Chapter 12
Negative-Pressure Wound Therapy

Lauren R. Bayer

Introduction

When Louis Argenta and Michael Morykwas published their seminal research on vacuum-assisted closure in 1997 [1], they likely could not have imagined that the technology would become one of the most revolutionary wound treatments of the late twentieth century. Basic treatment of acute, chronic, and surgical wounds is generally limited to normal saline-dampened gauze or other moist dressings based on work by Winter [2], who illustrated the importance of keeping the wound bed moist to avoid tissue desiccation. More advanced wound dressings include dressings impregnated with silver, collagens, alginates, and foams, but they may not be as effective or practical for large wounds or those with a large amount of exudate. Dermal substitutes and bioengineered skin have shown promise in several types of wounds [3].

Suction, irrigation, and drainage of infected internal cavities and large wounds have been employed in medical settings for decades [4]. Argenta and Morykwas showed that subatmospheric pressure applied to an open wound filled with an open-cell foam sealed with an adhesive drape could not only evacuate fluid but also induce granulation tissue formation and facilitate wound contracture [1].

Eventually marketed as vacuum-assisted closure (V.A.C.®) by Kinetic Concepts Incorporated (KCI) in 1997, the treatment has become ubiquitous and the subject of vast research. Because the KCI V.A.C. ® was the only marketed device for over 15 years, most published research has used the V.A.C.®. There are now dozens of

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negative-pressure wound therapy (NPWT) devices. Generic to most of the devices is an interface material ranging from standard gauze to open-pore foam, a semiocclusive adhesive dressing, suction tubing, and a suction device. Disposable, one-time devices are available for smaller wounds or those without much drainage. Some in vivo animal [5] and clinical studies [6] have compared gauze filler with open-cell foam and showed no difference in tissue growth and wound contraction. Nevertheless, open-cell, polyurethane foam interface is preferred by many users. Recently, the technology has been combined with instillation of a variety of fluids [7].

Mechanisms of Action

The primary and secondary mechanisms of action of NPWT systems have been studied extensively in preclinical models and in humans. Proposed primary mechanisms include macrodeformation when the wound edges are drawn together, microdeformation at the wound-foam interface, fluid removal, and maintenance of a stable wound environment (Fig. 12.1). Resultant granulation tissue formation, angiogenesis, neurogenesis, and cell proliferation are secondary mechanisms of action that enhance the wound-healing cascade [8].

NPWT depends on differential pressure applied to tissues. Based on cell culture work showing that cells that are stretched from their spherical shape tend to divide and proliferate [9, 10], Lu et al. [11] designed a model in which vacuum pressure is applied to tissue cells via incompressible foam in vitro. In vivo, different pressures and pore sizes were studied and surface deformations of the cells resulted. The deformations predicted by the model were similar to the undulations noted on the wound surface when an NPWT device was applied. The cells are stretched, allowing them to divide and proliferate. Thus, application of vacuum to tissues causes microdeformations in the tissues, inducing angiogenesis and cellular proliferation and explaining an important mechanism of action of NPWT [12].

The open-pore foam used in most NPWT systems transmits a vacuum quite efficiently and has been shown to decrease in size by about 80% when exposed to 125 mmHg suction [13, 14]. The wound collapses due to the centripetal forces placed on the wound surface and the degree of wound contraction will depend on the deformability of the tissues. Packing the wound with a piece of foam cut to fit inside will facilitate wound contracture as vacuum pressure is applied.

Excess fluid in a wound or in the extracellular space can adversely affect wound healing. Suction applied to the foam dressing evacuates the excess fluid in the wound and has been observed to decrease soft tissue edema, as in the case of fasciotomy wounds and large open abdominal wounds. Fluid removal decreases compression on the microvasculature, which in turn can increase tissue perfusion [8]. Toxins, bacteria, and harmful exudate are also removed, potentially improving wound healing.

The foam and semiocclusive polyurethane drape that make up most NPWT systems has limited permeability to gases and vapor and is therefore effective in keeping

