Negative Pressure Wound Therapy

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Introduction

Abdominal wall defects, whether spontaneous, traumatic or iatrogenic in origin, are a complex and heterogeneous problem and can challenge surgeons of all experience levels. One tool that that should be in the modern surgeon's armamentarium of useful adjuncts for complex abdominal wall repair is negative pressure wound therapy. Originally designed to expedite healing in chronic wounds such as diabetic foot ulcers, negative pressure wound therapy (NPWT) is a simple mechanical device that provides suction over a wound bed [1–4]. Suction is a long-established surgical practice method utilized for drainage of wounds. The advantages of formal negative pressure wound therapy devices versus simple suction are many and include the ability to tailor wound interface materials, to exchange canisters capable of removing large quantities of exudate, and the option to control both the level of suction (in millimeters of mercury) and the frequency of the suction (continuous vs. noncontinuous/intermittent). An important safety feature of all NPWT devices is the alarm system that warns the user of loss of seal, or excessive fluid output [1]. Some specially designed NPWT units are also capable of instillation of isotonic solutions that contain antibacterial or antimicrobial agents. NPWT units vary in size and some units have been developed that are portable and even disposable. All NPWT devices share a similar basic structure with the key components of each device consisting of a suction pump capable of generating negative pressure (with power supplied by either battery or electric cord), tubing, a storage canister for effluent, a sealing apparatus and wound interface material.

Mechanism of Action

There have been many speculations regarding the mechanisms of action behind NPWT and its ability to expedite wound healing. While the exact mechanism of NPWT is largely unknown, it is generally accepted that it is likely a medley of influences that contribute to the success of NPWT in healing both acute and chronic wounds.

The theories regarding the mechanism of action of NPWT can be categorized into three broad concepts: fluid-milieu, alteration or reduction of bacterial burden, and application of mechanical stress.

Wound healing is not a simple linear process but rather a complex series of exchanges among mediators and cells [2]. The environment or

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milieu in which these interactions occur can have a negative or positive effect on the wound-healing process [3]. The interstitial edema that accumulates in wounds can potentially compromise the delicate microcirculation causing deleterious effects on oxygen content delivery to the end tissues. The subatmospheric pressure exerted by NPWT units efficiently draws this excess fluid out of the wound bed thus improving the healing environment of the wound. The composition of the wound extracellular matrix is determined by a dynamic balance among overall matrix synthesis, deposition, and degradation. Wound extracellular matrix itself is a key regulator of cell adhesion, migration, proliferation, and differentiation during tissue repair [1]. NPWT can improve the extracellular wound matrix by removing negative impactors on the wound-healing milieu. These factors, which can act as local tissue toxins, include acute phase proteins, proteolytic enzymes, specific cytokines, and metalloproteinases. A recently published systematic review of the molecular bases behind NPWT mechanism of action suggests that, in contrast, promotion of wound healing occurs by modulation of cytokines to an anti-inflammatory profile, and mechanoreceptor/chemoreceptor-mediated cell signaling. These interactions then culminate in angiogenesis, extracellular matrix remodeling, and deposition of granulation tissue [4].

Another hypothesized mechanism of action of NPWT is the reduction of overall bacterial burden. Controlled animal studies have demonstrated logarithmic declines in bacterial burdens with use of NPWT, though this has not been able to be reproduced in clinical studies [5, 6]. It is thought NPWT may act to decrease the overall bacterial burden of a wound in three ways. First, the closed environment acts as a physical barrier to the encroachment of adjacent skin flora. Second, the subatmospheric pressure exerted by the unit physically moves any existing bacteria away from the wound with the interstitial effluent. Lastly, as demonstrated in animal studies by Morykwas, application of subatmospheric pressure at 125 mmHg to in vivo tissues improves blood flow levels fourfold [6]. This increase in oxygen in the local tissues not only interferes with the growth of anaerobic bacteria but also provides additional substrate for neutrophils to use for the oxidative bursts that kill bacteria.

An additional hypothesis on the mechanism of action of NPWT focuses on the biomechanical properties offered by the porous foam interface and the exerted negative pressure. There is a growing body of evidence that suggests healing tissue responds and adapts to the functional demands placed on it. These demands can be subdivided in those that exert macrostrain versus microstrain to the wound. The macrostrain theory postulates that the mechanical force from the interaction of the negative pressure with the wound interface is transmitted to the wound edges drawing them closer together [7]. In 2004, Saxena first introduced the concept that NPWT improves granulation through application of micromechanical forces or microstrain. Their tissue studies revealed that contact with the foam dressing particularly had physical effects on the tissue and noted an increase in the undulating contour of tissues corresponding to the pore geometry on the foam. The surface irregularities imposed by contact with the foam pores increased the surface area that could be subjected to negative pressure without an increase in the overall wound footprint. Specifically, the microstrain theory asserts that when more individual cells can be subjected to the application of subatmospheric pressure and the mechanical strain and deformational forces leading to cell stretch, cell proliferation and angiogenesis are stimulated leading to promotion of wound healing [8].

