Negative Pressure Wound Therapy in the Head and Neck: A Summary of Uses and Application Techniques

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Abstract

Negative pressure wound therapy (NPWT) has had an expanded role in the management of complex wounds including its increasing use for complex wounds in the head and neck region. Challenges for use in the head and neck region include variations in surface topography and the proximity of sensitive mouth, nose, ear, eye, and tracheal openings. Despite these challenges, NPWT has been used in the head and neck immediately following free flap surgery, to prepare wounds for skin grafting or local flaps, to treat orocutaneous and pharyngocutaneous fistulas, to treat necrotizing and deep neck space infections, to temporize and palliate, and to treat chronic wounds with exposed bone and hardware among others. This review demonstrates the proven track record of successful uses of NPWT in the aforementioned scenarios, provides suggestions to improve efficacy, as well as an algorithm for use in certain clinical situations.

Keywords
- negative pressure wound therapy
- head and neck
- fistula
- necrotizing fasciitis

Within the past 30 years, the advent and evolution of negative pressure wound therapy (NPWT) has caused a rapid increase in varied applications and improved results. A bit of housekeeping; NPWT has and will likely continue to be used interchangeably with other terms (subatmospheric pressure, vacuum-assisted closure, and wound vacuum, etc.). For clarity and consistency, NPWT will be used throughout this article. NPWT is the accepted Medical Subject Headings listing by the National Library of Medicine. Herein, we also discuss a newer concept: negative-pressure instillation therapy (NPIT), which allows various solutions to be irrigated into wounds concomitantly with NPWT.

History and Mechanism of Action

Fleischmann et al[1] are often credited with the first published use of NPWT in 1993 whereby open wounds were covered with a porous polyvinyl alcohol foam followed by a transparent polyurethane drape which was then connected via tubing to a vacuum bottle. In 1995, the V.A.C. (KCI, 3M, St. Paul, MN) became the first commercially available NPWT system. Much of the early success of NPWT is credited to Morykwas et al, who conducted studies of NPWT in pigs in which they were able to show a several fold increase in blood flow to the wound with laser Doppler as well as increased granulation formation, reduction in bacterial loads, and improved survival of transposed random pattern flaps compared with controls.[2] This group also described their clinical experience with NPWT to treat 300 wounds ranging from chronic to acute with a reported success rate of 98.6%.[3]

Mellott et al reviewed the NPWT mechanisms of action, including removal of exudate and interstitial edema, increased blood flow, and both macrodeformation and microdeformation forces.[4] NPWT has been shown to reduce wound bed bacterial loads, as initially demonstrated by Morykwas et al. Macrodeformation refers to reduction in surface area of

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Table 1 Indications and contraindications for use of NPWT and NPIT in the head and neck

Indications	Contraindications
• Dehiscent acute and subacute wounds, including exposed bone, dura, and hardware • Secure skin grafts or dermal substitutes • Prepare or temporize a wound for eventual skin grafting or flap coverage • Cover a difficult wound to provide comfortable and easy wound care in a palliative or end-of-life scenario • Treatment of advanced deep neck space infections and necrotizing fasciitis • Treatment of pharyngocutaneous and orocutaneous fistulae with salivary contamination • Treatment of low output chyle leaks	• Active tumor in wound in a nonterminal patient • Untreated osteomyelitis • Continued use without improvement in wound appearance, contamination/output, or wound dimensions despite correct application and patient compliance • Continued use if there is failure to maintain adequate seal

Abbreviations: NPIT, negative-pressure instillation therapy; NPWT, negative pressure wound therapy.

wounds following application of NPWT, while microdeformation refers to the pull of the negative pressure on the extracellular matrix within wounds, which results in increased mechanosignaling to promote the proliferative phase of wound healing.[5] Also described are secondary events such as moisture control, temperature stabilization, and mechanotransduction.

NPWT has seen wide acceptance for wounds of the extremities, trunk, and diabetic foot wounds. There has been a slower adoption of this technology in the head and neck surgical community, largely from inherent difficulties in application because of the complex topography and numerous orifices. Rosenthal et al published the first series describing NPWT use in the head and neck, treating 14 wounds including fistulas with exposure of the carotid and mandibular hardware exposure. They also used NPWT to bolster large skin grafts with a favorable rate of graft take.[6] Please see ►**Table 1** for a complete list of indications and contraindications for use of NPWT in the head and neck. Of note, the head and neck reconstructive surgeon may frequently employ NPWT at flap and graft *donor* sites; its use in this manner is beyond the scope of this article.

Systems and Basic Application Principles

In addition to V.A.C., several other manufacturers have produced comparable systems (►**Table 2**). However, one may only have access to certain models within a given health care setting. Furthermore, alternate NPWT models may be required when transitioning patients to the outpatient setting. The provided list of devices may not be exhaustive, and it is advised that you consult with your health care systems' wound nurses and medical social workers to see the availability and logistics of use of the various systems.