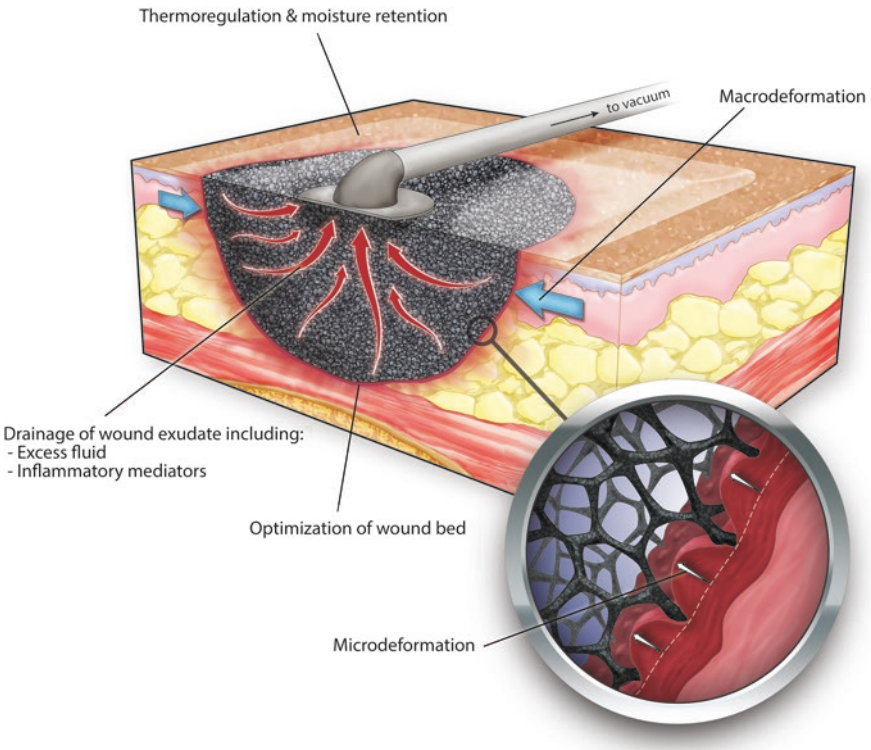

Fig. 12.1 The primary mechanisms of action of NPWT (From Huang et al. [8]. With permission from Elsevier)

the wound moist and normalizing the wound temperature, thus stabilizing the wound environment. In addition, the drape is impermeable to proteins and microorganisms, reducing the risk of infection transmission from the environment [8].

Induced microvascular blood flow has been reported in wounds treated with NPWT and is dependent on the amount of pressure, distance from the wound edges, and the type of tissue. Combined with increased partial pressure of oxygen and lactate levels, more robust wound healing has been noted [15].

Clinical Applications

NPWT has been used for a variety of acute and chronic wounds, anatomic locations, and wound etiologies. Common wound types include surgical and traumatic wounds, orthopedic wounds, diabetic and vascular ulcers, and pressure injuries. NPWT has been shown to heal complex wounds with less invasive surgical intervention [16, 17]. The reconstructive ladder is well known to surgeons and begins at

the bottom with primary closure of a wound and progresses upward in complexity through the rungs from skin grafts, local flaps, regional flaps to the most complex, and free flaps at the top [16, 17]. Using NPWT at the outset to treat a wound that would otherwise require surgical closure with a flap, for example, facilitates a shift down the reconstructive ladder, decreasing the need for a complex closure [18].

Basic Application of NPWT in an Open Wound

NPWT is most commonly used in an open wound. In order to be most affective, the open-cell foam packing is placed in direct contact with the wound bed. The exception being direct foam contact with visceral organs, large nerves, tendons, the heart, or large blood vessels where an intervening nonadherent layer, viable tissue, or tissue-engineered construct should be placed to avoid erosion. The foam is cut to fit the wound size and packed loosely into the wound. Ideally, only one piece of foam should be placed in the wound. The use of more than one piece of foam should be documented and checked at the time of removal when dressing is changed.

A semipermeable adhesive drape is placed over the wound, overlapping the surrounding skin 3–5 centimeters. Suction tubing is attached to the dressing and connected to the vacuum device. Vacuum settings range from 50 to 150 mmHg depending on the device and can be set as low or high as necessary to achieve adequate suction. The adhesive drape must be generally free of leaks or else suction cannot be maintained. A small amount of air that transits the system can help avoid a vapor lock. In the setting of large amounts of drainage, suction may need to be adjusted to maintain a seal and to fully evacuate the wound. Small, drier wounds may have little drainage (Fig. 12.2).

Dressings should be changed every 2–3 days, depending on drainage amount, wound etiology, and goal of therapy. For granulating a large wound with a large amount of drainage, more frequent dressing changes may be necessary. In the event of a device malfunction, the dressing should be removed within 2 h if suction cannot be maintained [19].

Optimal cycling of NPWT has been debated. Most manufacturers recommend the device be set on a continuous cycle, delivering a constant rate of vacuum suction. Intermittent suction has been shown in experimental settings to yield a greater biological effect and may be advantageous over continuous suction, but it can often be unpleasant for the patient. Too rapid cycling can also be deleterious [20, 21].

During dressing changes, care must be taken to avoid damage to the tissues, bleeding, and pain. Irrigating the foam with saline can loosen the foam from the tissues. Adding lidocaine to the saline or injecting the foam directly with a large bore needle can help reduce the pain sometimes associated with dressing removal. Once the dressing is removed, the wound should be inspected for residual foam adhered to the tissue, necrosis, and bleeding. Wounds should be cleaned and debrided if necessary prior to reapplying the dressing.

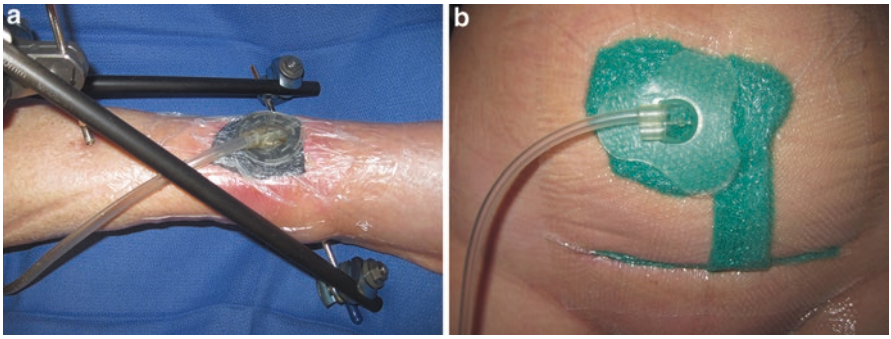

Fig. 12.2 (**a**) NPWT dressing on a traumatic wound after tib fib fracture, debridement, and external fixator (**b**) NPWT dressing on a cesarean section wound using the bridging technique

While there are few limits to the anatomic location or wound type for NPWT use, not all applications have been studied. The following section reviews common uses of NPWT and supportive data when available.