Foam vs. Gauze

The ability to tailor wound interface materials allows for customization of NPWT to the wound bed. By and large, there are two different dressing types that have been explored in the literature; dressing that have a gauze interface and those with a foam substrate. While studies have determined that the pressure transfer to the wound bed is similar in gauze and foam dressings, there may be particular clinical circumstances in which one product may be superior to another [9, 10]. Gauze dressings offer ease of application because they do not have to be cut and shaped to the wound bed. Some studies also report that patients experience less pain during dressing changes with gauze, which is likely related to having less tissues ingrowth with the dressing material [11]. In addition, as cost savings become an increasingly more pressing matter to our health system, gauze dressings may offer a financial advantage both in cost of materials and labor expenses. In a recent randomized trial, the daily cost of NPWT was found to be $96.51 for foam-based dressings versus $4.22 for gauze-based dressings. Likewise NPWT foam dressings were associated with increased time spent on the dressing change with the average time spent clocked at 31 min versus 19 min for the gauze group [12].

Since the inception of NPWT, foam dressings have been the more traditional wound interface material. Foam dressings are available in multiple shapes and sizes that are then cut to size to fit the wound bed during the dressing application. Several different foam contract dressings are currently employed and they are commonly known and referred to based on their color [13].

“Black” or open-cell polyurethane foam is the most traditional NPWT dressing and consists of reticulated large open pores (400–600 μm) making it particularly well suited for wounds that produce large amounts of exudate. The black foam is also hydrophobic and the large pore size allows for maximal interaction between the subatmospheric pressure provided by the NPWT and the wound bed, which results in optimizing granulation tissue formation [14].

Polyvinyl alcohol, or “white” foam, in contrast is hydrophilic and has a small, dense pore allocation (60–270 μm) making is less adherent to the wound. This composition also results in less removal of exudate and diminished ability of the NPWT to produce granulation tissue. This may be preferable in circumstances where the wound is shallow or overlying prosthetic implants or if its over/near areas that are sensitive to desiccation or pressure.

Green foam is composed of polyurethane and has an open pore structure that facilitates the monitoring of the wound bed. Green foam pore size is similar to that of black foam, but the tensile strength is superior allowing for less foam residue in the wound bed when the foam interface material is removed [15].

Silver sponges are either polyurethane or polyvinyl sponges that have been coated in silver substrate. The silver coating on the sponges has been found to decrease the odor of infected wounds likely by decreasing the wound bacterial load. Silver-coated sponges are particularly well suited for wounds where contamination is still present (Fig. 32.1). The antimicrobial ability of silver dressing is attributed to the strong oxidative activity of the silver nanoparticle (AgNP) surfaces and the release of silver ions into the biologic environment [16]. The oxidative activity and the effects of the silver ions themselves are thought to trigger a series of negative effects on the structures and functions of cells including cytotoxicity, immunological responses, and even cell death.

Subatmospheric Pressure

An additional feature of modern NPWT units is the ability to vary the level of negative atmospheric pressure that is placed over a wound bed. Animal model blood flow studies completed by Morykwas in 1996, plotted blood flow changes measured with a Doppler needle flow probe in soft-tissue and muscle against varying levels of subatmospheric pressure. The blood flow changes in both tissues demonstrated similar bell-shaped responses. The application of 125 mmHg of negative pressure produced the optimal response in the tissues with a peak blood flow of four times baseline values. Levels of pressure above 400 mmHg were found to have deleterious effects on granulation tissue formation, likely because blood flow decreased as the capillary bed blood flow was shut down when attempting to overcome perfusion pressure. Based on in vivo studies, pressure levels in the range of 75–125 mmHg are desirable for the microdeformation and strain that produces robust granulation tissue formation [17]. Clinically, the application of pressure over a wound can produce discomfort and while a pressure of 125 mmHg is generally the “default” setting from NPWT, this level may need to be adjusted lower based on patient tolerance.

