build and was successfully utilized by medical personnel during the disaster response after the 2010 earthquake in Haiti.[20] Their study provides a detailed supply list and technique guide for construction of a suction device that generates 125 mm Hg of negative pressure using a 100-gallon aquarium pump and commonly available hardware supplies. In their series, the Turtle VAC was utilized in conjunction with standard suction tubing, nonsterile sponge, and an adhesive drape to successfully perform NPWT for patients with complex extremity trauma. In a randomized controlled trial, Cocjin et al. demonstrated the noninferiority of a similar aquarium pump-based system compared with a commercially produced NPWT device.[21] Their fabricated pump, the AquaVac, is also built using an aquarium aerator pump but with the addition of a pressure regular that allows variable suction from 0 mm Hg to 160 mm Hg.

The most common pressure setting recommended for open wounds is negative 125 mm Hg based on preclinical studies of granulation tissue formation at varying pressures.[41] A recent Level I study found similar results in patients treated with negative 125 mm Hg and negative 75 mm Hg, suggesting lower pressure settings may also be effective.[42] Regardless of pressure setting or suction source, output of an improvised NPWT system must be closely monitored. The most serious complications observed with NPWT have been related to hemorrhage, as detailed in the warning issued by the FDA in 2009.[8,24,43] Although the warning addressed commercially manufactured devices, heightened vigilance is required when utilizing improvised NPWT systems due to their lack of built-in safety mechanisms and alarms for high-output that can warn medical personnel of ongoing bleeding.[1,44] If ongoing bleeding is identified, suction should be discontinued immediately, direct pressure should be applied, and care should be escalated as needed to achieve hemostasis. In addition to closely tracking output, risk of bleeding-related complications can be reduced by avoiding placement of NPWT dressings over a vascular graft, in wounds adjacent to large vessels after vascular ligation, and in high risk anatomical areas like the groin and presternal region. [8,44]

Another major potential complication associated with NPWT is a disruption of the vacuum seal resulting in an inability to maintain negative pressure. Suction leaks may arise secondary to factors such as improperly applied or damaged dressing material, loose connection between the tubing and canister, skin creases or irregularities adjacent to the wound, or suction device malfunction.[23,24,40] Short interruptions in suction, for example, during patient transport, can be managed by clamping the system. Pollack et al. described a series of patients undergoing NPWT that continued during air evacuation.[23] A subset of patients had in-flight device problems that could not be rectified, and their systems were instead clamped. Despite this interruption in therapy, no increased complication rate was observed in this cohort. If the interruption is planned, such as during patient transport with no option for en route suction, a Heimlich valve can be utilized to maintain the negative pressure gradient until the system can be reconnected.[29] Prolonged interruption of suction can lead to wound complications, but the time period of interruption beyond which patients are at risk for adverse outcomes has not been established.[45] Improvised systems do not have leak detection capabilities or alarms, which further complicates the determination of how long a system has been nonfunctional. The absence of automated leak detection increases the difficulty of identifying small leaks that do not completely disrupt the suction seal but may allow contaminants from the environment to enter the system. The authors recommend that a NPWT system which has been malfunctioning for an unknown period of time should be removed at bedside, provisionally irrigated, and transitioned to a wet-to-dry dressing until it is possible to return to the operating theater for a formal irrigation and repeat application of a NPWT system.

Table 1 provides a summary of the components utilized in randomized controlled trials and larger case series describing improvised NPWT systems developed in resource-limited settings. The utilization parameters and outcomes of these studies are summarized in Table 2. In addition, options for potential alternatives for each of the four primary NPWT system components are

TABLE 1. Summary of Components Utilized in Randomized Controlled Trials and Large Case Series Describing Improvised Negative Pressure Wound Therapy Constructs in Resource-Limited Environments