Diabetic Foot Ulcers

Diabetic foot ulcers (DFU) affect more than 25% of diabetics over their lifetime [22] and are the source of severe morbidity and mortality. Treatment of DFU includes debridement, moist dressings, and offloading with a goal toward avoiding amputation. Prevalence of lower extremity amputation in diabetics was 1.8 between 2006 and 2008, tripling in patients with concomitant peripheral artery disease [23]. DFU requiring advanced therapy include primary deep ulcerations and postsurgical wounds and may be amenable NPWT.

Randomized control studies with Level I–II evidence comparing NPWT with standard of care (moist wound therapy with alginates, hydrocolloids, foams, or hydrogels) [24, 25] on DFU showed increased granulation tissue, wound area reduction [26], reduction in operative intervention [27] including reamputation [24], and decreased infections [28]. Dumville et al. [29] reported some evidence that NPWT is clinically effective in reducing time to healing and risk of amputation in chronic DFU and postsurgical wounds.

DFU should be debrided prior to application of NPWT as the necrotic bone, connective tissue, or subcutaneous tissue will prevent healing [30] and may worsen with NPWT. Radiologic studies may be necessary to rule out underlying osteomyelitis before beginning therapy. Patients should be adequately offloaded [31] and blood glucose optimized to ensure maximum benefit.

Dressing application to the foot can be challenging and toe and heel contours may make keeping a seal difficult. Applying skin prep, a thin hydrocolloid or pieces of adhesive drape around the wound add an extra surface on which the wound-covering drape can adhere. Using the bridging technique if the wound is on the heel

or plantar foot moves the tubing away from the walking surface and can be more comfortable. The dressing foam cut slightly smaller than the wound size is packed into the wound. A piece of adhesive drape or hydrocolloid is applied from the wound to a relocation area on the dorsal foot or lower leg to protect the skin. A thin piece of foam is applied (bridged) from the wound to the relocation area over the drape or hydrocolloid. An additional piece of adhesive drape is applied to cover all pieces of foam, and the tubing connection is placed on the end of foam bridge. As long as the bridged foam and wound packing foam are contiguous, the vacuum will reach the wound (Fig. 12.3). Dressings should be changed two to three times per week, and wounds should be carefully monitored for necrosis and infection.

Deep Pressure Injuries

Wounds caused by pressure can be a devastating complication of prolonged hospital or nursing home stay, immobility, or debilitation. NPWT for stage 3 or 4 pressure injuries aids in fluid evacuation, granulation tissue proliferation, and wound contraction to optimize wounds for secondary closure or preparation for surgical closure [32]. There are few randomized control studies using NPWT in pressure wounds, and none compare NPWT with advanced therapies [33]. Despite the dearth of data, clinical use is ubiquitous as pressure injuries become more prevalent, especially in our aging population.

Wounds should be free of necrotic tissue prior to commencing therapy, facilitated by serial sharp debridements augmented by mechanical debridement with saline or ¼ strength Dakin's (sodium hypochlorite) dampened gauze packing. Imaging studies to rule out osteomyelitis and abscess should be obtained. Large, deep wounds should ideally be packed with only one piece of foam to avoid multiple pieces of foam that could be lost in the wound with subsequent dressing changes. Dead spaces, undermined areas, and tracks should be packed, using caution in areas of narrow tracking. Applying the foam just at the base of a narrow track to prevent tissue from walling off the area can often suffice. The foam should be trimmed to a size slightly smaller than the wound to facilitate wound contraction and the wound should never be overpacked. The device tubing can be "bridged" away from the wound to avoid the patient lying or sitting on the tubing (Fig. 12.4). Suction can be set at the lowest setting that maintains a seal and evacuates fluid; 100–125 mm Hg is recommended. Sensate patients may have pain with higher suction so the setting can be reduced.

Minimizing pressure on the wound with complete offloading with limited or no sitting, boots for extremity pressure injuries and use of a pressure relieving mattress can ensure effective treatment. Optimizing nutritional status, managing incontinence and cessation of nicotine products will also aid in healing. NPWT is not recommended in the setting of malnutrition, dermatitis, incontinence affecting the dressing seal, persistent tissue necrosis, bleeding, and pain.