Fig. 32.1 A patient with a complex abdominal wall presented for take-down of an enterocutaneous fistula (**a, b**). Following fistula take-down, the fascial defect was repaired with a large pore biologic mesh. A silver NPWT sponge was used for treatment of the contaminated soft-tissue defect because of its antimicrobial properties (**c, d**)

In addition to demonstrating the optimal pressure to induce peak blood flow, Morykwas and his colleagues also compared constant applications of pressure to intermittent pressure application. In the intermittent studies, peak increases in local blood flow declined when “off” intervals were less than 2 min. Based on these results, a 5-min-on/2-min-off cycle for intermittent NPWT was considered optimal for maximizing blood flow and granulation formation. These settings were then used in head-to-head comparisons with continuous NPWT. The mean increase in granulation tissue formation for the wounds that received the intermittently prescribed negative pressure was significantly higher than wounds subjected to continuous pressure, specifically the intermittently treated wounds demonstrated a near 100%increased rate of granulation tissue formation versus a 60%increase in the continuous pressure-treated wounds [17].

While intermittent pressure application can achieve increased rates of granulation tissue formation there are two problems that can be encountered with its use. The first is the application of pressure can produce discomfort and, in a sensitive patient, the pain would be experienced every few minutes with the cycling of the unit. In addition, in wounds that produce a large amount of effluent, the "off" period may allow fluid to accumulate and breach the adhesive barrier resulting in loss of suction.

Instillation Therapy

A more recent development in NPWT science is the development of units that have the ability for instillation. Antimicrobials or antibiotics in an isotonic fluid delivery system can be loaded into the units and then instilled over an acutely or chronically infected wound [18]. The interval and duration of the negative pressure can be controlled as well as the type of solution instilled and the solution dwell time. Several fluids that have been explored in the literature include silver nitrate, Dakin's solution, and mixed antibiotic solution [13]. An instillation fluid that has been utilized and studied specifically with use of NPWT is Prontosan (B. Brain, Inc.; Bethlehem, Pa.). Prontosan is composed of polyhexamethylene biguanide also known as Polyhexanide, which functions as a preservative that inhibits the growth of microorganisms and Betaine, a surfactant, which serves as a cleanser and provides immediate debridement [1, 19]. The positive effect of polyhexanide-containing irrigation is thought to be from reduction of bacterial load and biofilm formation. NPWT with simultaneous irrigation has been found to further reduce bioburden over NPWT-treated wounds alone. In addition, using NPWT with installation capabilities in grossly infected wounds may have the advantage of potentially reducing trips to the operating room for washouts [20].

Negative Pressure Wound Therapy and Abdominal Wall Reconstruction

Full-Thickness Abdominal Defects

Abdominal wall defects present primarily in two varieties, partial-thickness defects and full-thickness defects and the clinical applications of NPWT differs for each.

Full-thickness defects of the abdominal wall commonly occur after surgical intervention to manage a serious insult to the abdomen. Circumstances such as, abdominal trauma, peritonitis, decompression of abdominal compartment syndrome, or ruptured aneurysm repair, commonly lead to damage control laparotomies. In those circumstances, it is not only not possible to close the abdomen, but also is usually not safe to do so. In this situation, NPWT can be used as a bridge to future more definitive closure. Application of NPWT in the situation of an "open abdomen" serves several purposes, including removing exudates and decreasing bowel edema, removing wound contamination, maintaining a closed, moist environment for abdominal viscera and minimizing loss of domain. Early adaptations of NPWT utilized to contain the abdominal contents and evacuate infectious material involved the use of an inert, fenestrated plastic sheeting in contact with the viscera, towels, or laparotomy packs placed on top of the sheeting, drains hooked up to wall suction on top of the towels or packs, and an occlusive dressing to seal the wound. Modern NPWT devices for the open abdomen come ready-made with improved function and ease of use. As visceral edema and exudate are reduced by the negative pressure, the fascia is able to be more closely approximated allowing for either primary repair of the fascia, or repair with use of mesh (Fig. 32.2). Commonly, the patient is returned to the operating room every 3–5 days to perform further washout and attempt primary fascial closure or fascial closure with the use of mesh, once contamination is minimized.

