Current Concepts in Negative Pressure Wound Therapy

Lisa M. Howe, DVM, PhD

KEYWORDS
- Negative pressure wound therapy (NPWT) • Vacuum-assisted closure (VAC) • Dogs • Cats • Wound care • Wounds

KEY POINTS
- Negative pressure wound therapy (NPWT) has been effective in the treatment of a wide range of complex wounds in human medicine, and its use in veterinary medicine is expanding.
- Patients treated with NPWT achieve wound closure quicker than patients treated with other traditional modalities.
- NPWT has been demonstrated to improve skin graft “take” compared with traditionally used bandaging techniques.
- Numerous mechanisms work together with NPWT to increase blood perfusion, speed up granulation tissue formation, and hasten wound contraction.
- As the number and variety of NPWT devices and materials increase, it is important to understand the different modes and components of NPWT devices and how to select materials appropriately based on the selected mode of operation.

INTRODUCTION
Management of traumatic and surgical wounds is a frequent event in small animal veterinary practice. Dogs and cats possess an uncanny ability to suffer injury in the most inconceivable ways, and these injuries, as well as more common injuries, often require wound care for several days before the wound environment is suitable for closure. In addition, surgical wound infections occur and require wound care until the infection has cleared and closure, when needed, is appropriate.

Veterinarians regularly search for materials and methods of wound management that improve wound environment, speed up wound healing, provide comfort for the
patient during healing, and minimize the frequency of sedation or anesthesia for
wound care and bandage changes. Practitioners also look for wound healing stra-
tegies that are inexpensive for their clients and minimally labor intensive for themselves
and their technical staff.

One wound healing strategy that addresses many of these concerns is NPWT, also
referred to as vacuum-assisted closure (VAC) or topical negative (wound) therapy or
pressure. NPWT has been used extensively in human medicine as an advanced
wound healing strategy for more than a decade, and veterinarians are using the tech-
nique as well. NPWT is reported to enhance wound environment to the degree that
granulation tissue forms more quickly and wounds heal in shorter times than with
traditional or wet-to-dry bandaging.

This article discusses the theory and mechanism of action of NPWT, describes the
indications (and contraindications) for NPWT, describes the technique for application
of the NPWT bandage and device, discusses the advantages and disadvantages of
NPWT, and explores some of the new techniques and future directions of NPWT in hu-
man medicine that may prove useful for the veterinary patient.

ORIGIN AND DESCRIPTION OF NEGATIVE PRESSURE WOUND THERAPY

Origins of the use of medical vacuum dates back thousands of years, but the use of
medical vacuum in modern times dates back only about 20 years. Ancient people
used animal horns, bamboo canes, and other items to create a vacuum using their
mouths and then seal the hole with a plug of wax or other material held in their mouths
to maintain the vacuum.1 Numerous modifications of these devices were developed
and used through the early 1900s.2–4 These devices were thought to result in venous
hyperemia for treatment of suppurative inflammatory diseases. However, many of
these vacuum devices fell into disfavor until about the end of the twentieth century.

NPWT began to come into widespread use in human medicine in 1997 after the pub-
lication of 2 articles describing VAC.5,6 Since then, the use of NPWT has become
commonplace in human hospital settings. The use of NPWT has become more wide-
spread in veterinary medicine in recent years, although the scientific literature in vet-
erinary species is sparse. There are several reports describing the use of NPWT in
individual cats,7,8 horses,9 and dogs,10 as well as a few exotic animal species.11–13
There are also a case series14 and controlled experimental studies.15,16

NPWT involves the use of a vacuum, or suction, applied to an open wound that has
been covered with porous foam that is then covered by an adherent, occlusive sheet
of plastic bandage material to achieve an airtight seal. Controlled negative (subatmo-
spheric) pressure is applied to the wound, pulling exudates and effusions through the
foam and into a reservoir and bathing the wound in tissue fluids from inside to outside
to provide a healthy wound environment without maceration.