First Author (Year)	Study Design (N)*	Setting (Country)	NPWT Components			
			Sponge / Foam	Drape	Tubing	Suction
Cocjin (2019)	RCT (36 patients)	Tertiary hospital (Philippines)	Sterile gauze	Plastic food wrap	Suction tubing	Portable suction machine built from aquarium pump
Perez (2010)	RCT (20 patients)	Tertiary hospital (Haiti)	Surgical scrub sponge	Plastic adhesive dressing	Suction tubing	Commercial portable suction machine
Kamamoto (2017)	RCT (19 patients)	Tertiary hospital (Brazil)	Sterile gauze	Transparent adhesive dressing	Nasogastric tube	Wall suction
Mansoor (2015)	Case series (85 patients)	Military hospital (Pakistan)	Sterile gauze	Transparent adhesive dressing	Fenestrated surgical drain (JP)	Commercial portable suction machine
Chaudhary (2020)	Case series (56 patients)	Tertiary hospital (India)	Sterile polyurethane sponge acquired from discarded packaging material of bipolar hip replacement prosthesis	Semipermeable adhesive dressing	Nasogastric tube	Wall suction
Gill (2011)	Case series (44 patients)	Tertiary hospital (Pakistan)	Sterile scrub sponge	Plastic adhesive dressing	Suction tubing	Commercial portable suction machine or wall suction
Amlani (2024)	Case series (41 patients)	Tertiary hospital (Cameroon)	Sterile scrub sponge or gauze	Iodophor-impregnated OR drape or plastic adhesive dressing	Suction tubing	Commercial portable suction machine
Shalom (2008)	Case series (15 patients)	Tertiary hospital (India)	Surgical scrub sponge	Transparent adhesive dressing	Suction tubing	Wall suction

RCT, randomized controlled trial; OR, operating room; JP, Jackson-Pratt.

* Refers to the number of patients who received an improvised or experimental NPWT system. Case series with fewer than 15 patients were not included in this table but are described in the body of the article and listed in the references section.

presented in Table 3. The component substitutions presented do not represent an exhaustive list but can facilitate assembly of an improvised NPWT system in an austere environment or guide the selection of other potentially suitable materials.

AUGMENTS FOR NPWT SYSTEMS IN THE AUSTERE ENVIRONMENT

Various modifications or additions to the NPWT system can be made to augment its wound-healing potential, such as the addition of dermatotraction, an integrated drain, or local antibiotic delivery.

Dermatotraction

The mechanical effects of NPWT on wound edges can be further potentiated by the use of dermatotraction.[46,47] While commercial tensioning devices are available, multiple techniques have been developed for performing dermatotraction in a resource-limited setting with readily available supplies. A vessel loop or heavy suture can be applied over the sponge material in a Jacob's ladder configuration and secured with staples.[46,48] Alternatively, Govaert et al. described a system using sterilized cable ties that allows for progressive tightening outside of the operating room and provides increased rigidity compared with vessel loop or suture techniques.[49] The use of combined dermatotraction and NPWT may be especially helpful in the setting of fasciotomies. In addition to the previously mentioned benefits, NPWT has been associated with decreased time to fasciotomy closure, potentially due to reduction in the edema of surrounding muscles.[50] Morykwas et al. also demonstrated a reduction of myoglobinemia following fasciotomies for compartment syndrome using NPWT in an animal model.[51]

Integrated Drain

It can be helpful to incorporate a drain into an incisional wound vac for wounds or surgical incisions compatible with primary closure but overlying an area of dead space. The drain tubing is passed through the skin in close proximity to the primarily closed wound. A chosen sponge material is then placed over the closed wound, followed by the drain tubing modified to include fenestrations, covered by additional sponge material. A second piece of tubing is used to connect the sponge-drain apparatus to a suction source. The apparatus should be removed no later than 3 days postoperatively to minimize ingrowth into the sponge material.