After prolonged use, the wound, dressing, and/or canister can become malodorous. NPWT can be discontinued for 2–3 days while the wound is packed with gauze

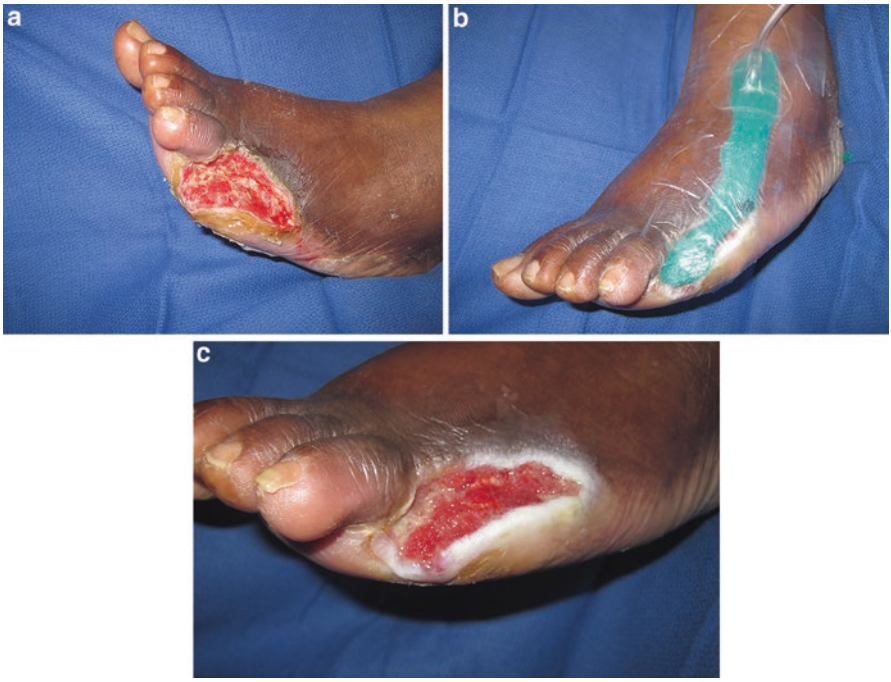

Fig. 12.3 (**a**) Diabetic foot ulcer before NPWT. (**b**) NPWT dressing with bridge. (**c**) Two weeks after NPWT treatment

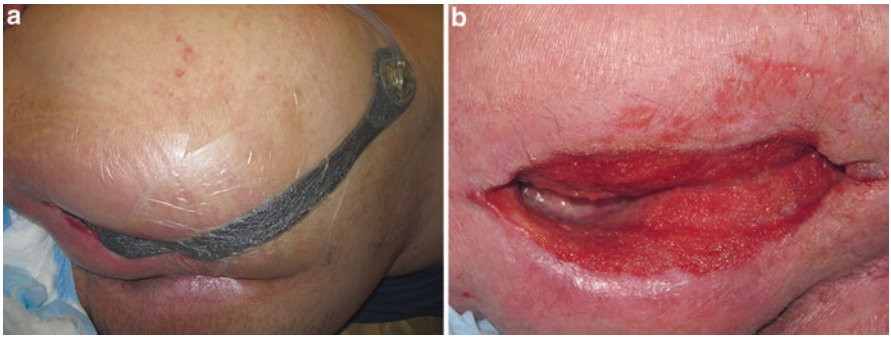

Fig. 12.4 (**a**) Bridged NPWT dressing. (**b**) Resultant granulating stage 4 left ischial pressure injury

dampened with saline or quarter strength Dakin's to treat bacterial colonization and odor. NPWT can then be resumed. Wound measurements should be obtained weekly, and once the wound is no longer decreasing in size, other treatments should be investigated, including flap closure for surgical candidates. Indolent infection, including osteomyelitis or abscess, may be a cause of a stalled wound, and should be ruled out with cultures or imaging studies.

Vascular Lower Extremity Ulcers (Venous/Arterial)

Chronic lower extremity ulcers are generally caused by either venous stasis or arterial insufficiency. The hallmark of venous stasis ulcer treatment is compression, and there are many advanced wound therapies also available. NPWT, while not commonly used, can optimize the wound bed for application of a skin graft or dermal substitute, aid in fluid management, decrease matrix metalloproteinases, and decrease bioburden in select cases [34]. NPWT has also been used in the treatment of lymphocele and lymph fistulas as a complication from vascular procedures. Case studies reported decreased lymphorrhea which led to eventual wound healing [35].

The use of NPWT in the setting of arterial disease is most commonly necessary after wound debridement, groin wound complications [36, 37], or amputations. NPWT should only be considered if the extremity has been adequately revascularized and debrided of all devitalized tissue. Complications of using NPWT dressings in open groin wounds include infection and bleeding. Exposed vital structures must be covered with fascia or a nonadherent dressing under the NPWT foam and should be carefully monitored during treatment. NPWT can be used to assist in secondary healing or preparation for skin graft or flap in open or dehisced amputation wounds. Wounds left open because of infection or edema can be optimized with NPWT and surgically closed at a later date.

Traumatic Wounds

Traumatic injuries of lower extremities, which often include both complex bone fractures (Gustilo Grade IIIA and B) [38] and soft tissue damage can be managed with NPWT. Early coverage of the exposed bone is important to prevent infection, and often the wounds require frequent washouts and debridements in the operating room before definitive fracture fixation and soft tissue closure [16]. Reduced morbidity and time of healing using NPWT compared to standard gauze dressings has been shown [39]. Sealing the wound in the sterile dressing serves to decrease wound infection [40–42] as it can decrease dressing changes and provide protection from nosocomial contamination [43]. Sinha et al. [44] saw significantly reduced wound size in open musculoskeletal injuries treated with NPWT, reduced bacterial growth by day 8, significant angiogenesis, and granulation tissue formation. When immediate primary closure is not possible, delayed closure with skin grafts or flaps may be required. When NPWT is used on lower extremity traumatic wounds, researchers have noted fewer free flaps were used for closure, trending toward the ability for delayed closures with local flaps and skin grafts [16, 18, 45].

