Edwina Paolo, 68, is hospitalized with a nonhealing saphenous vein donor site on her left leg three months after a coronary artery bypass graft. The distal portion of her wound is covered with fibrin, and bone is exposed. After several weeks of traditional wound care and moist dressings, vacuum-assisted closure (VAC) therapy is initiated to prepare the wound bed for a skin graft.

Figure 1 A nonhealing saphenous vein donor site on the left leg just before VAC placement Inset: the VAC device
The nurse caring for Ms. Paolo cuts a piece of sterile polyurethane foam sponge to fit the wound cavity. She places a tube with end and side ports inside the sponge and connects it to a disposable canister loaded into a programmable vacuum pressure pump. She covers the foam dressing and the embedded evacuation tube with a transparent film to hold the sponge and tubing in place, to ensure an airtight seal and to maintain a moist environment.

Negative suction pressure—pressure lower than that of the atmosphere at sea level—is applied by the VAC pump at 75 mmHg, increasing in increments of 25 mmHg (to prevent pain during therapy) to a target pressure of 125 mmHg. The device can be programmed to deliver an amount of negative pressure appropriate to a patient's comfort level and the characteristics of the wound. Continuous negative pressure is applied for 48 hours; then the sponge is changed and treatment is continued. For two weeks, Ms. Paolo receives therapy with intermittent negative pressure—suction is turned on for five minutes and off for two minutes—to remove excess fluids, promote formation of granulation tissue, and restore capillary flow.

ACCELERATING WOUND HEALING

VAC is among the newest and most effective non-surgical technologies available for healing both acute and chronic wounds. Invented by Louis Argenta, a plastic surgeon, and Michael Morykwas, a research scientist, the VAC system accelerates wound healing by promoting the formation of granulation tissue—the beefy red tissue made up of new capillaries, collagen, fibroblasts, and inflammatory cells—in order to completely close or improve the health of a wound in preparation for a skin graft.

Within seconds of injury, coagulation sets wound healing in motion; this is followed by inflammation, fibroplasia, and remodeling. Tissue edema, infection, poor blood supply, and necrotic tissue on the surface of the wound delay healing. A wound's normal healing may also be slowed if the patient suffers from diabetes or poor nutrition or is being treated with steroids or chemotherapeutic drugs.

Large wounds such as Ms. Paolo's, with extensive tissue loss extending through the full thickness of the skin down to underlying tissues, must be closely monitored for healing by "secondary intention," during which the wound bed fills with granulation tissue. The wound edges are drawn together by the contractile forces produced, it is supposed, by the myofibroblasts, which are also believed to produce collagen. The wound edges contract and epithelial cells migrate from the wound's margins toward its center to build a bridge for tissue growth. FIGURES 2-4
Figure 2 The same wound with the VAC in place. Note that tubing exits away from the bony prominence to decrease pressure and to allow for easier ambulation

Figure 3 The granulation wound bed has received a split-thickness skin graft
The negative pressure applied during VAC removes fluid from the area surrounding the wound, thereby reducing localized peripheral edema and increasing circulation. Bacterial counts drop to around 100 or 1,000 organisms per gram of tissue after three or four days of therapy.4 The negative pressure is applied from the foam dressing to the wound surfaces. This uniform mechanical force on the wound surface helps promote cell division.4

After two weeks of VAC therapy, the granulating wound bed in Ms. Paolo's leg is fully developed and ready for a split-thickness skin graft. VAC therapy is then applied over the meshed skin graft at 75 mmHg in continuous mode for five days without interruption. When used on top of skin grafts, the therapy ensures the uniform application of pressure and reduces the shear force that may impair graft adhesion. When the therapy ends, the graft shows 100% adherence to the granulation tissue. Ms. Paolo's activities are gradually increased, and she is able to return home. At her follow-up exam six weeks later, the graft is completely healed.