Foam/Sponge

Commonly used in the wound bed is porous polyethylene "black" sponge. However, it should not be placed directly over exposed vasculature or nerves or into deep-tracking, narrow spaces. Rather, a dense sponge with high tensile strength, polyvinyl alcohol "white" sponge can be used in these situations. Sponge materials are not biocompatible in the long term and retained sponge fragments can become a complication. Additionally, nonadherent dressings such as Xeroform can be placed directly over vessels or nerves to protect them when NPWT will be used. Some sponges (V.A.C. Granufoam Silver, 3M) are silver impregnated and have antimicrobial properties, which can be advantageous in the infected wound. NPWT can simplify wound care as it often reduces the number of requisite dressing changes. Further, a bridge of sponge between two separate wounds can be used to provide NPWT with a single suction apparatus.[7]

Semipermeable Membrane

The sponge and adjacent skin are covered with an adhesive semipermeable membrane (film) such as V.A.C. Drape (3M). Shaving, cleansing skin, placing adhesive prep around wound circumference, and layering smaller strips of film to adapt to the varied head and neck topography are all techniques used for the successful application of NPWT.[8] In our experience, applying the film is the most critical step to initiating and maintaining adequate seal.

Pad and Connection Tubing

The pad and connection tubing attach the suction apparatus to the wound via a perforation created in the film. Important considerations for this step in NPWT application include the size and shape of the perforation created, the potential space needed for two pads if NPIT is used (►**Fig. 1**), and placement of the pad in a location that will maximize patient comfort. A perforation too small can impair adequate suction and a perforation too large may cause debris to accumulate in and clog the suction tubing. One alternative that we have used is to create a ring of small perforations in the film.

NPWT Device

Typically, a suction device allows the provider to select from low, to medium, or high intensity of therapy as well as selecting a specific negative pressure level (mm Hg). Sections below outline a few clinical situations in which lower pressure settings are suggested. There are instances in which a patient may be poorly tolerant of the NPWT due to pain. The intensity and/or pressure level can be lowered to improve patient

Table 2 Negative pressure wound therapy devices and manufacturers

NPWT system	Manufacturer	Model available for home use?
ATMOS S 042	ATMOS MedizinTechnik GmbH & Co.	Yes
Avelle	ConvaTec	Yes
Invia	Medella LLC	Yes
V.A.C. Therapy	3M Health Care	Yes
V.A.C. Ulta (Veraflo, V.A.C., Abthera, Prevena)	3M Health Care	–
V.A.C. Via	3M Health Care	Yes
ActiV.A.C.	3M Health Care	Yes
RENASYS	Smith & Nephew	Yes
KALYPTO	Smith & Nephew	Yes
VT-ONE	Carilex	Yes
DeRoyal Pro	DeRoyal	Yes
Exsudex	Haromed Bvba	Yes
Avance Solo	Mölnlycke Health Care	–
CATALYST	Cardinal Health	No
ALLY	Cardinal Health	Yes
NPWT PRO	Cardinal Health	Yes
NPWT SVED	Cardinal Health	Yes
extriCARE	Alleva Medical Ltd.	Yes
Nisus	Cork Medical	Yes
Sanity G6	Progressive Wound Care Technologies	–
Vakito	Medway Inc.	Yes

Abbreviations: -, data not available; NPWT, negative pressure wound therapy.

comfort.[7] Most devices are equipped with alarms to detect a loss in pressure or a leak and most have some battery life to allow for patient transport or mobilization. Some models are designed for outpatient use and are purely battery powered. Newer devices allow the selection of a variety of modes of therapy such as NPIT or traditional NPWT (►**Fig. 2**).

Dressing Changes

NPWT can be maintained for 7 days or more, and some systems are designed for such use. However, for complicated, active, or infected wounds it is more common to change the NPWT dressing every 2 to 3 days. Depending on the location of the wound or tolerance level of the patient, the dressing