PROPOSED MECHANISMS OF ACTION OF NEGATIVE PRESSURE WOUND THERAPY

Numerous mechanisms of action have been proposed for the clinical benefits seen
with NPWT, many of which work together to improve the wound environment and opti-
mize the healing process (Box 1).

Several studies have demonstrated increased perfusion to wounded tissue during
NPWT 5,17–20. In the landmark study by Morykwas and colleagues,5 blood flow to the
wounds (as measured by Doppler ultrasonography) increased 4-fold when
125 mm Hg negative pressure was applied to the wounds and survival of random
pattern flaps increased by 21% compared with controls. Other studies have shown
similar results.17–20 In addition to the effect of the actual negative pressure on blood
flow, other mechanisms may be at work. Nitric oxide (NO) has been demonstrated to play a role in the circulatory change seen in wounds treated with NPWT. In the NO study, an NO synthase inhibitor (N\textsuperscript{\textalpha}-nitro-L-arginine methyl ester [L-NAME]) was administered and the inhibitor almost completely blocked the effect of NPWT in increasing the wound bed blood flow. It has also been found that the vascular response seen with NPWT is related to the physical presence of polyurethane foam. In that study, wounds exposed to uncompressed and compressed foam (without NPWT), or to standard NPWT, showed a 2-fold increase in vascularity compared with the occlusive dressing (no foam) with NPWT.

Good blood perfusion to a wound is needed to deliver oxygen and nutrients, as well as cells and growth factors, to the injured tissue. In addition, with increased perfusion there is increased delivery of antimicrobials to the wound in a patient receiving systemic antimicrobials. Increased blood perfusion also benefits a wound by removing free radicals, carbon dioxide, and waste products.

The blood flow in different areas of the wound is such that some areas of the wound are hyperperfused and some areas are hypoperfused; this is thought to be due to differing forces acting on the tissues in the superficial and deep portions of the wound (Fig. 1). Macropdeformations are those tissue deformations that result from the centripetal pulling of the wound edges caused by the NPWT. Effects of these macrodeformations differ depending on tissue depth of the wound. The superficial portion of the wound is subjected to compressive forces, which results in hypoperfusion. Deep portions of the wound are subjected to traction forces. This traction results in widening of the blood vessels leading to hyperperfusion. The superficial hypoperfusion and hypoxia results in a vascular endothelial growth factor gradient that promotes sprouting angiogenesis. The deep hyperperfusion increases nutrient and oxygen delivery. Hyperperfusion has also been documented at distances of 2.5 cm from the wound edges.

Microdeformations are caused by the interaction between the foam and the surface of the wound in contact with the foam. Microdeformations have also been demonstrated to be important factors in the efficacy of NPWT in cellular proliferation and increased granulation tissue production through the action of NPWT on myofibroblasts. Mechanical stress on the tissues by NPWT seems to activate transforming growth factor 1, which is critical for the vacuum-induced myofibroblast differentiation. In addition, myofibroblasts are important in vessel translocation (looping angiogenesis), which results in the neovascularization seen during wound healing and wound contraction.
Fig. 1. Mechanisms of action of NPWT, including macrodeformations (*middle portion of figure*) and microdeformations (*bottom of figure*). Macrodeformations are tissue deformations caused by the centripetal forces pulling the wound margins. Microdeformations are tissue deformations caused by foam and wound dressing interactions. ECM, extracellular matrix; VEGF, vascular endothelial growth factor. (*From* Daigle P, Despatis MA, Grenier G. How mechanical deformations contribute to the effectiveness of negative-pressure wound therapy. Wound Repair Regen 2013;21:499; with permission.*)
Reduced bacterial burden in the wound has been proposed as a mechanism that leads to improved wound healing with NPWT, a point advertised to do such by some manufacturers of NPWT supplies. However, results on this issue have been mixed.28–34 An early report found a reduction in bacterial loads with NPWT usage in pig wounds inoculated with *Staphylococcus epidermidis* and *Staphylococcus aureus*.5 Other clinical studies have not documented a decrease in wound bacterial loads,28,31,32 and some have shown an increase.33,34 Additional research is needed to determine the effects of NPWT on bacterial burden in the wound itself (rather than on the foam or gauze used as packing material in the wound). Regardless of whether bioburden is decreased, wound healing with NPWT seems to progress extremely quickly. It seems reasonable to speculate that wound bioburden is affected by wound fluid removal from infected wounds. Gauze impregnated with polyhexamethylene biguanide reduces bacterial load in wounds.35 Other pathogen-binding materials would also be expected to have similar results.