Local Antibiotic Delivery

Techniques for local delivery of antibiotics in surgical and traumatic extremity wounds are rapidly evolving. Although Stinner et al. demonstrated a decrease in effectiveness of antibiotic bead pouches (ABP) when used with NPWT in an animal model, a more recent study using the same animal model found no difference in bacteria levels when vancomycin powder was used topically in isolation compared with in conjunction with NPWT.[15,52] Topical antibiotics have also been shown to achieve higher sustained wound concentrations than PMMA beads.[52–54] Newer models of commercial NPWT machines allow for the intermittent installation of irrigants, which has shown promising

TABLE 2. Summary of Outcomes of Randomized Controlled Trials and Large Case Series Describing Improvised Negative Pressure Wound Therapy Constructs in Resource-Limited Environments

First Author (Year)	Study Design (N)*	Setting (Country)	Outcomes	
			Utilization	Results and Complications
Perez (2010)	RCT (20 patients)	Tertiary hospital (Haiti)	NPWT mean duration 16 days (range, 14–23); median 6 dressings (IQR, 3–7)	90% of wounds completely healed at final follow-up 30 days after direct wound closure or skin grafting; complications not reported
Cocjin (2019)	RCT (19 patients)	Tertiary hospital (Philippines)	NPWT duration 7 days for all patients	On average, 98% of wound area covered with granulation tissue at final dressing removal; improvised NPWT comparable to commercial system in application time, pain during dressing changes, wound contraction, granulation tissue coverage, exudate amount; no wound or periwound complications
Kamamoto (2017)	RCT (17 patients)	Tertiary hospital (Brazil)	NPWT mean duration 9.6 days (SD 4.5)	Compared with commercial VAC device, observed similar healing time and amount/rate of wound bed contraction and granulation tissue growth; complications not assessed
Mansoor (2015)	Case series (85 patients)	Military hospital (Pakistan)	NPWT mean duration 12.5 days (SD 6.8; range, 6–32); mean 4 dressing changes (SD 2.6; range, 2–13)	All patients achieved healthy granulation tissue and clean wound beds; no acute in-hospital wound complications; 3.4% of dressing changes complicated by loss of seal (all in anatomically complex areas), 4 patients with temporary malfunction of suction apparatus
Chaudhary (2020)	Case series (56 patients)	Tertiary hospital (India)	NPWT mean duration 8.6 days (range, 2–24); 57% of patients required <5 dressings before wound closure, 43% of patients required ≥5 dressings	All wounds showed formation of healthy granulation tissue and reductions in wound depth and necrotic tissue; wound size shrunk 20% on average (range, 3–62%); no major complications, minor wound edge maceration in 5 patients
Gill (2011)	Case series (44 patients)	Tertiary hospital (Pakistan)	NPWT mean duration 13 days (range, 9–26); mean dressing changes 3 (range, 2–6)	Significant tissue edema reduction and granulation tissue formation usually seen after 2nd dressing application; most wounds graftable or ready for flap coverage after 3rd dressing application; air leaks requiring dressing change (7.9%) or complementary dressing (10.5%)
Amlani (2024)	Case series (41 patients)	Tertiary hospital (Cameroon)	NPWT median duration 6 days (IQR, 3–7)	Wound margins improved or the same for 98% of dressing changes; 80% of patients achieved wound closure, 20% failed limb salvage; no cases of sepsis from wound; issues during dressing changes included inadequate seal (18%), suction device malfunction (6%), and cannister malfunction (4%)
Shalom (2008)	Case series (15 patients)	Tertiary hospital (India)	NPWT mean duration 12 days (range, 2–30)	All patients achieved healthy granulation tissue and clean wound beds; 1 case of dermatitis around wound margins

SD, standard deviation; IQR, interquartile range.

* Refers to the number of patients who received an improvised or experimental NPWT system. Case series with fewer than 15 patients were not included in this table but are described in the body of the article and listed in the references section.

results with both normal saline and antiseptic solutions; however, logistical and financial barriers may prevent the procurement of these systems in resource-limited environments.[55,56] Methods for integrating intermittent irrigation into improvised NPWT devices require further research. Dakin's solution and acetic acid warrant particular attention given their low cost and efficacy as antiseptics.[57,58] Notably, the use of NPWT with installation of Dakin's solution resembles the original Carrel-

