

# Vacuum-assisted Wound Closure after Resection of Musculoskeletal Tumors

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Resection of musculoskeletal tumors may result in large soft tissue defects that cannot be closed primarily and require prolonged dressing changes and complex surgical interventions for wound coverage. We retrospectively reviewed 23 patients with such defects treated with a vacuum-assisted wound closure system and compared the outcome of these patients with a control group. The study group included 15 women and eight men who had their wounds located at the back (two), pelvic girdle (11), thigh (eight), and leg (two). Treatment included sealed wound coverage with polyurethane foam and overlying tape connected to a vacuum pump. This system was disconnected and changed every 48 hours for 7 to 19 days, after which all defects were reduced in size by an average of 25% and covered with a viable granulation tissue. This allowed primary closure in seven patients, primary closure with skin grafting in 14 patients, and healing by secondary intention in two patients. Compared with the control group, patients in the study group had shorter hospital stays and number of surgical interventions and greater rates of primary wound closure. The use of vacuum-assisted wound closure facilitates wound healing and primary wound closure in patients who have a large soft tissue defect after resection of a musculoskeletal tumor.

**Level of Evidence: Therapeutic study, Level III (retrospective comparative study). See the Guidelines for Authors for a complete description of levels of evidence.**

Resection of large musculoskeletal tumors often necessitates removal of substantial volumes of bone and soft tissues. Such resections occasionally result in a major soft tissue defect that cannot be closed primarily and are further associated with increased risk of flap ischemia, wound dehiscence, and deep infections.<sup>5,13</sup> Those sequelae are even more prominent when surgeries are done for recurrent disease or in a previously irradiated field.<sup>4,10</sup> As a result, extensive skin grafting, delayed primary closures or healing by secondary intention, free myocutaneous flaps, and, occasionally, amputations are not uncommon in these situations.<sup>3</sup>

Vacuum-assisted wound closure (VAC) was first reported in the 1990s; the rationale behind its use was that continuous negative pressure evenly spread along the surface of an open wound will remove fluids and tissue debris from the extravascular space and improve circulation and proliferation of reparative granulation tissue.<sup>1,16,17</sup> After confirmation of its efficacy in animal studies and controlled human studies, VAC was shown to be effective for treatment of open orthopaedic, gynecologic, abdominal, and chest wounds; it decreased the amount of tissue edema, facilitated bacterial clearance, and decreased the surface area of the wound, all of which resulted in rapid formation of profuse granulation tissue.<sup>2,6,8,9,11,12,14,15,18,19</sup> DeFranzo et al<sup>6</sup> described the use of VAC in 75 patients with open wounds of the lower extremities with exposed tendons, bones, and hardware that otherwise would have required free flap coverage.<sup>6</sup> At the conclusion of treatment, 58 wounds (77%) subsequently were closed with a split-thickness skin graft, 12 wounds (16%) were treated by delayed primary closure, and only five wounds (7%) required a musculocutaneous or fasciocutaneous flap.<sup>6</sup>

We speculated that VAC also could be used for treatment of large and deep soft tissue defects remaining after

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**TABLE 1. Histologic Diagnoses**

Tumor Location	Tumor Type	Number
Soft tissue tumors	High-grade sarcomas	16
	Squamous cell carcinoma	1
	Metastatic melanoma	1
Bone tumors	Chordoma	3
	Chondrosarcoma	2
Total		23

resection of musculoskeletal tumors. We questioned whether this approach would result in greater rates of wound closure, shorter hospital stays, and lower rates of surgical débridements.