NPWT results in active drainage of wound exudates and, as such, is an effective tool for decreasing edema.6,24,26,36,37 The removal of excess interstitial fluid results in decreased interstitial pressure and decrease in edema.5,27,36 The effectiveness of fluid removal depends on direct contact between the wound bed and the filler material, the negative pressure applied to the wound, and the type of material used as a filler. Fluid removal from the wound was more effective with foam and pathogen-binding mesh than with gauze at pressures of −80 and −120 mm Hg.25 Perhaps healing would be somewhat slower in wounds in which there is less effective fluid removal and nonantimicrobial gauze is used.

Fluid removal with NPWT is also beneficial because it alters the fluid composition in the wound.38–41 Fluid removal decreases the levels of cytokines, metalloproteinases, plasmin, thrombin, elastase, and other proteolytic enzymes, which negatively affect wound healing.15,24 This change in fluid composition has been demonstrated in several studies examining the effects of NPWT on levels of metalloproteinases and cytokines.42–44 Removal of these proinflammatory cytokines and proteases improves wound healing.6,43–45

**INDICATIONS/CONTRAINDICATIONS**

There are numerous indications for NPWT in veterinary medicine (Box 2). The primary indication includes wounds of all types and configurations.5–9,15,45 NPWT is also used with skin grafts and flaps and is reported to result in improved graft take (the author’s anecdotal experience supports this observation).14,16 Other indications in human medicine that are used rarely in veterinary medicine thus far include NPWT for open abdomen management,46–51 closed incisional management,52–54 and installation NPWT (see later discussion).55–59 These techniques may become more commonplace in veterinary medicine in the future.

Some contraindications for NPWT should be kept in mind when selecting patients for this treatment modality (see Box 2). NPWT should not be used in the presence of any local malignancy, because it is reported to have led to tumor recurrence in a human and could potentially lead to spread of the tumor throughout the wound bed.60 Untreated osteomyelitis is also considered a contraindication for NPWT, as bone fragments could dislodge and puncture the plastic sheet and result in loss of suction or tissue damage if sharp edges are present.26 Such cases should be thoroughly surgically debrided of all necrotic and nonviable tissue before the initiation of NPWT.26 Necrotic bone fragments in cases of osteomyelitis can become covered with granulation tissue and lead to sequestration.7 NPWT should not be used over exposed vessels,
tendons, ligaments, and nerves because damage could occur and severe hemorrhage could result if NPWT is placed over arteries or veins.\textsuperscript{26} Unprotected organs or anastomotic sites are also contraindications for use of NPWT, unless they can be well covered by a nonadherent polyethylene sheet or other suitable nonadherent material placed over viscera to protect from subatmospheric pressure before initiation of NPWT.\textsuperscript{26}

NPWT should not be used in patients with bleeding and coagulation disorders (or those receiving anticoagulants) or in patients in which unsutured hemostatic agents have been placed in a wound because the agents could dislodge and result in severe hemorrhage. The presence of an eschar over necrotic tissue is a contraindication until the eschar and necrotic tissue are completely removed.\textsuperscript{26} The use of NPWT is also contraindicated in unexplored fistulae or wounds that could have unseen connections with the chest or abdomen.