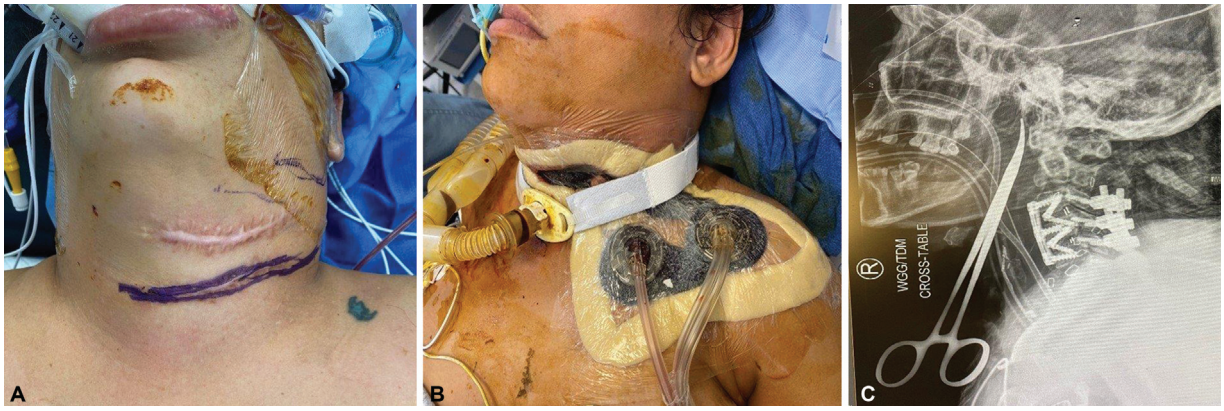

Fig. 1 Female with history of anterior cervical discectomy and fusion (ACDF) surgery and intravenous drug use (IVDU) presented in septic shock and prevertebral space necrotizing fasciitis. (**A**) Prior ACDF incision used for exposure, widened with scar removal. (**B**) Negative-pressure instillation therapy (NPIT) with hypochlorous acid solution (Vashe, Urgo Medical, Ft. Worth, TX) was initiated following tracheostomy and wound debridement on the second trip to operating room (OR). Note the separate pads for instillation and suction and use of Eakin's ring to help with seal. A bridging technique was also used to place the pads away from the tracheostomy and submental area. (**C**) This wound tracked superiorly to the clivus and the cephalad extent could not be visualized with the cervical exposure; thus, white sponge was placed superiorly to avoid retained foreign body with dressing changes.

Fig. 2 V.A.C. Ulta negative pressure wound therapy (NPWT) device which is compatible with negative-pressure instillation therapy (NPIT) in which various solutions (hypochlorous acid, Dakin's solution, saline, polyhexanide, etc.) can be set to irrigate through the wound. Note the irrigation attachment on the device's right.

changes can be performed in the operating room or at the bedside. One strategy to improve patient tolerance of dressing changes at the bedside is to soak the sponge in a dilute solution containing lidocaine or hydrogen peroxide.[7,9] The porous nature of the sponge results in an interface between the wound matrix and the sponge, the wound matrix can grow into the porous sponge. In this circumstance, the sponge may be adherent and difficult to remove. Strategies for easing sponge removal include moistening the sponge, more frequent dressing changes, denser (polyvinyl alcohol) sponge material, or placing a nonadherent dressing layer between the sponge and the wound bed.

Wound Nurses

The importance of collaborating with wound nurses, specifically those with the Wound, Ostomy, and Continence Nurses Society certification, cannot be overstated. These providers have specialized training in treating wounds all over the body and perform in this capacity *full-time*. They oftentimes have more experience with applying and troubleshooting NPWT/NPIT devices than the clinician treating the patient. We have routinely invited wound nurses to the operating room or bedside to assist us with the application of NPWT or NPIT in challenging scenarios. Their experience is evidenced by many tricks and techniques that can be employed. See ►**Table 3** for a complete list of pearls and pitfalls for use of NPWT in the head and neck.

Effectiveness in Head and Neck Wounds

Lin et al conducted a retrospective review of two cohorts following tumor ablation with radical neck dissection and free flap reconstruction: NPWT versus conventional wound care (CWC).[10] A total of 58 patients were included and were well matched except for age. Patients in the NPWT group had immediate placement of the system (V.A.C., 3M) at the caudal edge of the wound, some portion of the wound was closed but this is not entirely clear. Patients in both cohorts had concomitant placement of suction drain at the dependent portion of the neck wound. Postoperative complications were assessed. While the overall number of complications was significantly lower in the NPWT group (9.7% vs. 37%). The only specific complication that was significantly lower in the NPWT was rate of wound infection (0% vs. 14%). There was no significant difference in the suction drain output between groups. The NPWT cohort saw *no* instances of infection, flap failure, hemorrhage, seroma, plate exposure, or dehiscence. There was a trend toward shorter hospital stays in the NPWT cohort. NPWT can be applied in a variety of settings such as immediately following reconstruction as outlined above, in the subacute setting as complications inevitably arise, and in stable or chronic wounds. The endpoint of therapy can be tailored by the surgeon and includes complete closure/epithelialization, a healthy granulation bed left to heal by secondary intention, or temporize or prepare a wound for a locoregional flap or graft.

