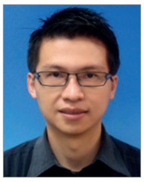
Successful orthopaedic limb salvage with negative pressure wound therapy (NPWT) in a high-grade open fracture



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High-energy trauma often causes severe soft tissue damage and high-grade open fracture, associated with exposed bone and tendon. Treatment of acute complex traumatic wounds remains a challenge in clinical practice. Early and suitable treatment for open fracture is essential, as an open fracture is associated with a higher risk of infection and complications during treatment. Soft tissue management in an open fracture is equally important as fracture management in orthopaedics. The wound is managed accordingly to the soft tissue reconstruction ladder after fractures are stabilised. Negative pressure wound therapy (NWPT) is one option in soft tissue coverage and usually used in moderate open fracture, grade II and IIIA. It is an affordable and effective dressing technique, which carries a major role in the treatment of complex traumatic wound. As an adjunctive treatment, it is combined with comprehensive surgical exploration and debridement in promoting wound healing. We present a case of successful lower limb salvage using NPWT in a 16-year-old teenager who sustained a huge degloving wound with high-grade open fracture (Gustillo Anderson grade IIIC) and exposed bone and joint, to complete granulation tissue coverage for split skin graft (SSG). Although the treatment course was protracted, the patient escaped from lower limb amputation and psychological stigma that society associates with the loss of a limb. His knee was stiff with fixed flexion, but he obtained a painless and functional lower limb in non-aided ambulation. NPWT dressing saved the patient from second soft tissue surgery (skin flap) and donor site mobility.

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Open fracture is defined as a contaminated soft tissue wound resulting from low-to-high energy trauma, communicating with fracture haematoma and/or fracture site (Buteera et al, 2009). Management of open fractures involves prioritizing life-saving and early limb salvage through resuscitation, AIDS (antibiotics, irrigation and debridement surgery) followed by soft tissue cover and skeletal stabilisation. Soft tissue management becomes an important stage of treatment in open-fracture management in limb salvaging (Diwan et al, 2018). Conventional treatment involved the use of wet dressings to achieve adequate granulation tissue followed by skin grafting. It was found that formation of healthy granulation tissue is difficult with exposed tendon, bone or implant (Arti et al, 2016; European Wound Management Association (EWMA, 2007). As a result, free-flap surgery was often required and introduced the issue of donor site morbidity. Negative pressure wound therapy (NPWT) was described by Morykwas and Argenta in 1997 (Robert, 2017), and initially utilised polyurethane foam as the dressing interface between wound

Table 1. Gustilo Anderson classification of open fractures (Barton, 2012)	
Type 1	Puncture wound of less than or equal to 1 cm with minimal soft tissue injury Minimal wound contamination or muscle crushing
Type 2	Wound is greater than 1 cm in length Moderate soft tissue injury Soft tissue coverage of the bone is adequate Contamination is minimal
Type 3a	Extensive soft tissue damage Includes massively contaminated, severely comminuted or segmental fractures Soft tissue coverage of the bone is adequate
Type 3b	Extensive soft tissue damage with periosteal stripping and bone exposure Usually severely contaminated and comminuted fracture Flap coverage is required to provide soft tissue coverage
Type 3c	Associated with an arterial injury requiring repair for limb salvage

bed and vacuum source. This dressing technique greatly increases granulation tissue formation and reduces the waiting duration prior to skin grafting (EWMA, 2007; Robert, 2017).

NPWT is used in handling complex traumatic wounds and, more frequently, is implemented in grade II and IIIA open fracture *[Table 1]*. With the latest operational concept for soft tissue coverage, grade I open fracture intended for primary closure, while grade II and IIIA open fracture employed NPWT and skin grafting. Lastly, high-grade open fractures (IIIB/IIIC) utilised skin flap for wound closure (Diwan et al, 2018). Commercially available NPWT devices are clinically proven in promoting wound healing with tight control of sub-atmospheric pressure range. However, these standard NPWT devices are expensive and they are hardly affordable by our patient who received treatment at government hospital. By applying the principles of NPWT, a modified NPWT using wall suction port with negative pressure gauge, Ryle's tube and polyurethane foam was used in our case. By using the wall suction, patient's mobility was compromised when the system was activated. Nevertheless, its utilisation in high-grade open fracture with severe soft tissue in our case found that this dressing technique was an effective method in wound healing even though it was applied across the joint.