TABLE 3. Field Guide Describing Alternative Components to Assemble Negative Pressure Wound Therapy Constructs in Resource-Limited Environments

NPWT Component	Open-Pore Sponge or Foam	Semiocclusive Drape	Tubing	Suction
Alternatives in the Resource-Limited Environment	Sterile gauze	Iodophor-impregnated operating room drape	Standard suction catheter	Wall suction
	Lap sponge	Sterile adhesive bandages	Nasogastric tube	Commercial portable suction
	Surgical scrub sponge	Plastic food wrap	Foley catheter tubing	Portable suction constructed from aquarium pump
	Repurposed foam packaging	Impervious stockinet	Jackson-Pratt drain tubing	
		Sterile glove material	Chest tube	

Dakin protocol developed for management of combat wounds during World War I.[57] Based on the current literature, the use of topical antibiotics like vancomycin and tobramycin powder can be considered in combination with improvised NPWT. Preclinical models utilizing topical antibiotics in wound care have demonstrated promising early evidence, and a high local concentration of antibiotics may minimize bacterial growth in the case of an inadvertent loss of suction or seal disruption.[47]

CONCLUSION

Negative pressure wound therapy offers a variety of benefits in the treatment of extremity wounds including improved blood flow, accelerated wound healing, and minimized bacterial burden. In austere environments like disaster response and combat, NPWT provides additional advantages including decreased manpower required for wound care and shorter times to definitive wound closure or coverage. Commercially available NPWT are expensive and can be difficult to procure depending on supply chain capabilities. A variety of improvised NPWT systems constructed from various low-cost, readily available medical supplies have been developed to overcome these barriers. The current research on these devices is limited to case series and three small randomized clinical trials but their results support improvised NPWT as a potential alternative for management of complex soft tissue injuries when commercial NPWT systems are not a feasible option. Further investigation would be required to demonstrate the noninferiority of improvised NPWT systems. Larger randomized controlled trials would be needed to identify differences in rates of uncommon but potentially serious complications including hemorrhage and infection secondary to an unrecognized seal disruption, both of which improvised devices have a potential increased risk for given their lack of automated monitoring. The military applications of improvised NPWT is another area that warrants continued research since changes in evacuation capabilities and military medical infrastructure may render a technique utilized in a previous conflict obsolete in a future battlespace. Despite their limitations, improvised NPWT systems are a promising development in the management of complex soft-tissue injuries in austere environments and an affordable option for delivering negative pressure wound therapy in resource-limited settings.

AUTHORSHIP

L.L. participated in the literature search, study design, data interpretation, article writing. R.M. participated in the literature search, critical revision. D. J.S. participated in the study design, data interpretation, critical revision.

DISCLOSURE

The authors have no conflict of interest to report, and all JTACS Disclosure forms have been supplied and are provided as supplemental digital content (http://links.lww.com/TA/E589).

No funding was received in support of this study.