**Box 2**  
Indications and contraindications of NPWT

<table>
<thead>
<tr>
<th>Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute traumatic wounds</td>
</tr>
<tr>
<td>Chronic wounds</td>
</tr>
<tr>
<td>Dehisced wounds</td>
</tr>
<tr>
<td>Burns</td>
</tr>
<tr>
<td>Ulcers</td>
</tr>
<tr>
<td>Skin grafts</td>
</tr>
<tr>
<td>Skin flaps</td>
</tr>
<tr>
<td>Closed surgical wounds</td>
</tr>
<tr>
<td>Open abdomens</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contraindications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remaining tumor in a wound bed</td>
</tr>
<tr>
<td>Undebrided osteomyelitis</td>
</tr>
<tr>
<td>Exposed vessels, nerves, tendons, or ligaments</td>
</tr>
<tr>
<td>Patients with bleeding or coagulation disorders</td>
</tr>
<tr>
<td>Patients receiving anticoagulants that cannot be carefully monitored</td>
</tr>
<tr>
<td>Active bleeding or over unsutured hemostatic agents</td>
</tr>
<tr>
<td>Unprotected organs or anastomotic sites</td>
</tr>
<tr>
<td>Eschar over necrotic tissue unless removed</td>
</tr>
<tr>
<td>Unexplored fistulae</td>
</tr>
<tr>
<td>Unexplored wounds that could connect with the chest or abdomen</td>
</tr>
</tbody>
</table>

**SELECTION OF MATERIALS**

There are several companies offering NPWT equipment and supplies. These companies often have prepackaged kits that contain all the supplies needed for an individual patient, which is a great convenience. The selection of these kits often depends on the type of NPWT therapy being used (Fig. 2). Vacuum may be applied with or without
Fig. 2. Selection of NPWT therapy and materials based on tissue application, environment, and desired action on tissue. AMGA, antimicrobial gauze; EST, ester; NPWTi, installation NPWT; PU, polyurethane; PVA, polyvinyl alcohol; SLVPU, silver-impregnated polyurethane.
installation of fluids into the wound. If the wound is both to be lavaged and to receive NPWT (NPWT instill [NPWTi]), then different kits containing different configurations of vacuum pads and foam type should be selected. Although veterinary usage of NPWTi has not been reported, it has been reported to have advantages for certain human wounds. Vacuum pumps that have both standard NPWT and NPWTi functions in the same machine (V.A.C. Ulta Negative Pressure Wound Therapy System, KCI, Inc, San Antonio, TX, USA) are available.

Installation therapy has been recommended for contaminated and infected wounds that could benefit from lavage therapy coupled with NPWT. With installation therapy, topical solutions (eg, antiseptics, cleansers, and antimicrobials) can be instilled directly to the wound bed in a controlled fashion. Such therapy has been shown to improve granulation tissue production. Installation NPWT has also been shown to have possible benefit in noncontaminated wounds.

With NPWTi, retrograde installation of topical solutions occurs into the sealed wound bed using an additional tubing system while the vacuum pump is paused, causing the foam to become soaked. The wound is soaked for a user-selected period. During the soak time, the topical solution is in contact with the foam and wound surface. Once the soak time is completed, negative pressure resumes and the remaining fluid is removed from the foam.

NPWT can also have differing suction modes that are user selected on some vacuum pumps (see Fig. 2). Two modes are available, continuous and intermittent. With continuous suction, the clinician-set pressure is constant during therapy as long as the vacuum pump remains on (and the airtight seal is intact). This suction mode is most commonly used in veterinary medicine, and it is the mode used in the author’s hospital. One type of noncontinuous pressure is intermittent NPWT, in which a set negative pressure is alternated with no pressure for programmed periods. The second type of noncontinuous NPWT is dynamic, or variable, NPWT. With dynamic NPWT, negative pressure transitions between high and low pressures follow programmed increase and decrease times. Some studies suggest improved granulation tissue production with both intermittent and dynamic NPWT compared with that observed with continuous NPWT, although one study did not. Intermittent suction causes more pain than continuous suction in human patients, especially with higher pressures.

Different types of foam may also be selected. The commonly used foam types include polyurethane (PU) foam (black foam; can be PU ether or ester), polyvinylalcohol foam (white foam), antimicrobial-impregnated gauze or mesh, and silver-impregnated black foam (see Fig. 2). At the author’s institution, before kits were readily available, sterilized thick black speaker foam, red rubber catheters, appropriate connectors and canisters, and wall or portable suction units for NPWT were used. This setup resulted in subjectively greatly improved granulation tissue production compared with standard wet-to-dry bandages with far fewer bandage changes. It was subjectively more cumbersome to place and maintain NPWT compared with the kits that are currently used. In addition, accuracy of suction pressure selected was not as precise with the homemade device.

