Vacuum-assisted closure for complex cranial wounds involving the loss of dura mater

Report of 5 cases

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The aim in this study was to describe the safety and efficacy of vacuum-assisted closure (VAC) in patients with complex cranial wounds with extensive scalp, bone, and dural defects who were not candidates for immediate free tissue transfer. Five patients (4 men and 1 woman) ages 24–73 years with complex cranial wounds were treated with VAC at Wake Forest Baptist Medical Center. Etiologies included trauma, squamous cell carcinoma, and malignant meningioma. Cutaneous wound defects measured as large as 15 cm in diameter. Four of the 5 patients had open skull defects with concomitant dural defects, and 1 patient had dural dehiscence. After surgical debridement, all 5 patients were treated with the direct application of a VAC device to a reapproximated dura mater (1 patient), to a pericranial flap (1 patient), or to a regenerative tissue matrix overlying CNS tissue (3 patients). In all cases involving open cranial wounds, the VAC device promoted granulation tissue formation over the dural substitute, prevented CSF leakage, and kept the wounds free from local infection. The duration of VAC therapy ranged from 16 to 91 days. Although VAC therapy was intended as a temporary measure until these patients could be stabilized for larger tissue transfer procedures or they succumbed to their primary pathology, 1 patient had a successful skin graft following VAC therapy. Hydrocephalus requiring shunt placement developed in 2 patients during VAC therapy. The VAC dressings applied to a tissue matrix or other barrier over brain tissue in extensive cranial wounds are safe and well tolerated, providing a functional barrier and preventing infection.

Key Words • complex scalp wound • vacuum-assisted closure • surgical technique

Abbreviation used in this paper: VAC = vacuum-assisted closure.

Addressing these defects requires a well-formulated plan to maximize the likelihood of a successful treatment while minimizing potential risks. This plan must consider the potential need for bone reconstruction, the timing of soft tissue and bone reconstruction, as well as the method of cranioplasty and soft tissue reconstruction. In many instances, patients are not candidates for immediate reconstructive procedures because of comorbidities. Such patients may have contaminated cranial tissues or moribund conditions that preclude immediate reconstructive efforts.

One therapy that has been used over the past decade with increasing frequency in patients with acutely unfavorable soft tissue conditions is VAC. The use of VAC for the treatment of tissue defects was first described by Morykwas et al. in 1997. Since its introduction, this therapy has gained wide acceptance for many problems. Uses have included treatment of thoracic and abdominal wounds, limb trauma, burn wounds, and skin grafting.

The past decade has also seen an expanded role for negative pressure therapy in complex head and neck
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wounds. A few case reports have described the successful use of VAC therapy for complex cranial wounds with exposed dura.20,39 In the present report we describe our experience with the use of VAC therapy in patients with extensive combined scalp, bone, and dural defects in whom immediate free tissue transfer was not an option. To the best of our knowledge, this is the first report of VAC therapy for complex cranial wounds involving the loss of dura.

Case Reports

Five patients (4 men and 1 woman) ages 24–73 years with complex cranial wounds were treated at Wake Forest Baptist Medical Center. A summary of patient demographics and wound characteristics is presented in Table 1. Preoperative conditions included trauma, squamous cell carcinoma, and malignant meningioma. Wound defects measured as large as 180 cm². Four patients had open skull defects with dural defects as the result of the inciting pathology. Three of the 5 had previously received wide-field radiation, which compromised wound healing. Four patients had evidence of wound infection before initiating treatment. Following surgical debridement, all 5 patients were treated via the direct application of a VAC device to a reapproximated dura (1 patient), to a pericranial graft (1 patient), or to a tissue matrix (3 patients). Alloderm (LifeCell Corp.) was the tissue matrix used when no other autologous barrier was available between the device to a reapproximated dura (1 patient), to a pericranial graft (1 patient), or to a tissue matrix (3 patients). AlloDerm was the tissue matrix used when no other autologous barrier was available between the brain and VAC dressing. The VAC sponges were changed every 2–4 days at the bedside or in the operating room. Pressure on the VAC device was set at −50 mm Hg for all patients.

In all cases involving open cranial wounds, the VAC device promoted granulation tissue formation, prevented CSF leakage, and kept the wound free from local infection. The duration of VAC therapy ranged from 16 to 91 days. Three patients died prior to undergoing a definitive coverage procedure. Except for the symptoms of hydrocephalus, both patients maintained stable neurological function during treatment with the VAC device. One patient later had a successful free flap transfer. One patient’s dural substitute granulated to allow a successful autologous skin graft. The duration of therapy, infectious status, and definitive coverage procedure for each patient are summarized in Table 1, and the clinical history and outcome for each patient are described below.