Goals with management of the open abdomen are primarily twofold—reduction of mortality rate and achievement of a high fascial closure rate. A consensus document from an expert advisory panel outlining best practices for management of the open abdomen was published in 2009 [21]. Both the expert advisory committee and a systematic review from the same year deduced that use of a NPWT unit was the superior technique for temporary abdominal closure (TAC). Closure rates were found to be highest with NPWT, ranging between 78 and 93%. In addition, the incidence of fistulas compared to other techniques was likewise reduced with NPWT

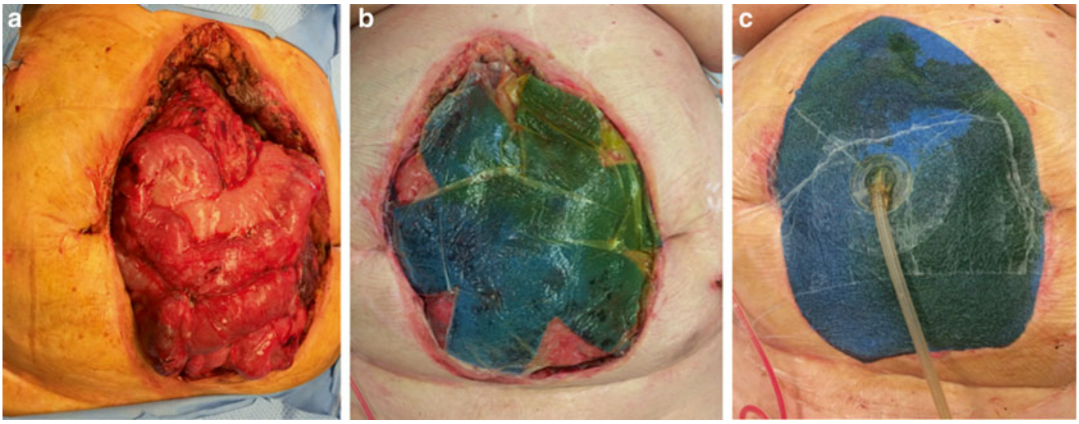

Fig. 32.2 This 67-year-old female underwent an emergent re-exploration hours after having a laparotomy with extensive lysis of adhesions, revision of her Roux-en-Y gastrojejunostomy, and duodenojejunostomy. On re-exploration she was found to have bleeding from the liver edge. Once the bleeding was addressed, the bowel wall edema was such that her abdomen was not able to be closed (**a**). She underwent placement of an ABthera device (KCI, San Antonio, TX) to decrease edema and prevent further loss of domain (**b, c**). She was returned to the OR every 3–5 days for attempts at closure

being associated with a 2.9%rate of fistula formation versus other techniques such as zipper, silo, and loose packing with resultant 5.7 to 28%occurrence of fistula formation [22].

Partial-Thickness Abdominal Defects

Partial-thickness abdominal wall defects indicate that there is some component of the native musculofascial abdominal wall or a mesh that is preventing the evisceration of the abdominal contents. In this situation, depending on the size of the defect and the situation in which it is being addressed, NPWT can serve as a primary treatment, a bridge to more definitive treatment, or as a mitigator of postsurgical complications. As a primary treatment, NPWT can be applied to an open soft-tissue wound to enhance granulation tissue formation. Once granulation of the wound is complete and the wound size has contracted, the device can be removed allowing for re-epithelialization of the wound. For particularly large defects, the NPWT can be used to temporize the defect and provide an optimal wound-healing environment, so that the wound footprint can be reduced by granulation and contraction until it is determined that coverage with a skin graft is feasible. In those cases, the NPWT device may also be used to help promote graft take. If a large defect is relatively clean, black foam can be used as the interface with the pressure set to 125 or 150 mmHg, if there is significant effluent. The continuous mode initially will aid in the evacuation of edema and promotion of blood flow. In the case of a contaminated wound bed, silver foam can be used initially in a similar fashion to help reduce bioburden until the first or second dressing change, at which time the black foam can be substituted. More frequent initial dressing changes may be necessary as well depending on the degree of wound contamination that is present. When the amount of effluent from the wound begins to stabilize or lessen, the NPWT can be prescribed in an intermittent mode as described above (5-min-on/2-min-off) in order to stimulate granulation tissue formation, provided the patient will tolerate it.

Negative Pressure Wound Therapy and Special Circumstances

Closed Incisions

Recently, the application of a short duration of NPWT on closed surgical wounds in order to prevent the morbidity of postsurgical complications has been publicized [23–25]. This technique, which was first appraised in the trauma and orthopedic literature, is aimed predominantly at reducing seroma formation, infections, and wound dehiscence. Seromas, in particular, have long been a frustrating complication following ventral hernia repair with the prevalence proven to be as high as 100%on routine ultrasound exams and 35%with clinical assessments [26]. In addition to seromas being a bothersome postoperative problem, they can also be a harbinger for more worrisome complications. Seromas can lead to wound complications because they can prevent the ingrowth of mesh, and can become seeded with bacteria either from seepage from the incision or iatrogenically from repeat fluid aspirations.