Black foam (V.A.C. GranuFoam Dressing, KCI, Inc) is probably used most frequently in veterinary wounds, and it is indicated for most veterinary applications in small animals (see Fig. 2). Both ether and ester forms of black foam have similarly sized reticulated open cells (400–600 μm); however, the ether form is slightly more hydrophobic. Because of this, the ether form (V.A.C. GranuFoam Dressing) is recommended for use with standard NPWT, whereas the ester form (V.A.C. VeraFlo Dressing, KCI, Inc) is recommended for installation therapy. White foam (V.A.C. GranuFoam
WhiteFoam Dressing, KCI, Inc) has much smaller open cells that stimulate less granulation tissue; therefore, this foam should probably not be selected for use with deep wounds that need heavy granulation tissue formation to fill a cavity.\textsuperscript{6,69}

Antimicrobial-impregnated medical gauze sponge (Kerlix AMD, Covidien, Mansfield, MA, USA) has been used frequently in human medicine, but its use in veterinary medicine has not been reported.\textsuperscript{17,67,69–72} It seems to be particularly useful because of its ease of application and moldability. More fluid is retained in the wound with gauze than with foam or antimicrobial-impregnated mesh, despite the fact that pressure transduction within the wound is similar to that for foam or mesh.\textsuperscript{25,38} Wound contraction is less than that seen with foam.\textsuperscript{25,69,73,74}

Antimicrobial-impregnated mesh (Cutimed Sorbact, BSN Medical, Inc, Charlotte, NC, USA) has been used for prevention and treatment of acute traumatic, postsurgical, and hard-to-heal wounds and burns.\textsuperscript{25} It has been used with NPWT and was found to provide similar pressure transduction throughout the wound as black foam and antimicrobial gauze, but wound contraction for antimicrobial mesh was less than that of foam.\textsuperscript{25} Silver-impregnated black foam (V.A.C. GranuFoam Silver Dressing, KCI, Inc) contains elemental silver (10%) as a sustained release formulation, and its use in infected wounds as an adjunct to standard treatment regimens is suggested.\textsuperscript{45,69,75–78} It cannot be used with installation therapy because any topical agent or solution may have an adverse reaction with silver and compromise the effectiveness of the dressing.\textsuperscript{45}

**TECHNIQUE/PROCEDURE**

The technique of placement and use of NPWT involves several consistent steps regardless of wound location (Fig. 3). The steps include wound preparation, application of foam or other wound filler and dressing, application of vacuum pad device, attachment of the NPWT unit, and close monitoring of the NPWT for loss of suction or other problems.

Complete wound preparation and exploration should occur before beginning NPWT. The presence of wound debris or necrotic tissue adversely affects NPWT wound healing. As noted earlier, if an eschar is present, it must be removed along with any necrotic tissue present under the eschar.

When the foam (or other wound filler material) is placed, one must completely fill the wound cavity to ensure that the vacuum over the wound surface works optimally. To prevent inadvertent foreign body retention, the number of pieces of foam placed in the wound should be counted and recorded in the medical record. It is important to be careful that the filler material does not overlap the skin edge as maceration and skin damage may occur.

A Tegaderm dressing (Tegaderm Film, 3M, 3M Center, St Paul, MN, USA), or other self-adhering occlusive plastic sheeting, is applied over the foam and secured to the skin. Although the instructions supplied with the kit recommend that the Tegaderm overlap the skin edges by 3 to 5 cm, the author prefers to overlap the skin edges by at least 4 to 6 cm, if the location of the wound allows. It is preferable to have as few wrinkles in the Tegaderm as possible during the application process, and the Tegaderm must be securely affixed to the skin. If a single large Tegaderm is too difficult to apply, it may be cut into smaller pieces and applied to the wound, being certain to overlap sufficiently the previously placed section of Tegaderm.