Case report

The authors present a case report of a 16-year-old Malay teenager, with no known medical illness, an active smoker, with an alleged motor vehicle accident (MVA) in 2017. The patient, who is a motorbike rider, had a head-on collision with an oncoming car and was dragged along the road. He sustained a huge degloving wound from proximal 3rd of right thigh to the middle 3rd of the leg. The wound size was 40 x 15 cm, with necrotic anterolateral muscles, an anterior tibial artery cut, exposed lateral right knee joint with vertically split patella bone and bone loss, open fracture of right lateral femoral condyle, open fracture lateral and posterior condyle of right tibial plateau and open comminuted fracture right fibula (Gustillo Anderson grade IIIC) *[Figure A]*. The patient underwent wound debridement, wound exploration, cerclage wire right patella, arthrotomy washout, cross knee and ankle external fixation, screw fix lateral condyle right femur and lateral tibial plateau within 12 hours post-trauma. He was treated with triple antibiotics.

Daily povidone wound dressing was done within 1 week post surgery. We noted bare bone and implant over the lateral aspect with knee joint exposed *[Figure B and C]*. NPWT was initiated and wound condition after 1 month post-trauma noted good granulation tissue coverage over previously exposed bone site *[Figure D]*. NPWT was continued and the wound showed promising result with more granulation tissue cover and good contact bleeding at wound base 2 months post-trauma *[Figure E]*. The patient underwent a total of 7 times of surgical wound debridement and 11 cycles of NPWT during the 103 days of hospitalisation. The application of NPWT on the large wound with an external fixator in situ was complex. Effort was made to enhance sealing around the pin site to prevent leakage.

NPWT was performed in a sterile condition. A single layer interface dressing (UrgoTul©) was placed between the foam and the wound. This lipido-colloid dressing resulted in less pain upon dressing exchange, prevented polyurethane foam from becoming embedded within the wound, prevented ingrowth of

Figure A. Wound size 40 x 15cm, with necrotic anterolateral muscles, anterior tibial artery cut, exposed lateral right knee joint with vertically split patella bone and bone loss, open fracture right lateral femoral condyle, open fracture lateral and posterior condyle of right tibial plateau and open comminuted fracture right fibula (Gustillo Anderson grade IIIC).

Figure B and C. Wound condition 1 week after wound debridement, circlage wire right patella, arthrotomy washout, cross knee and ankle external fixation, screw fix lateral condyle right femur and lateral tibial plateau noted exposed bone and implant over lateral aspect with knee joint exposed.

Figure D. Wound condition 1 month post trauma with NPWT dressing noted good granulation tissue coverage over previously exposed bone site.

Figure E. Wound condition 2 months post trauma noted more granulation cover and good contact bleeding at wound base.

Figure F. Wound condition 5 months post trauma after external fixation removed. The knee was in fixed flexion position. Patient was able to partially weight bear.

Figure G. Wound condition prior to SSG.

Figure H and I. Complete wound closure with successful SSG after 1 year post-trauma.