Case 1. This 69-year-old man had a history of squamous cell carcinoma that had invaded the scalp, skull, dura, and brain in the bilateral frontoparietal regions. He had undergone numerous resections and radiation therapy at an outside institution. A radical subtotal resection of approximately 100 cm² of superficially visible, fungating infected tumor and the involved dura, sagittal sinus, and left frontal lobe was performed. Dura was reconstructed with an AlloDerm patch over the frontal lobes bilaterally and the majority of the parietal lobes bilaterally with 4-0 Nurolon sutures (Ethicon). A small bioccipital posterior opening was also reconstructed with AlloDerm using 4-0 Nurolon sutures. Grafts were sutured to dural margins and anchored to adjacent soft tissue. Later, a latissimus free flap covered by a skin graft was attempted to repair the wound. Unfortunately, the graft failed, and the patient’s neurological status remained significantly impaired. His family later decided to change the emphasis of his care to comfort and dignity. He died of respiratory failure. At the time of his death, the wound had been exposed to approximately 3 months of treatment with the VAC device and revealed evidence of extensive granulation tissue over the AlloDerm. The wound was clean, and there were no signs of infection or CSF leakage.

Case 2. This 73-year-old man was involved in an explosion leading to an open brain injury. His open depressed left frontotemporal skull fracture was repaired, his frontal sinus was cranialized, and a partial left frontal lobectomy was performed to evacuate a hematoma and relieve mass effect. Unfortunately, his wound later dehisced and a subdural empyema developed. This area was debrided, and the dural defect was covered with a dural matrix graft that was sutured to the dural margins and

TABLE 1: Summary of demographics and clinical data in 5 patients with complex cranial wounds*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Inciting Pathology</th>
<th>Wound Location</th>
<th>Wound Size (cm)</th>
<th>Dural Defect</th>
<th>Previous Radiation</th>
<th>Evidence of Infection</th>
<th>Duration of VAC Therapy (days)</th>
<th>Definitive Closure Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>69, M</td>
<td>squamous cell carcinoma</td>
<td>vertex</td>
<td>12 × 15</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>2</td>
<td>73, M</td>
<td>high-energy blast to head</td>
<td>lt frontoparietal</td>
<td>5 × 6</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>3</td>
<td>70, F</td>
<td>anaplastic meningioma</td>
<td>lt frontotemporal</td>
<td>8 × 10</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>4</td>
<td>73, M</td>
<td>sinonasal carcinoma</td>
<td>ant skull base</td>
<td>4 × 5</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>none</td>
</tr>
<tr>
<td>5</td>
<td>24, M</td>
<td>self-inflicted gunshot wound to head</td>
<td>face, ant skull base</td>
<td>5 × 15</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>rectus abdominis free flap</td>
</tr>
</tbody>
</table>

* All patients had a skull defect. Abbreviation: ant = anterior.
adjacent soft tissue. The VAC was then applied over the graft. The patient’s family decided to emphasize comfort care approximately 1 month later. He died of respiratory failure. His wound demonstrated granulation with no evidence of infection or CSF leakage.

Case 3. This 75-year-old woman had undergone multiple craniotomies for resection, fractionated radiation, and 2 Gamma Knife treatments for a recurrent, aggressively behaving, atypical meningioma. An additional craniotomy was performed for tumor recurrence. Figures 1 and 2 reveal the preoperative MRI findings. Unfortunately, a rotational flap that was initially used to close the defect became necrotic and infected. Her bone flap was removed when the area was debrided. Figure 3 features a photograph of the debrided area. The area was closed with a combination of an Alloderm graft and rotated pericranial graft that was sutured to the dural margins. The closure was reinforced with sutures in the skin (Fig. 4). The VAC was applied over the dural closure (Fig. 5). Approximately 10 weeks later, the patient underwent a successful split-thickness skin grafting procedure (Fig. 6) over a well-granulated bed on the Alloderm patch and pericranial graft.

Case 4. This 73-year-old man had undergone an extensive anterior skull base procedure for resection of a sinonasal carcinoma with enucleation of his left eye. He had subsequently undergone radiation therapy. He then presented to us with evidence of a deep facial and infratemporal fossa infection. After irrigation and debridement of devitalized tissue all the way to the preclival region, the dura was reapproximated. The VAC was then applied over the reapproximated dura. His wound was managed with the VAC device for 12 days until his family selected comfort care. He died after withdrawal of the vasopressors maintaining his blood pressure in the setting of systemic infection. When the VAC device was removed, the wound revealed healthy granulation tissue and no CSF leakage.