Studies across many surgical fields have all demonstrated increased surgical complications including wound infections in the obese population [24, 27, 28]. Wound infections in the obese may originate because of traction and shear forces on wounds closed with suture, thereby permitting seepage of bacteria into deeper layers of tissue. In addition, as previously described in the cardiothoracic literature, skin incisions in the obese can present specific problems from a mechanical standpoint. In the supine position, the weight of the obese tissue on either side of the incision pulls the skin edges apart, this is especially problematic in the areas of skin folds where bacterial colonization can be ample [23]. Likewise, when the obese patient is in the sitting position, any areas of skin folding are subjected to increased traction pulling the skin edges apart. If mesh has been utilized to help facilitate primary closure of the abdomen, the avoidance of bacterial colonization of the wound becomes even more imperative. A recent retrospective study suggests that incisional NPWT following abdominal wall reconstruction, in particular, significantly improves rates of wound complications (22%vs. 63%) and skin dehiscence (9%vs. 39%) when compared with conventional dressings. Regardless of the surgical technique employed, in order to prevail over the specific obstacles that the repair of complex abdominal wall defects can present, the prophylactic use of NPWT in a continuous suction mode of 125 mmHg for 7 days duration over a closed incision has been shown to improve outcomes [29] (Fig. 32.3).

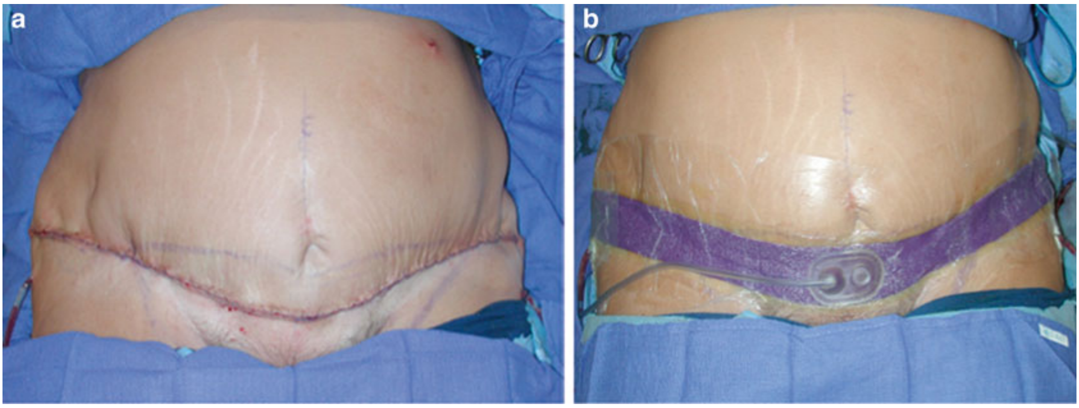

Fig. 32.3 A transverse incision was employed to repair the recurrent ventral hernia in this patient so that that a concomitant panniculectomy could also be performed (**a**). An incisional NPWT device (Prevena, KCI, San Antonio, TX) was placed over the closed surgical wound to splint the incision and prevent seroma accumulation (**b**)

Mesh Salvage

Infection is a formidable opponent of ventral hernia repair with the reported incidence of prosthetic mesh infection being as high as 8%[30, 31]. Previously, mesh that was colonized with bacteria causing infection left the surgeon with few options for definitive treatment other than the unsavory task of explanting the mesh entirely and frequently relegating the patient back to having a ventral hernia and an abdominal wall defect. As described previously, the application of subatmospheric pressure on a wound bed both increases blood flow and may decrease bacterial colonization. These biologic properties as well as the power to remove large quantities of fluid while still providing a closed, moist wound environment has gained NPWT a place in the treatment and salvage of infected large pore monofilament mesh. In 2013, a prospective study by Berrevoet et al. demonstrated effective salvage of large pore meshes composed of equal parts polypropylene and absorbable poliglecaprone 25 monofilaments with application of NPWT. In this monocentric study that spanned a 6-year period, 724 open ventral and incisional hernia repairs were performed. A total of 63 patients developed wound infections and had NPWT applied. With the exception of 4 patients who required operative debridement, all large pore monofilament meshes were able to be salvaged [31].