After thorough debridement, irrigation, hemostasis, fracture stabilization, and coverage of exposed vessels and nerves with a nonadherent dressing, NPWT is applied in the operating room. The dressing foam can be placed directly on exposed tendon to prevent desiccation and promote ingrowth of granulation tissue (Fig. 12.5).

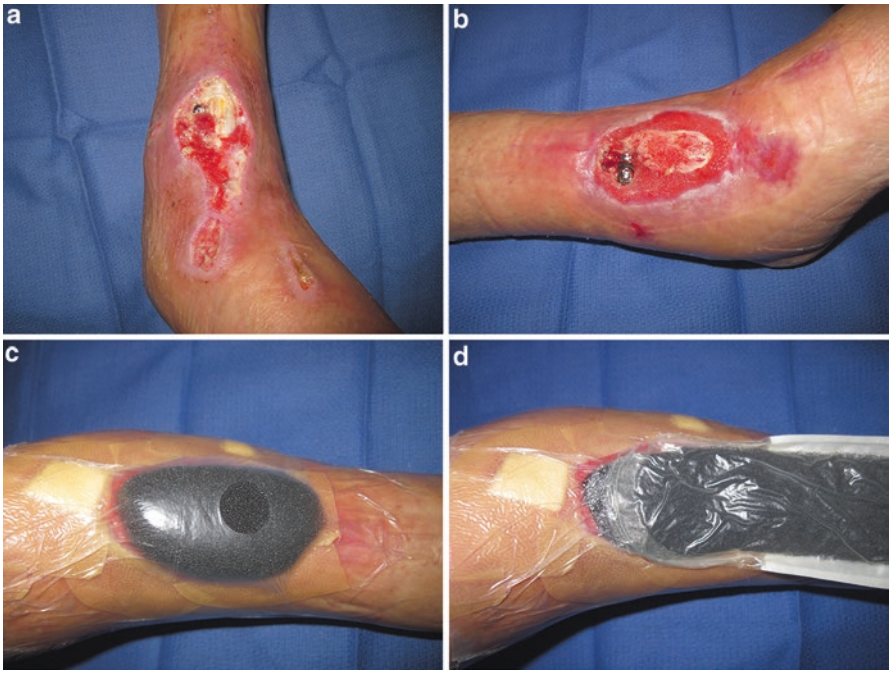

Fig. 12.5 (**a**) Traumatic tib fib fracture and wound dehiscence with exposed tendon. (**b**) After NPWT with granulating tendon. (**c**) NPWT dressing in place. (**d**) NPWT bridge dressing in place

Between debridements, wounds should be monitored carefully for bleeding. NPWT devices with the capability of instilling fluid may be beneficial in lower extremity traumatic wounds [7].

Patients with intra-abdominal trauma may require massive amounts of fluid resuscitation resulting in severe edema of the abdominal cavity and making closure of large abdominal wounds not possible. Applying NPWT for temporary abdominal closure (TAC) of a large open wound to facilitate delayed primary closure while the patient stabilizes has been shown to be successful [46]. A systematic review of NPWT for TAC [47] resulted in several observations and recommendations. The highest rates of primary fascial closure were seen using commercially available NPWT dressings and the "dynamic closure" technique, which includes mesh and retention sutures along with NPWT dressing. Septic patients did not fare as well. Other recommendations include using an interface layer over exposed organs to avoid adhesions between the foam and bowel and the abdominal wall and using a foam-based dressing instead of gauze, use for managing abdominal fluid, and the device should be set on a continuous rather than intermittent setting. Concern for enterocutaneous fistula is warranted but has been found to not be more common when using NPWT over plain gauze packing in open abdominal wounds [47].

Sternal Wounds

Complications from median sternotomy can be fraught with patient morbidity and extremely challenging due to the vital structures within the thorax. Prior to the advent of commercially available NPWT systems, sternal wound infection was routinely treated with antimicrobial irrigation via catheters and gauze packing [48, 49]. Once the infection was eradicated, closure was performed using pectoralis and/or omental flaps, with or without sternectomy. With the advent of NPWT, treatment of open chest wounds improved significantly. Several reports describe use of NPWT versus gauze dressings and showed better sternal stability and reduced need for mechanical ventilation while the chest was open, [50] increased granulation tissue formation, decreased C-reactive protein levels [51] and lower recurrence rate, and increased ability to salvage the sternum [52].

After OR debridement of the infected tissue, muscle, and bone, a fluid-permeable nonadherent dressing or fascia is applied to cover the heart, if exposed, large vessels, and friable bone to eliminate the risk of vital structure rupture. The foam interface is then placed into the wound. The adhesive drape keeps the open mediastinum sterile and maintains a moist wound environment. Vacuum suction pulls the wound edges together, stabilizing the chest, and evacuates fluid accumulation. If the sternum is open, dressings are changed under anesthesia. If the wound is superficial, with an intact sternum, dressings can be changed at bedside every 2–3 days. Superficial wounds can be left to heal by secondary intention. Deep sternal or chest wounds may require a flap. Once the wound is deemed ready for closure, omentum can be brought up to fill in any dead space and flaps, including pectoralis major, latissimus dorsi muscle, rectus abdominus muscle can be raised to cover the mediastinum [53].