Case 5. This 24-year-old man sustained a shotgun wound through the face to his anterior fossa bilaterally. The facial wound was debrided, his orbits were eviscerated, and foreign body material was extracted from the base of the brain. He required delayed cranialization and exenteration of the frontal sinus. The midline subfrontal dural laceration was closed with a pericranial flap. The wound VAC sponge was placed into the blast tract, and the VAC system was maintained for 32 days. His entire tract was granulated after 32 days, and delayed primary closure was performed.

Discussion

Using a pig model in 1997, Morykwas et al. demonstrated that the application of controlled subatmospheric pressure with a VAC device increased blood flow levels, increased rates of granulation tissue formation, and decreased tissue bacterial counts significantly. Over the following decade, numerous studies further elucidated the physiological and clinical benefits of VAC therapy. The mechanical forces generated by the VAC device significantly increase microvessel density and blood flow in the treated area. Exudate is removed and edema is reduced. Wound fluid composition is altered, and granulation tissue formation is enhanced.

Additional evidence has highlighted the utility of VAC treatment in a clinical setting. Wound volume is reduced and wound healing occurs more rapidly. Drainage time for acute wounds is decreased, response to first-line treatments is increased, and patient survival is increased. Vacuum-assisted closure therapy has also been shown to be cost-effective by reducing the duration of the hospital stay and overall costs of wound care.

A literature review demonstrated that VAC therapy has been used successfully across a number of medical disciplines. Uses have included treatment of sternal dehiscence, gynecological wound failures, abdominal and enterocutaneous defects, degloving injuries, spinal wound infections, and pressure sores. Vacuum-assisted closure therapy has also augmented successful skin grafts.

Management of open brain wounds involving dura, skull, and scalp without viable local tissue for primary closure is particularly challenging, although fortunately rare. Small defects may require only primary closure, a skin graft, or small rotation flaps. However, wounds of the cranium can have characteristics such as large volumes and intricate contours precluding primary repair. Poor arterial supply through the external carotid system due to
surgery, irradiation, or local tissue damage as well as infection makes healing and successful treatment difficult. Other complicating factors include chronic corticosteroid use and multiple previous procedures on the same side of the cranium.

Vacuum-assisted closure has been used increasingly to treat wounds in the head and neck region, although its use for open brain wounds without sufficient dura to cover the brain has not been described. Dhir et al. described a series of 19 patients with 33 complex head and neck wounds that were treated over a 2-year period at 2 tertiary care centers. All patients were treated with wound VAC therapy. Eighty-four percent of these patients healed completely without the need for additional surgical intervention. Adjuvant treatments included hyperbaric oxygen treatment, dermal grafts, and regional flap reconstruction. Similarly, Andrews et al. reported on a series of patients, many with wounds involving the skull, who were successfully treated using VAC therapy. Pedicled reconstructive flaps had failed in 4 patients, 3 patients had Mohs defects, 2 patients had traumatic scalp injuries, and 1 patient had a large neck defect following tissue resection for necrotizing fasciitis. All patients were successfully treated with VAC and experienced no complications. Tanna et al.39 documented a patient who underwent a neck dissection and composite resection of the left floor of the mouth for the treatment of squamous cell carcinoma. The cervical advancement flap dehisced 10 days later, exposing underlying bone. A VAC device was placed, resulting in a dramatic increase in granulation tissue, which allowed the patient to return to the operating room approximately 3 weeks later for a full-thickness skin graft. Numerous additional reports on the successful treatment of complex head wounds with VAC have also been published.5,14,20

Subotic et al. described the use of a VAC device on a mentally disabled boy with Apert syndrome who had a chronic wound with a community-associated methicillin-resistant Staphylococcus aureus infection after multiple neurosurgical operations. For wound closure, VAC therapy was initiated on the bony defect with exposed dura. The VAC device provided temporary coverage of the defect and wound cleaning. It also allowed a thick bed of granulation tissue to form over the dura. A second case featured a 50-year-old woman who had presented from a remote Pacific Island community with a 12 × 14–cm, necrotic, grossly contaminated eccrine gland carcinoma of the cranial vertex. The wound extended through the calvarium but did not violate the dura. The tumor was
extirpated, and the resulting bony defect was 10 × 12 cm in size with a concomitant scalp defect of 14 × 16 cm. Following tumor resection, the bony edges were covered with local scalp flaps, and the VAC device was placed over the wound at a constant setting of −50 mm Hg. The device was changed 3 times per week for 3 weeks. A thick, 1-cm bed of granulation tissue developed over the dura, and the scalp defect decreased in size by approximately 25%. The patient then underwent split-thickness skin grafting with excellent survival of the graft.