When cutting the hole in the Tegaderm dressing to permit placement of the self-adhering vacuum pad, the hole should not be cut too small such that it impedes the vacuum pull. Likewise, the vacuum pad through which suction is pulled must not
overlap the skin edges, as this potentially affects the vacuum pressure on the wound and also results in tissue damage to the skin. Although not recommended by the manufacturer, the author routinely applies a small piece of Tegaderm over the top of the vacuum pad (that is affixed to the foam) and tubing so the pad cannot inadvertently become dislodged and separated from the foam.

After all tubing has been correctly attached and clamps opened, the unit is ready to start. The mode of operation (continuous, intermittent, dynamic, or installation) must be set along with the appropriate vacuum pressure. Pressures typically have been set at $-125$ mm Hg for most utilizations and $-75$ to $-80$ mm Hg for use with skin grafts. Studies from the literature suggest, however, that pressures of $-75$ to $-100$ mm Hg

---

**Fig. 3.** Steps involved in NPWT application. The first 3 arrows and associated text boxes represent the steps of wound preparation and foam and dressing application, whereas the second set of 3 arrows and associated text boxes represent the portion of the procedure related to the application of the suction pads and devices.
may be more appropriate for optimal wound healing.\textsuperscript{20,64,79} After the machine variables have been set, the vacuum unit is started. The foam and top dressing must be observed to ensure that the foam contracts down and that there are no leaks in the NPWT system. Once it has been ascertained that there are no leaks, monitoring of the system should begin.

**CARE AND MONITORING OF NEGATIVE PRESSURE WOUND THERAPY**

Appropriate care and monitoring of the NPWT is extremely important in achieving a positive effect on wound healing rate and quality (see Fig. 3). Check the system frequently for any evidence of suction loss. Ideally, the system should be monitored at least every 2 hours, because it is recommended that the foam and dressing be changed and the wound be flushed after 2 hours of suction loss. Additional dressing changes would result in increased labor and costs. Should suction loss occur, examine the system to determine the location of suction loss, correct the cause of suction loss (if <2 hours), and restart the unit. Many vacuum pumps have seal check leak detectors with audio alarms that signal if a leak is detected. Such a feature can be of great assistance in a busy practice.

The character and volume of the fluid being suctioned from the wound need to be monitored to determine the effectiveness of NPWT in controlling infection and to determine that drainage volume is declining. The canister also needs to be emptied or changed as it approaches its maximum capacity and the volume recorded.

Dressings may be left in place for up to 3 days before changing, although the author often performs dressing changes after 48 hours.\textsuperscript{15,16} Changing the bandage at 48-hour intervals helps avoid granulation tissue growth into the sponge, as well as allows more frequent checking of the wound bed. The wound can be assessed at each bandage change, paying particular attention to the health and amount of granulation tissue. The degree of contraction should be assessed and recorded. Once a healthy bed of granulation tissue has formed, NPWT should be discontinued and closure or reconstruction performed.

The patient should also be intermittently monitored to ensure protein levels and hydration status are maintained, particularly with large heavily exuding wounds or open abdomens, although this seems to be a rare problem in humans.\textsuperscript{6} During bandage changes of large wounds, sedation may be needed. The patient’s pain score should be monitored frequently and appropriate analgesia administered. Devices (eg, e-collars, side braces) to prevent the patient from disturbing the NPWT should be placed.

**COMPLICATIONS**

Complications may occur with NPWT; however, most are preventable through attention to detail and vigilant monitoring (Box 3).\textsuperscript{45,80} Loss of suction is probably one of the most common problems associated with NPWT. Vigilant monitoring and inspection of the bandage and tubing help prevent this problem, as does protection of materials from the patient.

If vessels are not covered with tissue, the suction can cause erosion of the vessels and result in significant hemorrhage.\textsuperscript{6,45} If this occurs, the NPWT must be stopped immediately, hemorrhage controlled, and vessels covered before reimplementing NPWT or switching to a different bandaging system.