Asher et al published a large review of 108 patients receiving NPWT to the head and neck; most of the wounds were in the neck and following surgery for oncologic resection (80). Other indications in the series included trauma, severe infections, and following cervical spine surgery. Complete healing with NPWT alone was achieved in 61.8% of patients, while 34.5% underwent additional procedures with adjuvant tissue transfer.[11] A majority (79.1%) of treated wounds in their series were deemed complex due to: salivary contamination (64), bone exposure (40), exposure of great

Table 3 Pearls and pitfalls for application of NPWT to the head and neck

Pearls	Pitfalls
• Get to know your hospitals' wound nurses • Ensure oral cavity is sealed off if using NPIT • Use Eakin's ring, colostomy ring, stoma paste, or hydrocolloid dressings to help ensure adequate seal in difficult areas • Placement of sponge at the distal-most portion of a fistula will result in collapse of fistula walls and eventual closure • Be patient and reassess wound at regular intervals o *The most difficult wounds may require 10–14 days of therapy or beyond*	• Failure to remove all of sponge material during dressing change • Failure to protect vessels and nerves with nonadherent contact layer or denser (polyvinyl alcohol) sponge • Failure to recognize when NPWT or NPIT, despite adequate trial, are ineffective and move on to another strategy

Abbreviations: NPIT, negative-pressure instillation therapy; NPWT, negative pressure wound therapy.

vessels (25), following free tissue transfer (55), and peristomal wounds following laryngectomy (32).

Indeed, other authors have shown the effectiveness of NPWT in the head and neck in similar austere settings that arise after complex tumor ablation and defect reconstruction.[12,13] In smaller series by Reiter and Harréus, 23 head and neck wounds ranging from flap loss or wound dehiscence to necrotizing fasciitis (NF) and salivary fistulae were treated with NPWT.[14] Seventy-eight percent of patients in their series had wound closure without any additional surgical treatment. They also showed that lowering the negative pressure setting can improve patient tolerance. Others have published on head and neck applications of NPWT to secure and help revascularize skin grafts or dermal substitutes.[15,16]

In the setting of advanced malignancies, which often require adjuvant radiation therapy and/or chemotherapy, a wound complication or slow healing may delay the initiation of these imperative treatments and result in worse rates of disease control and survival. The American College of Surgeons Commission on Cancer and the American Head and Neck Society have recently released a quality metric: adjuvant radiation therapy should begin within 6 weeks from surgery. NPWT has been shown to speed the healing of some wounds relative to conventional techniques, which is of greatest importance for those patients with wounds in the setting of malignancy.[16] No published reports of adjuvant radiation administration with a NPWT dressing in place were discovered in our review and we have no experience with this in our practice.

Much of the published work on NPWT in the head and neck is limited to case series and retrospective reviews with essentially no randomized controlled clinical trials. However, some large reviews have been able to show the favorable success rates of NPWT use in the head and neck across a variety of sites and situations. The review by Mir et al included 522 patients with an overall favorable response rate of wounds reported at 85.7%.[17] The review by Faisal et al focused on the use of NPWT in the setting of primary reconstruction following ablation of head and neck cancer. Their analysis was able to identify history of radiation and diabetes mellitus as significant risk factors for an unfavorable response to NPWT when success of therapy was defined as granulation tissue covering at least 80% of the wound surface area.[18] Additionally, across 380 patients included they were able to report mean length of use of NPWT (10 days) as well as mean number of dressing changes (3.2). Their overall success rate of 88.2% was comparable to that of Mir et al.

NPWT for Chronic Wounds

Chronic wounds often arise in the head and neck in the setting of radiation, infection, or salivary contamination (sometimes all three). In these cases, multiple revision surgeries in the form of regional or free tissue reconstruction, or hardware removal may be required. To treat these chronic wounds, some surgeons have implemented NPWT. Eckstein et al report a retrospective study of wounds in 15 patients with either osteoradionecrosis (ORN) or osteomyelitis of the mandible. NPIT was maintained for a mean of 13.3 days in these patients. The solution instilled was 0.04% polyhexanide and was set to instill every 3 hours with a 10-minute soak time. They found a statistically significant reduction in white blood cell count, C-reactive protein levels, and in subjective pain scores following NPIT therapy. Healing by secondary intention was achieved in all but one patient.[19] The authors did comment on the added importance and difficulty in achieving a watertight seal with NPIT as opposed to traditional NPWT.

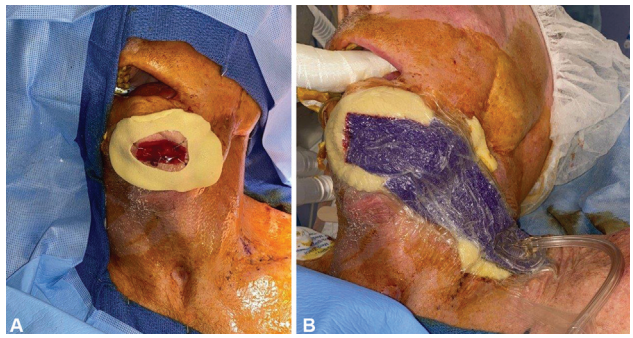

Fig. 3 Negative pressure wound therapy (NPWT) is used to treat a radiated, chronic wound with exposed neo-mandible bone. (**A**) To help ensure seal as wound is close to oral aperture, Eakin's ring is placed around the dermal substrate which was used to cover the exposed bone. (**B**) Prevena (3M, St. Paul, MN) sponge is used with film to seal the system, note location of pad at periphery for patient comfort and camouflage.