Several reports have addressed the extracranial use of VAC with synthetic matrices to facilitate or expedite host colonization of the matrix. It has been shown that VAC therapy increases concentrations of vascular endothelial growth factor and augments neovascularization. Molnar et al. have demonstrated in a case series that blood vessels colonize a synthetic matrix more rapidly when a VAC device is applied to the matrix. In addition to a decreased time to vascularization, these authors also demonstrated substantially improved graft take rates in patients treated with VAC compared with previously published results. Expedited colonization of a synthetic matrix by host cells in the case of complex cranial wounds with loss of dura is critical to restore the competency of the CSF compartment and eliminate infection.

One concern about using VAC on open cranial wounds is the creation of a CSF fistula or CSF overdrainage. In all of our cases, we attempted to compartmentalize the CSF space by closing the dura primarily or by suturing an autologous graft or synthetic dural matrix to dural margins. In cases in which dural margins were not robust, we reinforced the closure by anchoring the grafts to skin or surrounding soft tissue. We did, on occasion, encounter small dural rents when changing VAC dressings. These were repaired primarily before replacing the VAC sponges. However, the wounds were not watertight in all cases. We found that VAC output was minimal, with < 50 ml total output in all cases. Output decreased for each patient during treatment as wounds healed. No CSF fistula developed as a result of VAC treatment. We have no reservations about using the VAC dressings at any location on the cranium. All of our patients were initially managed in the intensive care unit. While there, the patients received standard care (serial neurological examinations, frequent laboratory studies, and routine neuroimaging) during VAC treatment.

An interesting occurrence in this series was the development of hydrocephalus in 2 of the 5 patients during VAC treatment. The tumor in the patient in Case 1 had significant involvement of the superior sagittal sinus. Several days after resection, CT scans revealed bilateral frontal and parietal edema consistent with venous congestion. There was also a new subarachnoid hemorrhage adjacent to the sagittal sinus probably due to venous infarction. Approximately 5 weeks later, imaging revealed the development of hydrocephalus. We suspect that the hydrocephalus resulted from blood products and proteinaceous debris introduced into the subarachnoid space from surgery and hemorrhagic infarction. Impaired CSF resorption from venous congestion may have also played a role. Hydrocephalus also developed in the patient in Case 3 approximately 4 weeks into her VAC treatment. We also attributed blood products and proteinaceous debris introduced into the subarachnoid space during surgery as the primary cause of the hydrocephalus. She also had a history of cranial irradiation, which may have reduced her capacity to resorb CSF and placed her at higher risk for hydrocephalus from a second insult. We do not suspect VAC therapy as the etiology of hydrocephalus in either of these patients.

Both patients tolerated shunting well, and the hydrocephalus resolved. Shunt infection occurred in neither patient. The patient in Case 1 later died during the same hospitalization. The patient in Case 3 was later seen in clinic 3 months after discharge and was experiencing no problems related to her shunt.

We present a unique patient population with extensive tissue defects including dural defects leading to exposed brain tissue. These cases represent the first reported uses of a VAC device directly on an artificial matrix overlying the brain. Vacuum-assisted closure dressings applied to

**Fig. 5.** Case 3. Photograph showing VAC sponge placed into debrided area.

**Fig. 6.** Case 3. Photograph of successful split-thickness skin grafting procedure.
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AlloDerm overlying the brain are safe, well tolerated, and durable, providing a temporary barrier for the CNS and preventing infection.

Conclusions

The VAC device has the potential to become a vital component of the neurosurgeon’s armamentarium to treat complex cranial wounds that may involve exposed brain tissue.

Disclosure

Wake Forest University has patents pertaining to the VAC device and receives royalties from KCI for the device. Dr. Argenta receives a portion of these royalties by university policy.

Author contributions to the study and manuscript preparation include the following. Conception and design: Powers, Neal, Argenta, DeFranzo, Tatter. Acquisition of data: Powers, Neal, Tatter. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Study supervision: Powers, Tatter.

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