Incisional NPWT along with a methylene blue tracking system can be employed to salvage more focal mesh infections. On occasion, a patient who is several months to years status post ventral/incisional hernia repair will present with a complaint of chronically draining sinuses from their repair. In the operating suite, these tracts are gently probed with a blunt needle and diluted methylene blue is instilled into the tract. An incision is then performed and the methylene blue tracts can be followed through the tissue to the infectious nidus, usually knots of permanent suture. The sutures and tracts are then removed and any focal granuloma or abscess is debrided. After all the tracts have been addressed, a skin ellipse that encompasses all the sinus tracts is excised, the wound is irrigated thoroughly and closed primarily in a layered fashion. An incisional VAC is then placed over the closed incision and stays in place for a week (Fig. 32.4).

Skin Grafts for Abdominal Wall Reconstruction

Negative pressure wound therapy can be employed for two different indications in some patients with partial-thickness abdominal wall defects. The NPWT unit is first used to granulate the base of the wound bed in order to provide an optimal surface for skin grafting. A split-thickness skin graft can then be harvested and placed on the wound bed and NPWT can again be applied over the skin graft for 5 days to improve skin graft take [32]. Maintaining contact between the wound bed and a skin graft, especially if the wound surface is uneven or concave/convex as is commonly the case on the abdomen, can be especially daunting. The advantages of NPWT versus traditional bolster dressings are many and include uniform compression of the wound bed, and prevention and minimization of dead space, including the very concave areas. NPWT also drains the exudate or blood and avoids the shear phenomenon [33]. Seroma, hematoma, and shear are adversaries of skin graft take and, if these are present, plasmatic imbibition, inosculation, and revascularization will not take place and the graft will slough. Several studies have observed that with the use of negative-pressure wound therapy, the split-thickness skin graft take rate is significantly higher approaching 100%, compared with 87–89%for conventional graft bolstering [34, 35].

Complex Abdominal Wall Defect Reconstruction

A multipronged approach to the problem of abdominal wall defects is vital to achieve the goal of re-establishing continuity of the abdominal wall with one surgery. Appropriate patient selection for abdominal wall reconstruction procedures

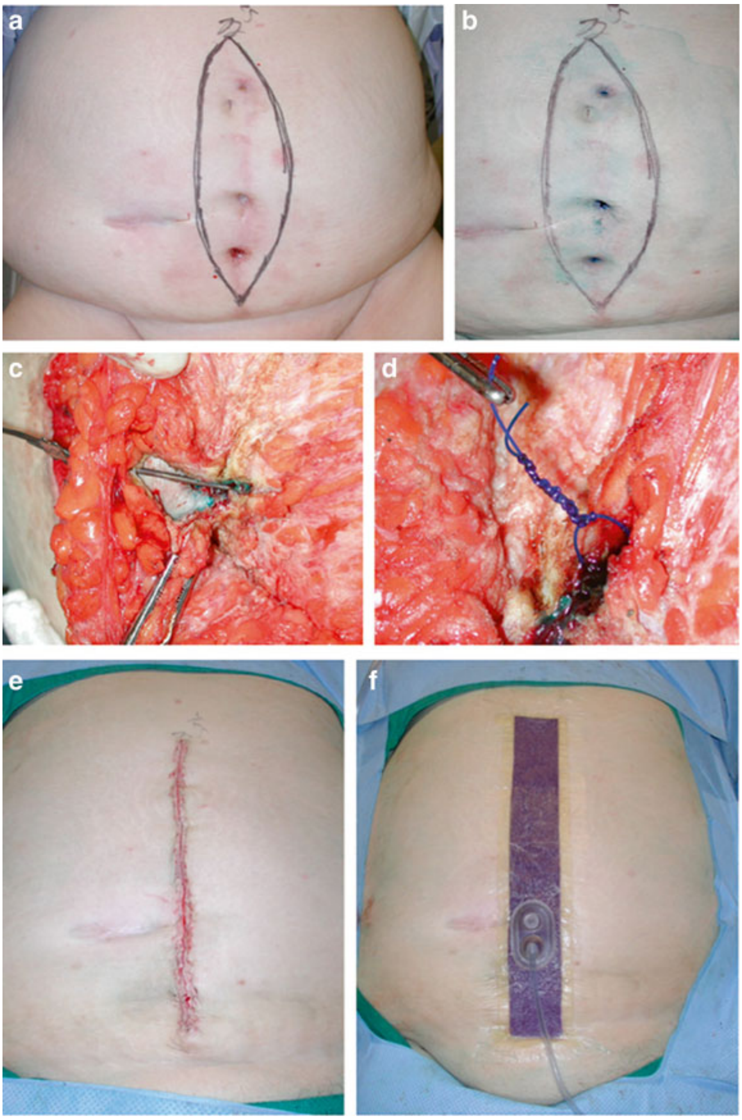

Fig. 32.4 This patient presented nearly a year after recurrent ventral hernia repair with complaints of "draining holes" in the abdomen (**a**). Each sinus tract was filled with methylene blue (**b**) and after incision; a probe was used to locate the base of the tract (**c**). Knots of polypropylene suture with associated stitch abscess were found at the base of each sinus tract. The sutures were removed, the focal abscesses debrided, and the sinus tracts were excised. The patient underwent primary closure with placement of incisional NPWT