Subotic et al published a case report of use of NPWT applied over a chronic wound *and exposed dura* in a 10-year-old with Apert syndrome following prolonged wound complications and removal of exposed titanium mesh. After 3 weeks of NPWT in the syndromic child there was a healthy bed of granulation tissue and epithelialization occurred by secondary intention.[20] These reports indicate that NPWT and NPIT can be highly effective in the treatment of long-standing and chronically infected wounds. Similarly, we have employed NPWT in this setting (►**Fig. 3**).

NPWT for Deep Neck Space Infections and Necrotizing Fasciitis

In a study by Cao et al 12 patients with deep neck space infections (DNSIs) were treated with incision and drainage followed by a modified NPWT dressing placement.[21] Small "logs" of black foam were placed alongside flat, latex drains in the surgically opened spaces and were connected by a superficially placed larger piece. The film was applied over the larger block foam and connected the NPWT device. NPWT was maintained without dressing change for 5 to 7 days prior to removal. The latex drains were left in place an additional 2 to 3 days. All wounds healed over a mean of 12.5 days, which is lower than their historically reported mean of 15 days for DNSI. No patients required further wound debridement or tracheostomy.

Multiple case reports and series have documented the effectiveness of NPWT in the treatment of NF of the head and

neck. Campana et al describe a case in which a patient developed extensive neck swelling and necrotic skin in the anterior and midline neck. Following removal of the causative third molar and debridement of the anterior neck skin and soft tissues, NPWT was applied and resulted in complete healing by 35 days.[22] A series by Chen et al included 7 cases of NF.[23] Only one patient required a secondary debridement following NPWT. Mean wound healing time was 17.3 days, lower than the authors' previously reported mean of 27.2 days with CWC. Due to the extent of necrosis, cases of NF often require aggressive wound debridement followed by large excisions of skin. Balcı et al published a case series of 11 patients diagnosed with NF of the head and neck, 3 of whom received aggressive debridement and CWC and 8 whose wounds were debrided and only limited amounts of skin removed followed by application of NPWT.[24] The authors do report an apparent difference in the amount of skin that was excised between the groups in favor of NPWT.

Wounds resulting from NF can be complex due to their location and exposure of critical underlying structures. Sukato et al describe a complex wound following debridement of NF which resulted in communication between the oropharynx and neck. This group employed a technique described by Asher et al for intraluminal wound vacuum in the oropharynx followed by traditional NPWT placed on the cervical aspect of the wound.[25,26] Therapy was maintained for 2 weeks with dressing changes every 2 to 3 days until a healthy bed of granulation tissue was observed. The remaining skin defect was later closed with regional pedicled flap with no further noted issues. Linkov et al present a case of NF of the left face, neck, and upper chest with an exposed, skeletonized upper division of the facial nerve (lower division sacrificed due to involvement in infection). The resulting wound was addressed with NPWT employing white sponge over the exposed infratemporal fossa and facial nerve branches. After 7 days of therapy, there was sufficient granulation tissue such that the facial nerve branches were no longer visible. The defect was eventually covered with full-thickness skin graft with complete function of the upper division of the facial nerve.[27]

Use for Temporizing or Palliation of Wounds

Sometimes immediate reconstruction of a complex wound following tumor extirpation may be cautioned. One such instance is the treatment of dermatofibrosarcoma protuberans (DFSP) because of its ability to recur if the margins are not taken widely and examined closely. Agostini et al used NPWT in a series of 5 patients with DFSP of the head and neck (4 neck and 1 scalp). Following wide resection, the wounds were covered with dermal regenerative template (Integra Life Sciences, Princeton, NJ). The template was secured to the wound with NPWT (V.A.C., 3M). NPWT was maintained for 2 weeks and then removed along with the silicone layer of the template. The wound was then covered with a split-thickness skin graft and then NPWT was reapplied. Advantages of this technique in this setting are ability to revise the margin without compromising the reconstruction use in frail or medically complex patients who are not candidates for free tissue transfer.[28]

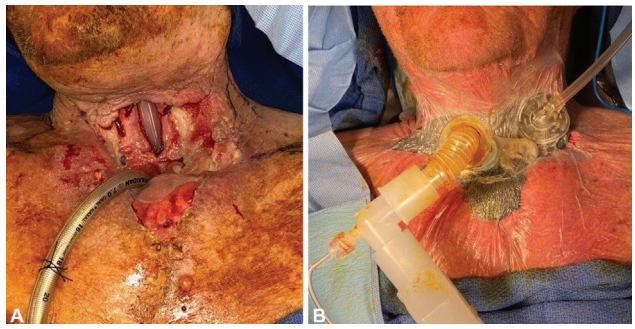

Fig. 4 (**A**) Dehiscent wound with large neopharyngeal leak following resection of stomal recurrence. (**B**) The wound was temporized with negative pressure wound therapy (NPWT) and cuffed tracheostomy tube.