REFERENCES

1. Argenta LC, Morykwas MJ, Marks MW, DeFranzo AJ, Molnar JA, David LR. Vacuum-assisted closure: state of clinic art. *Plast Reconstr Surg*. 2006; 117(7 Suppl):127S–142S.
2. Stannard JP, Robinson JT, Anderson ER, McGwin G, Volgas DA, Alonso JE. Negative pressure wound therapy to treat hematomas and surgical incisions following high-energy trauma. *J Trauma*. 2006;60(6):1301–1306.
3. Webb LX, Dedmond B, Schlatterer D, Laverty D. The contaminated high-energy open fracture: a protocol to prevent and treat inflammatory mediator storm-induced soft-tissue compartment syndrome (IMSICS). *J Am Acad Orthop Surg*. 2006;14(10 Spec):S82–S86.
4. Stannard JP, Volgas DA, McGwin G, Stewart RL, Obremskey W, Moore T, Anglen JO. Incisional negative pressure wound therapy after high-risk lower extremity fractures. *J Orthop Trauma*. 2012;26(1):37–42.
5. Scherer LA, Shiver S, Chang M, Meredith JW, Owings JT. The vacuum assisted closure device: a method of securing skin grafts and improving graft survival. *Arch Surg*. 2002;137(8):930–933.
6. Orgill DP, Manders EK, Sumpio BE, Lee RC, Attinger CE, Gurtner GC, Ehrlich HP. The mechanisms of action of vacuum assisted closure: more to learn. *Surgery*. 2009;146(1):40–51.
7. Winter GD, Scales JT. Effect of air drying and dressings on the surface of a wound. *Nature*. 1963;197:91–92.
8. Streubel PN, Stinner DJ, Obremskey WT. Use of negative-pressure wound therapy in orthopaedic trauma. *J Am Acad Orthop Surg*. 2012;20(9): 564–574.
9. Argenta LC, Morykwas MJ. Vacuum-assisted closure: a new method for wound control and treatment: clinical experience. *Ann Plast Surg*. 1997; 38(6):563–576 discussion 577.
10. Morykwas MJ, Argenta LC, Shelton-Brown EI, McGuirt W. Vacuum-assisted closure: a new method for wound control and treatment: animal studies and basic foundation. *Ann Plast Surg*. 1997;38(6):553–562.
11. Morykwas MJ, Simpson J, Punger K, Argenta A, Kremers L, Argenta J. Vacuum-assisted closure: state of basic research and physiologic foundation. *Plast Reconstr Surg*. 2006;117(7 Suppl):121S–126S.
12. Labler L, Rancan M, Mica L, Härter L, Mihic-Probst D, Keel M. Vacuum-assisted closure therapy increases local interleukin-8 and vascular endothelial growth factor levels in traumatic wounds. *J Trauma*. 2009;66(3):749–757.
13. Scherer SS, Pietramaggiori G, Mathews JC, Prsa MJ, Huang S, Orgill DP. The mechanism of action of the vacuum-assisted closure device. *Plast Reconstr Surg*. 2008;122(3):786–797.
14. Powell ET. The role of negative pressure wound therapy with reticulated open cell foam in the treatment of war wounds. *J Orthop Trauma*. 2008; 22(10 Suppl):S138–S141.
15. Stinner DJ, Hsu JR, Wenke JC. Negative pressure wound therapy reduces the effectiveness of traditional local antibiotic depot in a large complex musculoskeletal wound animal model. *J Orthop Trauma*. 2012;26(9):512–518.
16. Lowry KF, Curtis GM. Delayed suture in the management of wounds; analysis of 721 traumatic wounds illustrating the influence of time interval in wound repair. *Am J Surg*. 1950;80(3):280–287.
17. Leininger BE, Rasmussen TE, Smith DL, Jenkins DH, Coppola C. Experience with wound VAC and delayed primary closure of contaminated soft tissue injuries in Iraq. *J Trauma*. 2006;61(5):1207–1211.
18. Machen S. Management of traumatic war wounds using vacuum-assisted closure dressings in an austere environment. *US Army Med Dep J*. 2007; 17–23.
19. Amlani L, Ndasi H, Aminake G, Penda X, Timam S, Lechtig A, Dejean CB, Agarwal-Harding K. The utility of low-cost negative pressure wound therapy in Cameroon. *Pan Afr Med J*. 2024;48:151.
20. Barau Dejean JMC, Pean JTM-A, Ottesen TD, Woolley PM, Qudsi RA, Dyer GSM. Advantages of a new low-cost negative pressure wound therapy using the "turtle VAC": a case series. *JBJS Case Connect*. 2021;11(2).
21. Cocjin HGB, Jingco JKP, Tumaneng FDC, Coruña JMR. Wound-healing following negative-pressure wound therapy with use of a locally developed AquaVac System as compared with the vacuum-assisted closure (VAC) system. *J Bone Joint Surg Am*. 2019;101(22):1990–1998.
22. Mansoor J, Ellahi I, Junaid Z, Habib A, Ilyas U. Clinical evaluation of improvised gauze-based negative pressure wound therapy in military wounds. *Int Wound J*. 2015;12(5):559–563.
23. Pollak AN, Powell ET, Fang R, Cooper EO, Ficke JR, Flaherty SF. Use of negative pressure wound therapy during aeromedical evacuation of patients with combat-related blast injuries. *J Surg Orthop Adv*. 2010;19(1):44–48.
24. Fang R, Dorlac WC, Flaherty SF, Tuman C, Cain SM, Popey TLC, Villard DR, Aydelotte JD, Dunne JR, Anderson AM, et al. Feasibility of negative pressure wound therapy during intercontinental aeromedical evacuation of combat casualties. *J Trauma*. 2010;69(Suppl 1):S140–S145.
25. Wake MC, Patrick CW, Mikos AG. Pore morphology effects on the fibrovascular tissue growth in porous polymer substrates. *Cell Transplant*. 1994;3(4): 339–343.