is essential and its importance cannot be overstated. There are several patient factors that can quickly undermine even the most well-devised surgical plan if they are not addressed or controlled for. These patient factors include tobacco abuse, chronic obstructive pulmonary disease, glucose control, history of wound infection, and high body mass index (BMI) [36]. In 2010, the Ventral Hernia Working Group proposed a grading system from Grade 1 (low risk) to Grade 4 (infected) to stratify hernias based on wound classification as well as patient-risk factors for surgical site infection [37]. This grading system was recently further modified by Kanters et al. to include three grades with statistically significant differences in surgical site occurrences serving as the separation criteria for the grades [38].

A clinical algorithm for deciding which patients would be best served by NPWT is based in part on the Modified Hernia Grading system. In the high-risk abdominal wall reconstruction patients (high Grade 2 or Grade 3 with clean-contaminated wounds), who have obesity and *plus* one of more additional comorbidities, as outlined by the Modified Hernia Grading System, we have employed a novel technique, as described below, of NPWT application method following hernia repair that gives this population a “best chance” at healing by controlling the risk of dehiscence and seroma.

Prior to repair of the hernia, the abdominal contents are freed from aberrant attachments, lysis of adhesions is performed, scar and devitalized tissue is debrided and mesh is explanted if needed. As previously described by Butler, and as subsequently modified by Janis, a minimally invasive component separation is then performed [39, 40]. Repair of the native musculofascia is the gold standard in ventral hernia surgery and all surgical efforts should be geared toward this goal. As is commonly the case though, mesh is frequently employed to provide additional structure and support to the musculofascial repair as a retrorectus sublay mesh. This placement is preferred as it is associated with lower ventral hernia reoccurrence rates [41]. The minimally invasive component separation technique uses tunneled incisions for external oblique aponeurosis release and thus preserves both the connection between the subcutaneous fat and the anterior rectus sheath and the myocutaneous perforator vessels originating from the rectus abdominis. This accomplishes two goals:

1. Reduction of subcutaneous dead space thereby reducing seroma formation
2. Improved vascularity to the skin flaps

Following the minimally invasive components separation, NPWT can be incorporated into the sutured skin closure in order to mitigate the risk of dehiscence, which is almost preordained in this population (Fig. 32.5).

1. The Scarpa’s fascia is approximated in an interrupted fashion with a 2-0 absorbable suture with each suture being placed about 3 finger breadths apart.
2. Interrupted sutures or staples are placed in the deep dermis along the entire length of the incision. These are again placed about 3 fingerbreadths apart.
3. Following placement of the deep dermal sutures, the midline closure should have a “string of pearls” appearance with areas that are closed (the string) and area that are an open ellipse (pearls).
4. A piece of “extra large” black, polyurethane foam that is already pre-perforated is separated into strips, or alternatively, silver foam is cut into strips. These strips are then placed into each opening between the interrupted closures (“French fries”).
5. The foam strips are inserted into the openings in the incision, ensuring that each strip traverses the entire thickness of the abdominal flap and rests against the myofascial closure. The foam strips should protrude from the incision a few centimeters.
6. The closed sections of the incision between with foam strips are covered with a nonadherent contact layer such as Xeroform (Covidien, Mansfield, MA) or Adaptic (Johnson & Johnson, New Brunswick, NJ) to prevent desiccation.
7. A rectangular strip of black foam is then cut to size that will allow it to act as a “crossbar” and traverse the entire length of the incision over the tops of the previously placed black foam strips.
8. The occlusive dressing is then applied over the foam, allowing for a considerable area of contact with the skin. A skin adhesive can be applied to the skin to promote adhesion. The suction tubing is applied to the dressing and the suction device is set to a continuous suction mode at 125 mmHg.