In some circumstances a microsurgeon is not available for coverage or reconstruction of complex wounds and other techniques will need to be employed. Pereira et al report use of NPWT for a complex scalp wound with exposed cranium following removal of advanced basal cell carcinoma. After 1 week of CWC, no granulation tissue had formed. Thus, NPWT was applied and maintained in an outpatient setting for 6 weeks. Following this, healthy granulation tissue covered the calvarium to which a skin graft was applied.[29]

Postoperative wounds can arise at any time and such a time is rarely convenient for the reconstructive surgeon. NPWT can be a powerful tool to temporize wound complications like dehiscence or infection following primary reconstruction. It can maintain the wound in a low-maintenance, comfortable setting for the patient until a definitive repair can be performed. Poglio et al treated a wound with exposed mandible reconstruction bar following reconstruction of a patient with ORN. The NPWT system was maintained for 20 days prior to coverage with a pectoralis major pedicled flap.[30] NPWT may be more comfortable for the patient as they await definitive reconstruction compared with CWC.[31]

We have used NPWT to treat a massive scalp wound following free flap failure. The patient was able to be treated as an outpatient and remained comfortable despite the large wound. We have also employed NPWT to palliate a patient with a large neopharyngeal leak following resection of a stomal recurrence. NPWT was able to draw saliva away from his stoma and reduce his coughing and discomfort as well as reduce maceration of the skin and remove need for frequent suctioning or cleaning (►**Fig. 4**).

Negative Pressure Wound Therapy for Head and Neck Fistula Management

Orocutaneous (OCF) and pharyngocutaneous (PCF) fistulae will usually persist and worsen if the fistula is not actively managed. The presence of a salivary fistula can compromise the greater reconstructive effort, leads to longer hospital stays or more office visits, and additional time without per oral nutrition. Our review found several published reports of

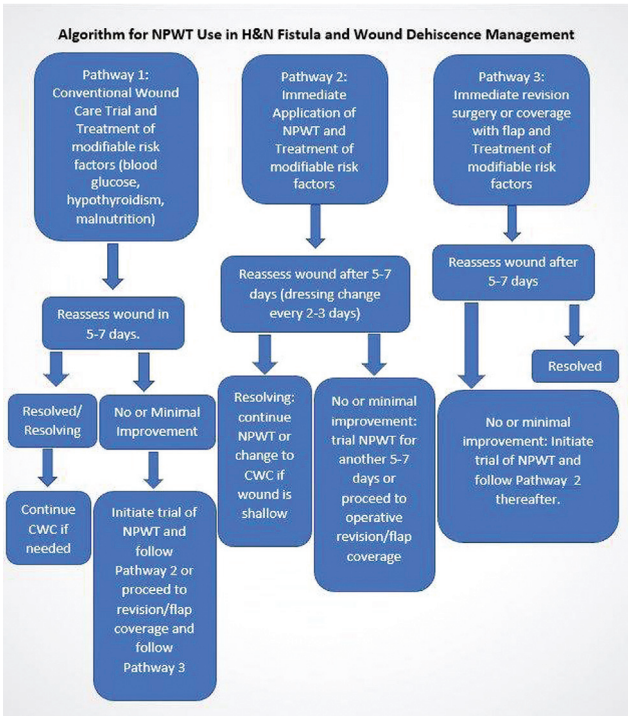

Fig. 5 Algorithm for the use of negative pressure wound therapy (NPWT) in the head and neck for management of salivary fistulas and wound dehiscence.

successful use of NPWT for the management and oftentimes complete resolution of fistulae arising in the head and neck. Many authors have provided creative solutions to be able to employ NPWT in this setting. Additionally, we have included an algorithm for the incorporation of NPWT for the management of salivary fistulae (►**Fig. 5**).