26. Timmers MS, Graafland N, Bernards AT, Nelissen RG, van Dissel JT, Jukema GN. Negative pressure wound treatment with polyvinyl alcohol foam and polyhexanide antiseptic solution instillation in posttraumatic osteomyelitis. *Wound Repair Regen*. 2009;17(2):278–286.
27. Herscovici D, 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(10):683–688.
28. Malmsjö M, Gustafsson L, Lindstedt S, Gesslein B, Ingemansson R. The effects of variable, intermittent, and continuous negative pressure wound therapy, using foam or gauze, on wound contraction, granulation tissue formation, and ingrowth into the wound filler. *Eplasty*. 2012;12:e5.
29. Faulconer ER, Davidson AJ, Bowley D, Galante J. Negative pressure temporary abdominal closure without continuous suction: a solution for damage control surgery in austere and far-forward settings. *J R Army Med Corps*. 2019;165(3):163–165.
30. Kamamoto F, Lima ALM, Rezende MR, Mattar-Junior R, Leonhardt MC, Kojima KE, Santos CCD. A new low-cost negative-pressure wound therapy versus a commercially available therapy device widely used to treat complex traumatic injuries: a prospective, randomized, non-inferiority trial. *Clinics (Sao Paulo)*. 2017;72(12):737–742.
31. Berkowitz MJ, Rediske MWR, Chance MJ, Kim MD. Technique tip: creation of a vacuum-assisted closure system for wound management in an austere environment. *Foot Ankle Int*. 2007;28(3):388–391.
32. Hemmanur SR, Siddha LV. Role of the surgical glove in modified vacuum-assisted wound healing. *Arch Plast Surg*. 2013;40(5):630–632.
33. Perez D, Bramkamp M, Exe C, von Ruden C, Ziegler A. Modern wound care for the poor: a randomized clinical trial comparing the vacuum system with conventional saline-soaked gauze dressings. *Am J Surg*. 2010;199(1):14–20.
34. Shalom A, Eran H, Westreich M, Friedman T. Our experience with a "home-made" vacuum-assisted closure system. *Isr Med Assoc J*. 2008;10(8–9):613–616.
35. Jeffery SLA. Advanced wound therapies in the management of severe military lower limb trauma: a new perspective. *Eplasty*. 2009;9:e28.
36. Chaudhary S, Kumar V, Gandhi P, Koichade M, Mandal S. Low cost, modified negative pressure wound therapy in infected orthopaedic wounds: can it be as effective as its costly counterparts? *J Clin Orthop Trauma*. 2020;11(Suppl 5):S876–S882.
37. Leijnen M, Steenvoorde P. A retained sponge is a complication of vacuum-assisted closure therapy. *Int J Low Extrem Wounds*. 2008;7(1):51.
38. Judd DB, Warme W, White CE. The "bluie," a simplified method for applying a vacuum-assisted closure dressing in residual limbs and complex war wounds. *Am J Orthop (Belle Mead NJ)*. 2009;38(4):199–200.
39. Sreelesh LS, Laxminarayan Bhandari P. An easy technique for negative-pressure wound therapy for extremities using collagen powder and sterile gloves. *Indian J Surg*. 2017;79(1):81–83.
40. Bergin PF, Wild JR, Weber TG. "Jelly VAC" for negative-pressure therapy for complex wound closure: a report of two cases. *JBJS Case Connect*. 2018;8(1):e18.
41. 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(5):547–551.