Complications from using NPWT in the chest have been reported and should serve as cautionary tales. Bleeding from coronary artery venous bypass grafts, ascending aorta, and the sternum [54] and right ventricular rupture [55] have been reported.

Fasciotomy Wounds

Fasciotomy incisions are created to relieve pressure in the setting of compartment syndrome. Because concurrent edema is common, incisions are difficult to close primarily even after the pressures have normalized. After debridement and hemostasis, NPWT can be applied directly to the open wounds to facilitate edema reduction and splint the wound edges together allowing for either delayed primary closure, skin grafts or healing by secondary intention [18, 56]. If a skin graft is employed, NPWT can continue to be utilized as a bolster to further limit fluid collection under the graft and improve graft take [56].

Burns

Management of large acute burns includes medical stabilization and particular attention to the wounds. NPWT may assist in the goals of burn wound care including preventing infection, preventing burn progression, and providing a moist environment that will facilitate healing and minimize fluid evaporation. NPWT may also be beneficial at preventing burn wound progression [18]. A porcine study of NPWT application within 12 h of burn injury reduced the depth of tissue necrosis, but not after 18 h. Optimum window of time for NPWT to prevent burn progression may be less than 12 h, but there are no robust studies to support its use. Progression of burn depth has been studied in both porcine [57] and human models [58] and shown to decrease progression as well as reduce inflammatory infiltrates [57].

NPWT dressings on large burns can limit the frequency of often painful dressing changes and offer stabilization of the microenvironment during physiological recovery [58]. The dressings can prepare the burn wound beds for skin grafting by stimulating granulation tissue and vascularity and potentially decreasing the surface area and wound depth ultimately needing closure [59]. When used as a bolster, NPWT dressings can secure the skin grafts and improve graft take [60].

Clinical application is similar to that of any large wound, with some modifications. Due to pain and patient instability, dressings may need to be changed under sedation or in an operating room. Silver impregnated foam can be used to potentially decrease bioburden in the wounds and help prevent infection [61]. Keeping a dressing seal can be challenging on large TBSA burns, and methods such as preparing the skin with benzoin, securing the adhesive drapes with staples or sutures, using additional layers of drape, and using multiple pumps have been described [62]. NPWT can be used for residual open wounds after skin grafting, and using silver foam in the event of early graft failure may prevent further graft loss and promote healing [63].

Skin Grafts

Skin graft take is dependent on elimination of fluid accumulation under the graft, immobilization and stabilization of the graft, keeping the graft moist to avoid desiccation, and providing an environment that limits infection risks [64]. For most skin grafts, a cotton or foam bolster is sufficient, but for larger grafts or those at higher risk of failure, using NPWT before and after graft placement is a viable option. Optimizing the wound bed prior to skin graft placement with debridements and NPWT has been shown to increase split- and full-thickness graft take in various wound types such as Achilles [65], lower extremity traumatic wounds [64], burns [66], and fasciotomies [67]. Pretreatment with NPWT is dependent on the severity and depth of the wound. Multiple debridements and several weeks of NPWT treatment may be required before the wound bed is ready for grafting, but often, 5–7 days of NPWT followed by coverage with a spilt-thickness or fenestrated full-thickness skin graft is enough to improve skin graft take substantially [18, 66].

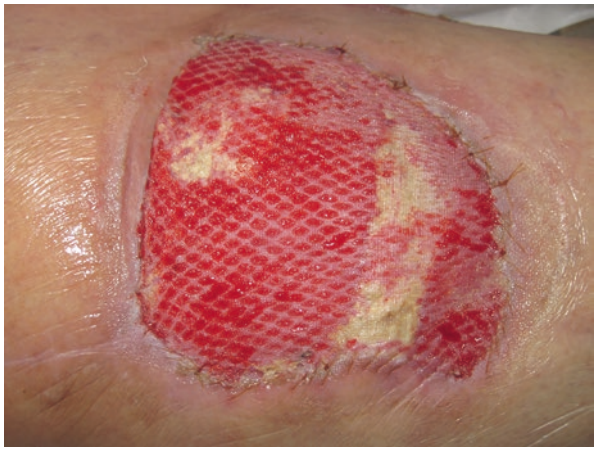

Fig. 12.6 Knee wound after removal of infected hardware, debridement, skin graft, and NPWT

The skin graft can be applied to the wound and anchored with suture or staples per surgeon preference. A nonadherent dressing (petroleum gauze, meshed nonadherent dressing) is usually placed over the skin graft and the NPWT dressing is applied, covered with adherent drape (Video 12.1). The vacuum is set at 75–100 mm Hg, continuous. The dressing is left for 4–5 days and then carefully removed and replaced with a moist dressing according to surgeon preference (Fig. 12.6).

Instillation and Incisional Applications

Surgical site infections (SSI) in acute care facilities are still relatively common, estimated at over 160,000–300,000 per year in the United States with 2–11 times higher mortality rate compared with surgical patients without SSI and a financial cost of $3.5 billion to $10 billion annually in healthcare expenditures (adjusted for 2007 dollars) [68, 69]. Preventative measures have been mandated by the CDC and Healthcare Infection Control Practices Advisory Committee [68]. Applying NPWT to closed incisions and using instillation therapy are both showing promise in further decreasing the risk of SSI [69].