Tian et al cleverly used a piece of surgical glove sutured over the intraoral communication of four PCFs so that a seal could be initiated with NPWT. The NPWT system was able to maintain a seal and provide a cleaner wound with healthy bed of granulation tissue and eventual definitive surgery.[32] Umezawa et al devised a fistula management technique by which they covered the wound with adhesive membrane *first* and then pierced this membrane and threaded a 6-mm Penrose through into the wound. The external portion of the Penrose drain was then surrounded by a small piece of split black sponge and both of which were covered by a second layer of membrane which was then connected to the suction device. NPWT dressing was changed every 3 days with a mean duration of therapy of 10.2 days. Eleven patients with fistulas following head and neck cancer resection were treated in this manner; half of the uses followed failed pectoralis major flap and the other half with NPWT used initially.[33]

In a relatively large series, Inatomi et al treated 34 patients with fistulae with NPWT and/or NPIT with success in 32 of 34. Thirty had no further surgical intervention. Mean time to fistula closure was 17.9 days (range 2–79), some patience may be necessary. They also stratified their results by history of radiation and fistula location (OCF vs. PCF) and found that mean time to fistula closure with NPWT was not statistically different if patients had been radiated or not nor by location. Helpful techniques mentioned by this group are use of flexible hydrocolloid (Adapt Barrier Rings, Hollister Inc., Libertyville, IL) around complicated surfaces, shallow placement of the sponge within the wound, cuffed tracheostomy tube and placement of adhesive film over the tracheostomy tube, and lastly bending the patient's neck toward the affected side to help initiate vacuum seal.[34]

When a fistula communicates adjacent to laryngectomy stoma, application of NPWT can be problematic and less effective. While they do not refer to this a success, Andrews et al were able to spur some granulation tissue when a fistula developed at this trifurcation area. A small piece of black sponge was placed in the wound and suction tubing placed within this and exteriorized through the skin closure. A purse-string suture and high degree of negative pressure (–150 mm Hg) were employed but the dressing was taken down after 2 days secondary to inconsistent seal. The same wound was left to heal by secondary intention and resolved in 4 weeks.[35]

Another technique is noted by Loaec et al in their successful treatment of seven fistulae in this setting. They created a *counter incision* above and lateral to the stoma to help redirect and close the fistula. Additional helpful measures employed by this group included use of colostomy wafer and hydrocolloid dressings around the perimeter to help maintain seal and the use of tulle gras (a paraffin-embedded dressing) under the film as it reportedly is aspirated into leaking areas and helps seal them.[9] Endoscopic negative pressure therapy is another novel method used to close a fistula or esophageal perforation. With this technique open-pore drains are placed within the lumen, spanning the defect and then NPWT is placed in the wound cavity in standard fashion. One group reported successful treatment of 10 defects over a mean of 13.7 days with this method.[36]

Locatello et al published a systematic review of nonsurgical techniques for treatment of PCF following laryngectomy which included three studies using NPWT applied at bedside (intraoperative NPWT reports were excluded). Only 8 patients were treated in this manner, but there was a 100% resolution in a mean of 20.1 days.[37] We have successfully used NPWT at the bedside to treat a PCF that developed years after a salvage laryngectomy. We simultaneously placed fibrin sealant (Vistaseal, Ethicon, Raritan, NJ) intraorally to the approximate location of the intraoral communication.

Referenced studies using NPWT for fistulae all include radiated patients; 29 of 61 total patients.[8,32–37] However, only Inatomi et al stratified patients by history of radiation and they surprisingly showed that there was no significant difference in resolution rate.[34] The accepted, speculated mechanism of action of NPWT for resolution of head and neck fistulae is that, when sponge is placed near the superficial aspect of the fistula tract, the negative pressure results in the walls of the fistula collapsing and opposing one another resulting in eventual seal.

Uncommon and Novel Uses

As its use in the head and neck becomes more common, reconstructive surgeons have sought out new applications of NPWT. As previously stated, Asher et al investigated the efficacy of intraluminal application of NPWT during reconstruction of pharyngeal defects following laryngectomy.[26] The authors describe the process as follows: a nasogastric tube (NGT) is passed through the nose until it reaches the pharyngeal opening. The surgeon then cuts the sponge to span 1 cm superiorly and inferiorly to the pharyngeal defect. A stab incision is made in the sponge and the NGT is inserted and sewn into the sponge. Often a Xeroform bolster is sewn to the cephalic portion of the sponge to maintain adequate suction. The pharyngeal defect is then closed with free or regional flap. Continuous suction is then applied at 125 mm Hg. Sponge removal must then be performed under general anesthesia by flushing the sponge with normal saline and withdrawing the NGT until it can be removed orally. Eleven of 12 patients in their study achieved pharyngeal closure using the negative pressure dressing. Another novel use proposed by Dong et al involves modification of an infusion apparatus to achieve negative pressure drainage of an auricular pseudocyst.[38] All 32 patients in their study had complete resolution of their pseudocysts with no long-term complications.