42. Lavery LA, La Fontaine J, Thakral G, Kim PJ, Bhavan K, Davis KE. Randomized clinical trial to compare negative-pressure wound therapy approaches with low and high pressure, silicone-coated dressing, and polyurethane foam dressing. *Plast Reconstr Surg*. 2014;133(3):722–726.
43. White RA, Miki RA, Kazmier P, Anglen JO. Vacuum-assisted closure complicated by erosion and hemorrhage of the anterior tibial artery. *J Orthop Trauma*. 2005;19(1):56–59.
44. Sartipy U, Lockowandt U, Gäbel J, Jidéus L, Dellgren G. Cardiac rupture during vacuum-assisted closure therapy. *Ann Thorac Surg*. 2006;82(3):1110–1111.
45. Collinge C, Reddix R. The incidence of wound complications related to negative pressure wound therapy power outage and interruption of treatment in orthopaedic trauma patients. *J Orthop Trauma*. 2011;25(2):96–100.
46. Eceviz E, Çevik HB. Shoelace technique plus negative-pressure wound therapy closure in fasciotomy wounds. *Adv Skin Wound Care*. 2020;33(9):497–500.
47. Quacinella MA, Yong TM, Obremskey WT, Stinner DJ. Negative pressure wound therapy: where are we in 2022? *OTA Int*. 2023;6(4 Suppl):e247.
48. Barnes JW, Sherman G, Dubin J. Wound closure with acute dermatotraction. *J Surg Orthop Adv*. 2018;27(2):155–159.
49. Govaert GAM, van Helden S. Ty-raps in trauma: a novel closing technique of extremity fasciotomy wounds. *J Trauma*. 2010;69(4):972–975.
50. Yang CC, Chang DS, Webb LX. Vacuum-assisted closure for fasciotomy wounds following compartment syndrome of the leg. *J Surg Orthop Adv*. 2006;15(1):19–23.
51. Morykwas MJ, Howell H, Bleyer AJ, Molnar JA, Argenta LC. The effect of externally applied subatmospheric pressure on serum myoglobin levels after a prolonged crush/ischemia injury. *J Trauma*. 2002;53(3):537–540.
52. Shiels SM, Sgromolo NM, Wenke JC. Negative pressure wound therapy does not diminish efficacy of topical antibiotic powder in a preclinical contaminated wound model. *Bone Joint Res*. 2021;10(2):149–155.
53. Ottesen TD, Qudsi RA, Kahanu AK, Baptiste BJ, Woolley PM, Socci AR, Dyer GSM. The continued utility and viability of Dakin's solution in both high- and low-resource settings. *Arch Bone Jt Surg*. 2020;8(2):198–203.
54. Jennifer Gurney C. Joint Trauma System Clinical Practice Guideline (JTS CPG) War Wounds: Debridement and Irrigation (CPG ID:31). https://jts.health.mil/index.cfm/PI_CPGs/cpgs.
55. Kim P. Negative pressure wound therapy with instillation: an adjunctive therapy for infection management in orthopaedic trauma. *J Orthop Trauma*. 2022;36(Suppl 4):S12–S16.
56. Back DA, Scheuermann-Poley C, Willy C. Recommendations on negative pressure wound therapy with instillation and antimicrobial solutions—when, where and how to use: what does the evidence show? *Int Wound J*. 2013;10 Suppl 1(Suppl 1):32–42.
57. Levine JM. Dakin's solution: past, present, and future. *Adv Skin Wound Care*. 2013;26(9):410–414.
58. Jeong HS, Lee BH, Lee HK, Kim HS, Moon MS, Suh IS. Negative pressure wound therapy of chronically infected wounds using 1% acetic acid irrigation. *Arch Plast Surg*. 2015;42(1):59–67.