Incisional NPWT

In a meta-analysis of studies comparing incisional NPWT to standard surgical closure, Semsarzadeh et al. [69] found overall SSI rate in the closed incision NPWT group to be 6.61% compared to 9.36% in the control group. Used when patients are at high risk of surgical wound dehiscence, seroma formation, or infection – diabetics, obese, and orthopedic trauma – an incisional dressing may prevent SSI or wound dehiscence by evacuating accumulated serous fluid, reducing wound dead space and keeping the incision splinted under a sterile adherent dressing [70].

Incisional NPWT has been shown to decrease wound complications in hip arthrectomies [71] and in lower extremity fractures at high risk for wound dehiscence and infection [72].

A cost analysis by Australian authors noted incisional NPWT cost-effective for preventing SSI in obese patients undergoing cesarean section [73]. Lewis et al. [74] conducted a cost analysis for laparotomy for gynecologic malignancies in high-risk, obese patients and proposed there would be a cost savings if incisional NPWT reduced wound complications by at least 33%.

NPWT dressings are placed over the sutured or stapled incision, either with a specifically made system (PREVENA®) or using standard NPWT systems with a contact layer over the skin (meshed nonadherent dressing, petroleum gauze). Device setting is recommended at 75–100 mmHg. The dressing remains in place for up to 7 days and is then removed and replaced with a dry dressing.

Instillation Therapy

Chronic or contaminated wounds may harbor high bacterial burden, negatively effecting wound healing. Although Morykwas et al. saw modest success in reducing wound bioburden using NPWT in a porcine model of infected wounds [75], conflicting results have been seen in humans. In 1998, Fleischmann suggested instilling various solutions into wounds to facilitate wound closure [76]. Goss et al. [77] studied a small cohort of 16 chronically infected lower extremity wounds treated with operating room debridement with NPWT and instilled ¼ strength Dakin's solution. They found a statistically significant reduction in absolute bioburden in the wounds treated with NPWT with instillation (NPWTi). In a retrospective historical cohort-controlled trial examining NPWT with and without instillation, Kim et al. noted a reduction in total number of operative debridements, shorter time to wound closure, and shortened length of stay in patients with infected wounds treated with NPWTi [78]. Other types of instillation fluids have been studied including saline, polyhexamine [79], superoxidized water, diluted iodine, and antibiotic solution [80]. Kim et al. randomized 100 patients with infected wounds in a prospective study comparing instillation of saline and 0.1% polyhexanide plus 0.1% betaine and found no statistical difference in the number of operating room visits, length of hospital stay, proportion of wounds closed or covered, and proportion of wounds that remained closed at 30 days of follow-up [80]. Brickert et al. prospectively studied 131 wounds treated with NPWT with saline instillation, and in 98% of the cases, the wounds could be closed after debridement and NPWTi used for 12–19 days [81]. There are no clinical studies comparing different types of instillation solutions and their efficacy on decreasing bioburden in wounds.

Instillation therapy uses a modified NPWT device to add fluid to the wound through the dressing. A separate port is employed to instill fluid directly into the wound (Fig. 12.7). The vacuum suction is shut off, and the fluid remains in the wound for a predetermined dwell time before the vacuum is resumed and the fluid is evacuated [82]. Complete debridement of all devitalized or infected tissue is still required prior to commencing treatment.

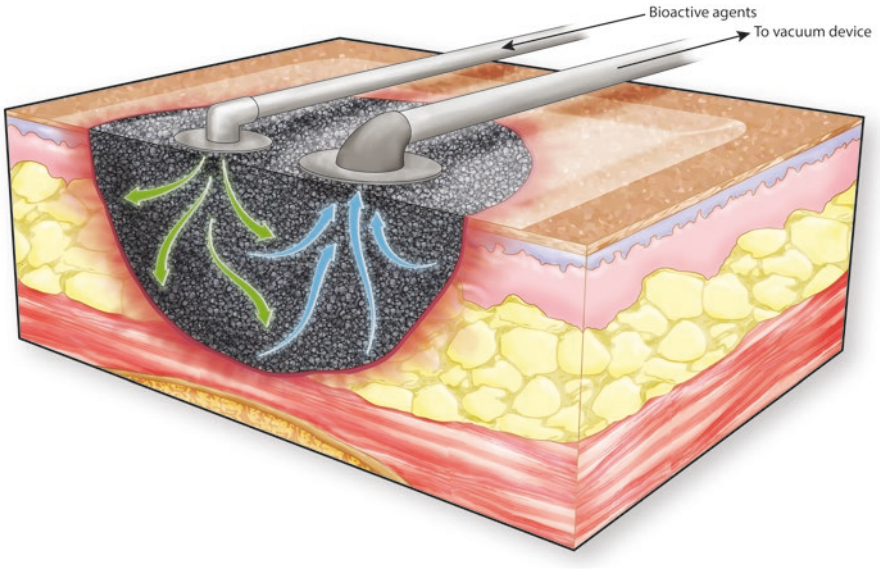

Fig. 12.7 NPWT with instillation (From Huang et al. [8]. With permission from Elsevier)

Contraindications

According to FDA guidelines [83], the use of NPWT is specifically contraindicated in patients with malignancy in the wound, untreated osteomyelitis, non-enteric, and unexplored fistulas and necrotic tissue with eschar in the wound, exposed vasculature, nerves, anastomotic sites, and organs. In addition, the FDA recommends caution in patients at high risk for bleeding and hemorrhage, especially when anticoagulated, patients with friable or infected blood vessels, sharp edges in the wound, and spinal cord injury (may induce stimulation of sympathetic nervous system). An NPWT device should be removed for MRI, hyperbaric oxygen therapy and if defibrillation is required. Care should be taken when the device is used near the vagus nerve, as it may cause bradycardia. Circumferential dressing application should be used with caution.