DEVELOPING THE VAC SYSTEM
Morykwas and Argenta first tested VAC technology on pigs to study the effects of both continuous and intermittent negative pressure on blood flow, the rate of granulation tissue formation, the clearance of bacteria, and muscle flap survival. They found that

- Blood flow level in wounds increased fourfold when 125 mmHg negative pressure was applied
- Rates of granulation tissue formation increased significantly
- Tissue bacterial counts were lower after four days of application
- Muscle flap survival improved (because of increased nutrient blood flow)

The researchers subsequently studied the effects of therapy on 300 patients divided into three groups. The first and largest group (175 patients) all had chronic wounds; open for a minimum of one week with no signs of healing. Most of these wounds (141) were stage III and IV pressure ulcers. The second group (94 patients) had subacute wounds that had dehisced or had bone exposed for less than seven days. The 31 remaining patients had acute wounds, such as eviscerations, that had been open for less than 12 hours.

After application of the treatment, 171 patients in the first group responded favourably to the therapy. Thirty-two percent of the wounds in the patients with pressure ulcers healed completely in two to 16 weeks; 46% of the wounds closed more than 80% and were treated with skin grafts or other methods that completed the healing process; and 15% of wounds healed 50% to 80% and were also treated using other methods. In venous stasis ulcers, granulation tissue started to form after four to six days, and 90% of the wounds reacted well to the first skin graft.

The 94 subacute wounds responded even more rapidly to the therapy than did the chronic wounds. Twenty-six of the wounds healed completely and the remaining 68 wounds contracted, becoming small enough to be healed with use of split-thickness skin grafts or other methods.

The patients with acute wounds developed granulation tissue at an extremely rapid rate and healed more quickly than did patients in the other two groups. The wound was covered with a graft, a flap was rotated into the healthy granulation tissue, or the wound closed by itself. The studies did not include a control group.
INDICATIONS AND CONTRAINDICATIONS

VAC therapy may be used to treat both acute and chronic wounds, including those resulting from pressure, trauma, infection, IV extravasation, arterial and venous insufficiency, and skin grafting. Following a split-thickness skin graft, for example, the VAC assists with evacuation of fluid from under the graft and prevents shear force from displacing the graft. VAC therapy has been used to treat a variety of wounds, including those involving the lower extremities, chest, abdomen, sacrum, back, and orbit of the eye. Kinetic Concepts, Inc. (KCI), the product's manufacturer, doesn't currently advise use of VAC therapy for wounds with necrotic tissue, wounds with cancer in the wound margins, wounds that communicate with fistulous tracts, or wounds with untreated osteomyelitis.1,2 Although anticoagulation treatment is not a contraindication, close monitoring of wound drainage and laboratory values is required.1,4 (See Guidelines for VAC Therapy, above.)

SPECIAL PATIENT CARE RECOMMENDATIONS

Pain management Patients may report pain when the foam dressing is being applied or changed, or when the pump's suction fluctuates during intermittent therapy, which is used within 24 to 48 hours of the start of VAC therapy. If analgesics were required during traditional gauze dressing changes, they will probably also be necessary, at least initially, during VAC therapy. Patients with
acute wounds have reported that pain resolves approximately 20 minutes after the initial foam compression. Nursing recommendations include the following.

- For pain related to excessive adhesion of tissue to the foam, use small amounts of normal saline to loosen the sponge before gently removing the dressing. If the problem persists, more frequent dressing changes may be needed or a topical anaesthetics can be administered through the tubing before removal of the foam.

- For persistent pain at the intended target pressure, decrease the pressure to 50 mmHg for approximately 20 minutes, and then slowly increase in 25-mmHg increments until you reach the target pressure.

- For pain associated with intermittent VAC therapy, consider switching to continuous therapy.

- For fragile skin-related discomfort during removal of the transparent film, use a skin barrier or frame the wound with a hydrocolloid dressing.

**Maintaining an airtight seal** To avoid wound desiccation, the wound must stay sealed once therapy begins. The most difficult wounds to seal are those around the joints and near the sacrum. Air leaks commonly occur at the tube exit site and from wrinkling of the film. Other indications of leakage are a sponge that hasn't collapsed a hissing noise, or an alarm that sounds on the pump. An extra pair of hands during application can help create the seal and prevent air leaks. The following suggestions may also help to maintain an airtight seal.

- Shave hair around the wound cavity.

- Cut the transparent film to extend at least 5 cm beyond the wound margins.