As previously noted, the presence of devitalized bone in a patient with fracture or osteomyelitis undergoing NPWT can result in coverage of the devitalized bone by granulation tissue and subsequent sequestration.\textsuperscript{6,45} This situation has been reported
in the human literature, but it illustrates the importance of careful debridement of necrotic tissue and devitalized bone in veterinary osteomyelitic patients before implementing NPWT.

Less frequent complications reported in the human literature include nonresponse to NPWT, skin erosion, and skin maceration. Rarely patients have been found to be unresponsive to NPWT, but insufficient wound debridement or failure to maintain NPWT for a sufficient length of time may have contributed to some of the reports. Erosion of the skin from the vacuum tubing passing over the skin has been reported. This report cites patients lying on their tubes, an event possible in nonambulatory veterinary patients. There exist sporadic reports of maceration of skin adjacent to the wound if foam or other cavity filler material overlap the skin edge, so care should be used in veterinary patients to avoid this. Enteric fistulae have been reported in humans undergoing open-abdomen NPWT.

Pain is commonly identified as a complication of NPWT in human patients, and in some patients pain is so severe that it results in discontinuation of the therapy. Pain occurs most frequently when the vacuum unit is turned on and begins to pull a vacuum and typically subsides by 20 to 30 minutes. Because typically veterinary patients receiving NPWT are heavily sedated during bandage placement and initiation of suction, the only time that the author has observed unsedated patients having vacuum restarted is after suction is lost. Overt discomfort or pain was not observed, but such patients are treated with analgesics. If there is ingrowth of granulation tissue into the sponge, dogs act painful as the sponge is being removed. Patient pain should be well controlled not only as part of a good patient care protocol but also to avoid stress in the patient.

ADVANTAGES AND DISADVANTAGES OF NEGATIVE PRESSURE WOUND THERAPY

Advantages and disadvantages of NPWT (Box 4) likely vary depending on the differing types of veterinary practices. Some practices are well suited for NPWT and can readily add this technology to wound management treatment options, whereas in other practices disadvantages may outweigh advantages. NPWT should probably not be used in practices that have no overnight monitoring of patients or a nearby 24-hour emergency clinic for overnight monitoring.

For practices that can provide NPWT, the therapeutic benefits outweigh the disadvantages. Those advantages include increased rate of healing, decreased labor (assuming suction loss can be avoided), and likely decreased client expense. The

---

**Box 3**

Complications that may occur in small animal patients undergoing NPWT

- Loss of suction
- Erosion of vessels
- Dislodging of hemostatic agents
- Granulation tissue coverage of devitalized tissue; bony sequester
- Lack of response to therapy
- Pain
- Enteric fistula*

*Complication has not been reported in veterinary medicine but has potential to occur as more laparostomy NPWT is used.
primary disadvantage of NPWT is the initial equipment expense and the learning curve (albeit steep) associated with NPWT.

**OUTCOMES**

In both anecdotal reports and the scientific literature, it is evident that NPWT offers great benefit for the patient in terms of speed of wound healing, such as the speed and improvement in vascularity, decreased edema, increased rate of granulation tissue formation, increased rate of wound contraction, potential decrease in bioburden, decreased bandage size and thickness (in most patients) that encourage early mobility, and potential shortened hospitalization.

**FUTURE CONSIDERATIONS**

In addition to installation NPWT, there are several interesting developments in the human medical field that likely have applicability to veterinary patients. Laparostomy NPWT, or open-abdomen NPWT, has been used successfully in human patients with septic peritonitis and has also been reported in veterinary medicine.\textsuperscript{46,47,49,50,84,85} With laparostomy NPWT in humans, a special foam for abdominal usage (ABThera Open Abdomen Negative Pressure Therapy, KCI, Inc) is attached to visceral protective sheeting and inserted into the abdomen, making certain that the foam fingers are slid along the sides of the inner abdominal walls and rest deeply into the dorsal recesses of the abdominal cavity. The special usage foam is covered with a Tegaderm sheet and attached to the vacuum unit in a standard manner. In dogs and cats, homemade devices have been used to drain the abdomen. The caudal aspect of the abdomen is closed, whereas the cranial half is loosely closed, leaving a gap between the edges of the body wall, subcutaneous tissue, and skin. The foam is laid external to the loose body wall closure, a red-rubber catheter is inserted into the middle of the foam and attached to the suction canister, and the foam is covered using a Tegaderm dressing. In some instances, additional bandaging materials were placed over the Tegaderm