Risk Factors and Complications

The most common complications from NPWT include bleeding, infection, foam retention, skin irritation, and pain. The most serious complication with NPWT use is bleeding, with 12 deaths reported since 2009 [83]. Most of the bleeding complications were seen in patients who had synthetic bypass grafts with wound infection and were anticoagulated when the foam dressing would become adherent to the underlying vascular structures causing bleeding upon removal. There were 27

reports of retained foam causing worsening infections in open infected wounds and many reports of the foam attaching to the wound tissues requiring hospitalization for removal. Most complications were noted in home care and long-term care facilities. Reported complications with NPWT use in open abdominal wounds include a higher incidence of intestinal leakage and enterocutaneous fistula formation [84, 85]. Skin irritation from the adhesive drape or from the foam placed directly on the skin has been reported.

Given the commonplace use of NPWT by clinicians with varying experience in the technology, the number of complications may increase. Education about the use of NPWT, as well as careful attention to potential complications, vigilant monitoring of the device, and early recognition of adverse events, is paramount. As with any wound care therapy, if there is a complication, the wound is worsening or not progressing, NPWT should be discontinued (Fig. 12.8).

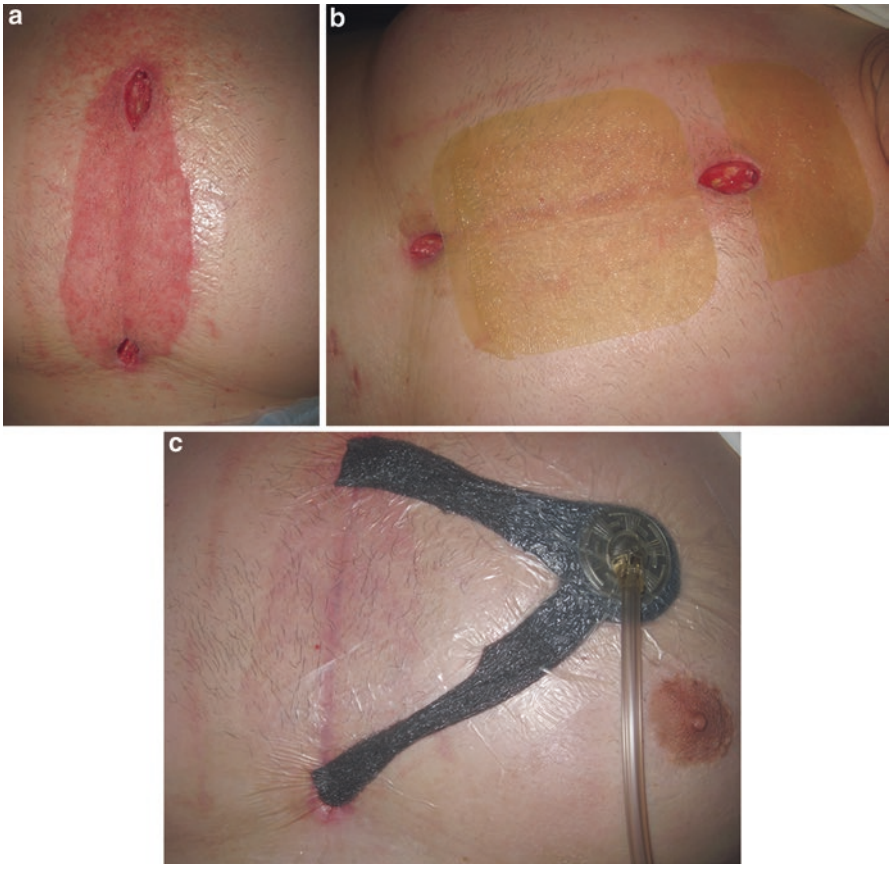

Fig. 12.8 (**a**) Sternotomy incision dehiscence with dermatitis from dressing foam placed directly on the skin. (**b**) Resolved dermatitis with thin hydrocolloid for skin protection. (**c**) Bridged foam dressing

Conclusion

In a short time period, the use of NPWT in the treatment of acute and chronic wounds has become widely accepted and has changed the landscape of wound healing despite few robust prospective randomized trials. Clinicians have experienced improved healing in a variety of wounds that otherwise would have lingered or required complex surgical closure, adding to increased patient morbidity and possibly even mortality. Researchers continue to debate the optimum interface product and level of vacuum applied, the kinetics of application and the use of instillation solutions. New, smaller devices have been developed. There does not seem to be much debate, though, that negative-pressure wound therapy holds an integral place in our wound-healing portfolio.

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