The negative atmospheric pressure distributed within the closed wound environment allows for removal of exudate from the thick abdominal flaps. The blacks foam “French fries” also eliminate any potential dead space within the abdominal flap closure thus preemptively thwarting seroma formation. In addition, the uniform negative pressure essentially holds the tissues in gentle static compression thus offering a significant reduction in mechanical tractive forces and shearing forces between the skin flaps. Placing a negative pressure wound dressing on clean skin

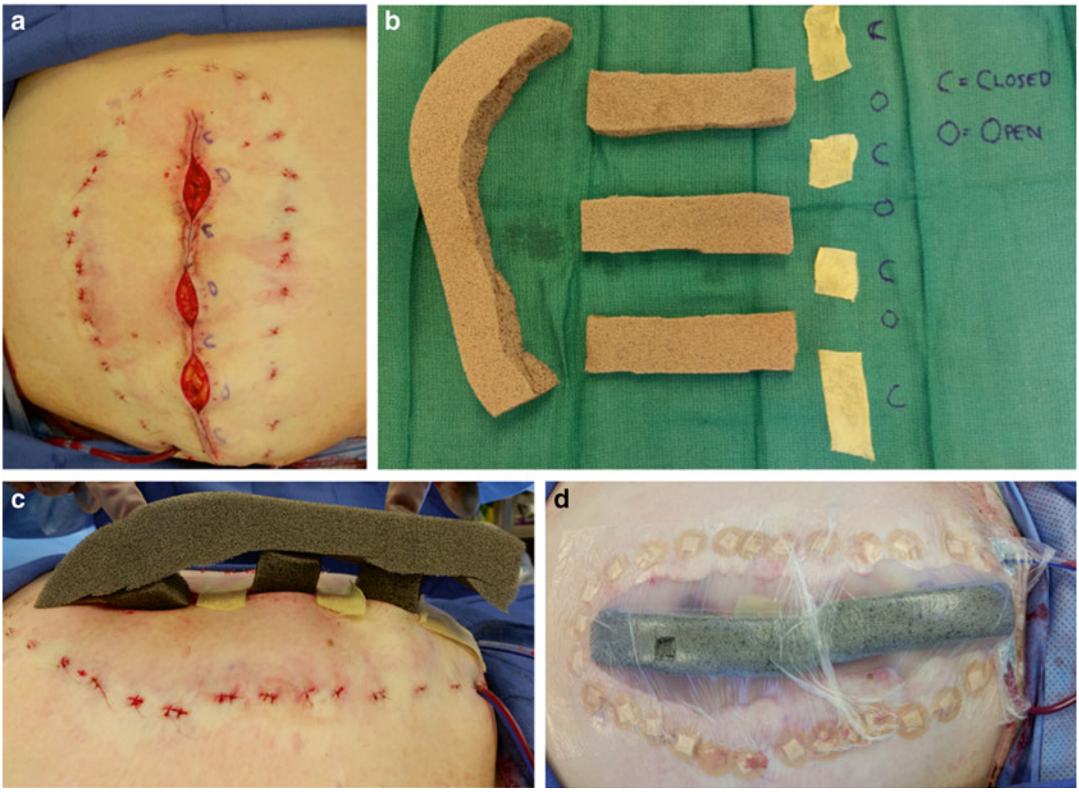

Fig. 32.5 This high-risk obese patient with a recurrent ventral hernia had removal of an old mesh and placement of a new widely placed retrorectus mesh (**a**). Foam strips and occlusive dressings were laid out in a template fashion with "C" representing the closed areas of the incisions and "O" representing the open areas (**b**). The NPWT was then incorporated into the closure (**c**) and the sealing apparatus applied (**d**)

immediately after suturing also provides a closed environment that discourages the seepage of encroaching skin flora as the suction provides a one way egress from the incision. In essence, this "French fry, string of pearls" technique is a combination of open NPWT to reduce fluid build-up, improve local blood flow, and apply macro- and microstrain advantages combined with the benefits of incisional NPWT along the intermittent areas of primary closure.

The final group of hernia patients are those with either open abdomens or enterocutaneous fistula (Grade 3). These patients are commonly treated with a two-step approach with the affected bowel addressed first and NPWT utilized as a bridge to address contamination and infection and decrease bowel edema, if abdomen is left open. In those with open abdomens, reoperation with washout and attempted definitive abdominal repair should be staged at 3–5-day intervals after the initial surgery with intra-abdominal NPWT applied between closure attempts.

Conclusion

NPWT is an easy-to-use versatile treatment with a broad range of clinical indications. Understanding the use and application of variables such as wound interface material, level of subatmospheric applied, mode of pressure application, and use of instillation allows the practitioner to prescribe NPWT that is customized to the patient's specific needs.

While NPWT is not a panacea for defects of the abdominal wall, its ability to expedite wound healing, improve skin graft take, salvage mesh infections, and mitigate surgical complications such as wound infections and dehiscence makes NPWT a valuable implement for the modern surgeon.

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