Figure J and K. Patient was able to walk with right lower limb without aid (Shortening of right lower limb was due to significant bone loss from initial injury and necrotic bones that were debrided throughout the treatment course).

granulation tissue into foam, and protected fragile granulation tissue buds from bleeding when dressing removed. Polyurethane foam was touched on the wound to get wound size estimation. The foam was cut in a size ~ 1 cm larger than the wound to enable the foam to accommodate well inside the wound, allowing no dead space. Maceration occurred in cases where the Opsite adhesive drape did not completely seal to the skin on the wound borders. The polyurethane foam was prepared by using a surgical blade to make a tunnel to pass a Ryle's tube through it. Transparent Opsite adhesive dressing was applied to seal the dressing and the Ryle's tube. The Ryle's tube was secured to a suction catheter that emptied into a suction canister, which was connected to a vacuum pressure gauge that attached to wall suction port. Skin preparation solution was used to thoroughly clean and dry the skin before adhesive drape application. Pressure was set at negative 125–150 mmHg on negative pressure gauge meter according to patient's tolerance of pain. Dressings were changed every 4–5 days, depending on the condition of the dressing (soaked or leaking) after wound inspection. While removing the dressing, the negative pressure was turned off around 30 mins earlier to reduce pain and injury to wound bed. Opsite adhesive drape was removed followed by removal of polyurethane foam. If the foam was sticked to the wound bed, normal saline would be instilled into the dressing, combined with lignocaine if required. This modified NPWT system was used instead of commercially available NPWT system because of patient's financial limitation taking into the concern of the long treatment course.

NPWT was terminated when adequate granulation tissue covered exposed bone and knee joint (after 2 1/2 months of NPWT combined with surgical debridement). The patient was put on antiseptic dressing while awaiting further generation of granulation tissue. The external fixator was removed 5-months post trauma *[Figure F]*. Prior to skin graft, wound bed swab culture and sensitivity was taken and it showed no growth *[Figure G]*. He underwent split skin grafting 6 months post-trauma, with donor site of SSG from right upper thigh. The SSG uptake was promising and the wound achieved total wound closure 1-year post-trauma *[Figure H and I]*. Although the treatment course is protracted, the patient escaped from lower limb amputation and the psychological stigma that society associates with the loss of a limb. His right lower limb was shortened with stiff knee in fixed flexion, but he obtained a painless and functional lower limb in non-aided ambulation *[Figure J and K]*.

Discussion

Management of open fracture is crucial as the open fracture is associated with increased risk of infection and complications during the treatment (Zalavras, 2017). The infection rate of open fracture can be estimated by Gustillo Anderson classification with 0–2% in grade I, 2–12% in grade II, and 10–50% in grade III (O'Brien, 2018). Novak et al (2014) showed that the infection rate was 12.5% for grade IIIA open fracture, increased to 45.8% in grade IIIB and 50% in grade IIIC. This latter group had more significant soft tissue damage and inadequate soft tissue coverage of the bone.

NPWT is identified as an adjunctive treatment in handling difficult wound and many clinical trials have cited the success of this dressing technique in open wound treatment. The complex traumatic wound in high-energy injury always associated with significant skin loss, resulted in poorly vascularised tissue at its base such as bone, tendon or implant causing difficulty in wound management. Attempts at closure by secondary intention may fail due to the inability of these tissues to heal with conventional wound care method (Hinck, 2010). Skin grafting will be unsuccessful with difficult adherence and resulted in thin, unstable coverage. Rapid granulation tissue formation is essential for the healing of open fracture wound as earlier wound closure reduces the incidence of chronic osteomyelitis (Lee, 2009).

Traditional wet dressings were no longer a popular option in wound management due to several drawbacks such as frequent change of dressing (2–3 times/day), pain in dressing change, exposing the wound to the environment frequently, being unable to address deep infection and poor exudate handling. These pitfalls lead to protracted treatment course and unsatisfactory results (Arti et al, 2016). On the other hand, NPWT was effective in clearance of exudate, reduced of wound exposure frequency and therefore less painful episodes, reduced of periwound oedema, reduced time to wound closure, control bacterial proliferation and reduced deep infection (Arti et al, 2016).

NPWT creates an environment that prepares the wound bed for closure and promotes wound healing by secondary or tertiary intention. Both macrostrain and microstrain forces are applied to the wound bed during NPWT dressing (Blum et al, 2012).