<table>
<thead>
<tr>
<th>Box 4</th>
<th>Advantages and disadvantages of NPWT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td></td>
</tr>
<tr>
<td>• Improved wound healing</td>
<td></td>
</tr>
<tr>
<td>• Early mobility</td>
<td></td>
</tr>
<tr>
<td>• Possible earlier release from the hospital</td>
<td></td>
</tr>
<tr>
<td>• Decreased labor</td>
<td></td>
</tr>
<tr>
<td>• Possible cost savings to the client</td>
<td></td>
</tr>
<tr>
<td>• Sets practice apart</td>
<td></td>
</tr>
<tr>
<td>• Easy to learn technique</td>
<td></td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td></td>
</tr>
<tr>
<td>• Some practices may not be well suited for NPWT</td>
<td></td>
</tr>
<tr>
<td>• Initial equipment costs</td>
<td></td>
</tr>
<tr>
<td>• Increased inventory</td>
<td></td>
</tr>
<tr>
<td>• Must learn new technique</td>
<td></td>
</tr>
</tbody>
</table>
dressing. Mortality rates reported in the veterinary literature were approximately 50% using this technique. This mortality rate is similar or higher than most of those reported for open abdominal drainage (33%–48%) or closed suction drains (30%) in dogs and cats.86–90

NPWT has become useful in human medicine for closed surgical incisions.53,54,91–93 Patients selected for this therapy are typically orthopedic (fractures or total joint replacements) or sternotomy patients that are at high risk for incisional healing issues or dehiscence. It has been calculated that when NPWT has been applied over a surgically closed incision, the force required to disrupt the incision increases by 50% in a model of freshly incised skin.94 The NPWT is applied immediately postoperatively, and a nonadherent layer is placed between the foam dressing and the skin to prevent possible skin maceration. Alternatively, a dressing that is designed for this purpose and is skin friendly (Prevena Incision Management System, KCI, Inc) may be used and can be attached to a standard pump or a portable, single-use device.

Single-use, portable pumps that are preset to −80 mm Hg are a recent new development in human medicine.94–96 The life span of these devices is typically 1 week. Although patients return for dressing changes and wound checks, the cost savings is remarkable and patients are often able to return to their normal lifestyle (including work), thus improving patient outlook, appetite, stress levels, and overall well-being. These devices may prove useful to select veterinary patients and could potentially be secured to dogs’ bodies with a vest similar to that used to attach Holter monitors to veterinary patients.

The use of stem cells and scaffolds combined with NPWT may offer new treatment options for complex wounds. Such therapy has been examined for use in human medicine, and it may prove useful in both human and veterinary medicine in the future.26 As newer, improved equipment and increased applications become available for NPWT in human medicine, veterinary patients of all sizes may benefit by having more options for complex wound management.

SUMMARY

- NPWT has been effective in the treatment of a wide range of complex wounds in human medicine, and its use in veterinary medicine is increasing.
- Patients treated with NPWT achieve wound closure quicker than patients treated with other traditional modalities.
- NPWT has been demonstrated to improve skin graft take compared with traditionally used bandaging techniques.
- Numerous mechanisms work together with NPWT to increase blood perfusion, speed up granulation tissue formation, and hasten contraction of wounds.
- As the number and variety of NPWT devices and materials increase, it is important to understand the different modes and components of NPWT devices and how to select materials appropriately based on the selected mode of operation.
- Before purchase of equipment and use of NPWT, it is important to understand the indications and contraindications, as well as the advantages and disadvantages of NPWT for each patient and practice situation.

REFERENCES