- Avoid wrinkles in the transparent film.

- Reinforce the tube exit site with an additional film layer.

- Pinch the area around the tubing exit—or any area that may appear to be a leak source, such as a skin fold—as the pump is activated.
• Patch leaks with transparent film.

• Use several small strips of transparent film to hold the dressing in place before covering the entire dressing with one large piece of film.

• Avoid using adhesive remover when removing the transparent film. It leaves a residue that subsequently hinders film adherence.

**Maintaining skin integrity** Skin integrity may be impaired in patients who are receiving corticosteroids or who have had previous radiation therapy, as a result of the repeated removal of the transparent film dressing.

To reduce this risk,

• apply a skin barrier product.

• use a nonadherent plastic wrap to secure the sponge foam to an extremity wound. Secure the plastic wrap with tape and cover with a bandage to ensure an airtight seal. This technique requires frequent monitoring of the color, temperature, sensation, and movement of the extremity as well as checking for proper foam dressing alignment.

• rotate the tubing exit site to avoid pressure points.

• pinch the transparent film completely around and under the tubing to prevent pressure damage.

**Wound drainage** Frequent assessment of color, volume, and odour of drainage fluid will aid in the detection of localized infection. Normal drainage for a patient undergoing VAC therapy depends on the patient's disease process and the size of the wound. For example, a patient with a fasciotomy may initially produce more drainage fluid during the first 48 hours of therapy than will a patient with a vasculitic ulcer. Take the following measures to avoid localized infections during periods of high drainage.

• Change dressings frequently. Although the dressing is usually changed every 48 hours, it may be changed as often as every 12 hours.

• Administer hydrotherapy between dressing changes.
• Reassess VAC use. Consider switching to gauze dressing with local antibiotic treatment.

**Dressing changes** The VAC dressing change can be performed at the bedside, in the operating room after wound debridement, or during a skin-grafting procedure. Rotate the tubing exit at each dressing change to reduce the potential for tissue damage from pressure.

**Multiple wounds** Two cost-effective ways to treat more than one wound are to connect the sponge tubing to a Y connector or, if they're not in close proximity, to bridge the wounds with foam. The bridge will assure negative pressure delivery to each wound. To avoid maceration, the skin beneath the bridge should be protected with a hydrocolloid dressing or nonadherent gauze dressing.

**Patient mobility** Wounds should be exposed to negative pressure as long as possible to promote wound closure. But patients may ambulate during VAC therapy by using the battery mode on the pump unit or a portable version of the machine, called the "miniV.A.C." At our institution, patients are not disconnected from the device for longer than 30 minutes a day.

**Emotional support** Patients who have undergone previous wound treatments may be anxious about VAC therapy, so you'll need to provide reassurance. Body image concerns may also arise as patients endure being connected to a machine for long periods of time. Some patients may feel immobilized and tied down.

**Discharge planning** Sending patients home with VAC therapy requires extensive planning and collaboration among physicians, nurses, discharge planners, social workers, and KCI to ensure that the patient obtains the necessary equipment and training. Determine reimbursement for VAC therapy prior to discharge. Not all insurance policies cover the therapy. On October 1, Medicare began assigning a unique code for VAC coverage under its outpatient medical program. In most cases, a home health nursing referral will be needed for VAC application and wound monitoring. KCI offers an educational session for the patient, family, and home health agency on the first home visit after discharge, to ensure proper usage. Patients may be discharged with a moist dressing in the wound bed instead of the foam dressing to decrease the risk of maceration if the VAC is not in place during discharge. The patient and family are taught how to manage the wound until they get home; once there, a home health nurse can assess the wound.

**Staff education** At our facility, KCI conducted educational sessions for the nursing staff on the plastic surgery nursing units as well as for the surgical clinical nurse specialists and educators. Procedural guidelines were developed and placed on the department of nursing's intranet. Ongoing educational sessions were instituted, and a mobile learning cart was created. The cart contains a poster
explaining the procedures involved a VAC unit and supplies for hands-on practice, a wound model with a properly fitted VAC dressing, and print and video resources. The learning cart can easily be transported to any nursing unit.

REFERENCES