Macrostrain happens when negative

Document: Topical Negative Pressure in Wound Management*. Available at: https://bit.ly/2FzOmaX (accessed 21 June 2019)

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pressure contracts the sealed foam dressing, approximating the wound margin, providing direct wound bed contracture, distributing equal negative pressure, and removing exudate and infectious materials (Wang et al, 2018). Negative pressure on the foam causes it to shrink and become a soft but firm anchor point for muscles and fascia from the superficial and deep compartments of the wound, drawing the wound margin to centre. Wongworawat et al observed an average of 43% reduction in the original size of the wound during a mean duration of 10 days (Wongworawat, 2003). The seal created by the foam and adhesive drape reduces the risk of environmental contamination and reduced wound odour (EWMA, 2007).

Exudate from the wound contains harmful components such as cytokines, matrix metalloproteinases and collagenase that impeded wound healing. NPWT removes the exudate while maintaining a moist wound environment and protects the surrounding healthy tissues from maceration and exudate damage (EWMA, 2007). Preventing pooling of exudate and therefore bacterial load (exotoxin and endotoxin), also reduce the risk of deep infection and septic complications (EWMA, 2007). Blum et al (2012) found that NPWT could reduce the risk of deep infection by almost 80%.

Wound ischemia is one of the main cause of delayed wound healing in both acute and chronic wounds (EWMA, 2007). NPWT improves blood flow directly by negative pressure and indirectly by removing interstitial fluid from the wound bed and reducing periwound oedema. Negative pressure of 125 mm Hg was noted to increase vascularity and blood flow 4 times more than usual in wound bed (Arti et al, 2016). Timmer et al (2005) reported an increase of five-fold in blood supply by using negative pressure with polyurethane foam.

Microstrain induces tissue micro-deformations within the wound at cellular level, and this mechanical stretching of the cells stimulates proliferation and acceleration of wound healing by triggering growth factor pathway (Saxena et al, 2004). In chronic wounds, this mechanism stimulates angiogenesis and epithelisation, enhancing the development of high-quality granulation tissue (Greene et al, 2006). Applying subatmospheric pressure in traumatic wounds was proven to show increase local interleukin (IL-8) and vascular endothelial growth factor (VEGF) concentration, which may trigger accumulation of neutrophils and angiogenesis, leading to acceleration of neovascularization (Labler et al, 2006). DeFranzo (1999) reported that rapid granulation tissue was achieved in 80% of patients compared to simple wound dressing even in exposed bone, tendon or hardware.

NPWT is also helpful in reducing systemic infection and deterioration. Severe skeletal muscle injury leads to disruption of muscle cell integrity with the release of intracellular content, such as myoglobin, potassium, phosphate and creatinine kinase into interstitial fluid space. Without active removal, the released myoglobin eventually entered systemic circulation and lead to acute renal failure. Myoglobin level was able to be reduced with the use of NPWT in cases of severe muscle injury (Wang et al, 2018).

The requirement of a free flap was reduced by 30% with the use of NPWT and half of the patients were able to achieve wound closure by skin grafting, primary closure or secondary intention (Novak et al, 2014). NPWT was recommended not to use on bare bone which the periosteum of the exposed bone was stripped off (Robert, 2017). However, we drilled the bone when performing surgical wound debridement and followed by NPWT application in operation theatre. This technique successfully achieved granulation tissue cover over exposed bone and ultimately thicker granulation tissue formation that makes the wound suitable for SSG.

Conclusion

NPWT remains a useful adjunct in complex traumatic wounds. The combination of NPWT with extensive and thorough wound debridement and appropriate usage of antibiotics is an option in handling high-grade open fracture wound. With the frequent use of NPWT, it makes a significant change in practice, reduces the need for free flaps and more delayed closure and skin grafting down the reconstruction ladder. Despite this, there are several other options in current advanced wound care that awaiting more exploration and clinical data to prove their efficacy and value in open fracture wound management and limb salvage. WAS

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