NPWT was used to treat a perforation of the endolarynx in the setting of a DNSI.[39] Katz et al report impressive results with the use of NPWT for seven pediatric lymphatic malformations of the head and neck with no reported recurrences.[40] In an effort to obtain an adequate seal for a deep wound with dead space adjacent to a laryngectomy stoma Johnston et al placed Eakin's ring *over* the patient's stoma and then punctured this with a cuffed tracheostomy tube. Additional Eakin's ring was placed over the tracheostomy tube in a second layer followed by filling the wound with black sponge and application of the adhesive membrane in standard fashion.[41] Others have used NPWT for the successful management of a chyle leak following neck dissection.[42] We have successfully used NPWT over a large area of exposed muscle of a pectoralis major flap, which resulted in rapid epithelialization.

Innovation of NPWT for use in the head and neck has yielded interesting prospects. In their work, Bharath and Madabhushi have theorized and modeled a sleeved sponge device equipped with a perforated inner drainage tube specifically designed for the fascial spaces of the head and neck.[43]

Complications

A variety of complications with NPWT have been described, ranging from minor to severe. Our review of the literature for head and neck NPWT use found no reported instances of major vessel blowout or catastrophic bleeding; however, this has been reported at other anatomic locations. Special attention should always be paid to application of NPWT when vessels or nerves are in the wound bed, as outlined above.

Incomplete sponge removal, particularly if the sponge tears, can produce foreign body complications with resultant infection.[36] It has been speculated that when the suction apparatus malfunctions, or the NPWT device has a "leak," the sponge can act as a foreign body. This resulted in a case of acute otitis externa in one report.[44] While rare, there are reports of development of toxic shock syndrome with use of NPWT.[45] The only manufacturer recommendation for antibiotics is in the setting of osteomyelitis, otherwise their use is at the discretion of the treating physician.

Common but minor complications include device malfunction and contact dermatitis.[33,40] A malfunctioning device, in our experience, is usually the result of an inadequate seal. This can become an annoying problem for the patient, nurse, and clinician. The negative pressure device may not maintain suction, which can undermine its intent. If a seal cannot be obtained, a temporizing workaround is to disconnect the suction tubing from the device and reconnect it to a wall-suction apparatus. New applications of telemedicine such as video visits may allow providers to help patients troubleshoot their NPWT device from home during outpatient therapy. To reduce or avoid dermatitis or skin maceration one can use thinner pieces of sponge to fit the contour of the wound. If the sponge sits proud relative to the level of the skin, a tenting effect can expose the adjacent skin to wound exudate or saliva. Another method is to apply Eakin's ring, colostomy ring, or hydrocolloid dressing (Allevyn, Smith & Nephew, Watford, U.K.) around the periphery of the wound, or apply the adhesive film directly to the adjacent skin as a barrier layer and then apply the film over the wound and sponge in standard fashion.

Use of NPWT in the setting of active malignancy is a relative contraindication to its use. It is speculated that the same mechanisms that promote the development of granulation tissue and a healthy wound bed could promote tumorigenesis. However, as noted, the use of this technology can provide all-important palliation to the patient. In one instance, NPWT was employed in a wound with tumor at the margins. A wound closure was achieved, which allowed the patient to participate in a clinical trial.[46] Though, we did encounter one anecdotal report of insurance denial of NPWT because tumor was present in the wound. Wang et al demonstrated that when tumor is completely excised, there is no difference in locoregional recurrence rates compared with CWC if NPWT is applied.[47]

Pain with use of NPWT is a potential complication, as outlined above, there are several strategies that can be employed to reduce pain and increase patient tolerance. In a review by Li and Yu, the loss of protein through the wound bed is associated with use of NPWT and can be greater than the losses experienced by burn patients.[48] Furthermore, many patients who undergo treatment with NPWT may already be malnourished. Therefore, it is recommended that patients be under the care of a dietitian to ensure that they are adequately supported with calories and macronutrients during the healing process. Fluid losses through NPWT should be regularly followed by documenting the output in the device's reservoir.

Critics of NPWT cite its increased cost compared with CWC. While the cost of the device and component materials may be higher, the benefits of more rapid resolution of complex wounds often outweigh those costs, and in some studies represent a comparable or lower-cost treatment than CWC.[49,50] Granted, these published reports were not specific to NPWT in the head and neck. The reduced work burden of wound care on nurses and clinicians due to less frequent dressing changes with NPWT is also worth mention.

Conclusion

NPWT can be employed in the head and neck in a multitude of wound locations and clinical settings. The consensus of these reports shows favorable and expanded use of this technology. NPWT is finding increasing footing and its place among the armamentarium of the head and neck reconstructive surgeon. Except for time and cost, there is minimal risk and morbidity to a trial of NPWT for a complex head and neck wound with the oftentimes added benefit of avoidance of additional incisions or donor sites. The included uses and techniques described herein should serve as a reference or perhaps inspiration to those treating head and neck wounds as NPWT continues to expand since its relatively recent advent.

Conflict of Interest
None declared.

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