**MATERIALS AND METHODS**

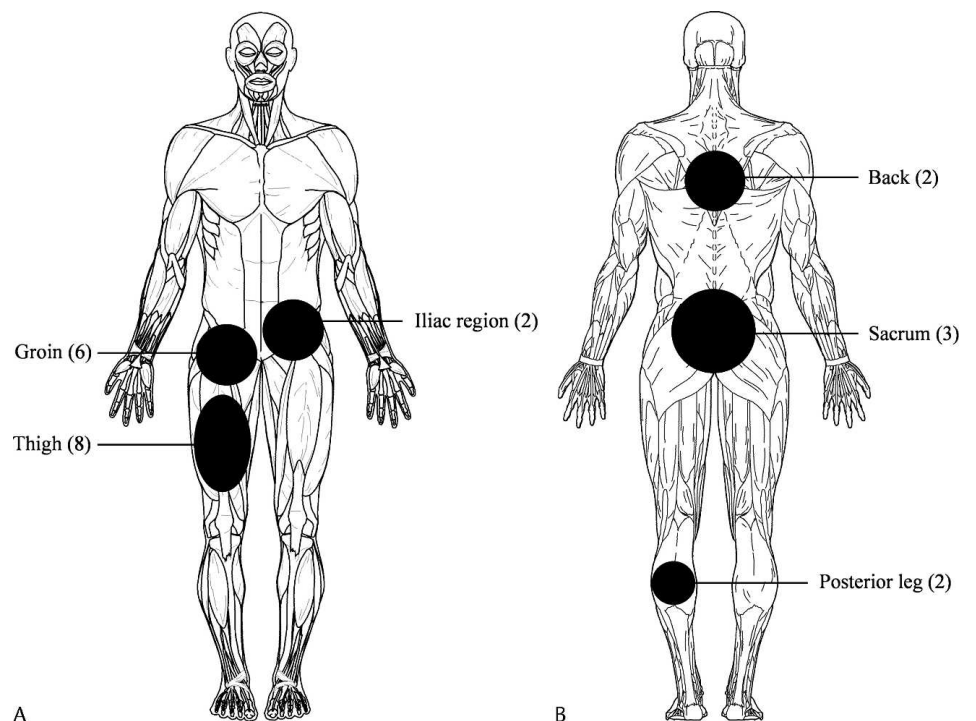
We retrospectively compared 23 consecutive patients with large defects after tumor resection treated in 2002 and 2003 with VAC to a control group of 39 patients with similar defects who were treated before the introduction of this technique to our service. The study group included 15 women and eight men who ranged in age from 36 to 72 years (median, 46.5 years) and who initially were diagnosed as having 18 soft tissue and five bone tumors (Table 1). Anatomic locations of the soft tissue defects included the back (two), pelvic girdle (11), thigh (eight), and leg (two) (Fig 1). Area of the soft tissue defects ranged from 64 cm<sup>2</sup> to 520 cm<sup>2</sup> (median, 320 cm<sup>2</sup>; mean, 345 cm<sup>2</sup>). Six wounds (leg, two;

thigh, three; back, one) had an exposed bone or tendons in the wound surface, and an open knee was present in one patient with a distal thigh defect. None of the patients had an exposed artery or nerve.

Nine patients were referred after chemotherapy and seven after radiation therapy. In four patients, the soft tissue defect had been created after tumor resection, in 18 after débridement of a complicated surgical wound, and in one patient after débridement of radiation-induced skin necrosis (Table 2). Patients who had gross infection or residual tumor at the surgical site were not referred for treatment with VAC but rather for definitive surgical treatment, wound débridement, or extension of margins of resection, respectively.

The VAC system consists of: (1) a sterile, elliptic polyurethane foam, which is connected to a plastic evacuation tube and is available in three sizes; (2) a transparent self-adhesive drape; (3) a collection canister; and (4) a vacuum pump equipped with a handle, which allows the patient to ambulate.

Before application of the VAC system, devitalized tissue is meticulously removed from the surface of the wound under sterile conditions. After wound débridement, the polyurethane foam is applied on the wound surface. The foam is trimmed to conform to the size and shape of the open wound and is placed in direct contact with its entire surface. It is imperative that the foam dressing be placed in direct contact with the deepest surface of the wound and, in large wounds, several foam dressings can be placed in close contact to one another. The foam dressing and the evacuation tube then are covered with the adhesive drape, extending 5 cm beyond the margins of the wound to the adjacent intact skin and forming an airtight seal. The evacuation



**Fig 1A–B.** Twenty-three patients had soft tissue defects remaining after surgery. (A) The anatomic locations of anterior soft tissue defects for 16 patients and (B) posterior soft tissue defects for seven patients are shown.

**TABLE 2. Indications for Surgery**

Tumor Type	Indication for Surgery	Preoperative Radiation Therapy	Number of Patients
Primary tumor	Wound defect after tumor resection	—	2
	Wound defect after debridement of flap necrosis	1	10
	Wound defect after debridement of deep infection	1	3
Recurrent tumor	Wound defect after tumor resection	1	2
	Wound defect after debridement of flap necrosis	2	3
	Wound defect after debridement of deep infection	1	2
Radiation-induced skin necrosis		1	1

tube is connected to the collection canister and placed in the receiving slot of the vacuum pump to create a closed system (Fig 2). A continuous negative pressure of 125 mm Hg then is applied.

The foam dressing is changed at bedside, and the wound is evaluated every 48 hours, during which the collection canister is replaced one to three times, depending on the rate of fluid secretion through the wound surface. Treatment with VAC is terminated when the wound is covered with viable and thick granulation tissue, which allows primary closure, skin grafting, or healing by secondary intention, depending on the size of the remaining defect and overall medical status of the patient (Figs 3–6).

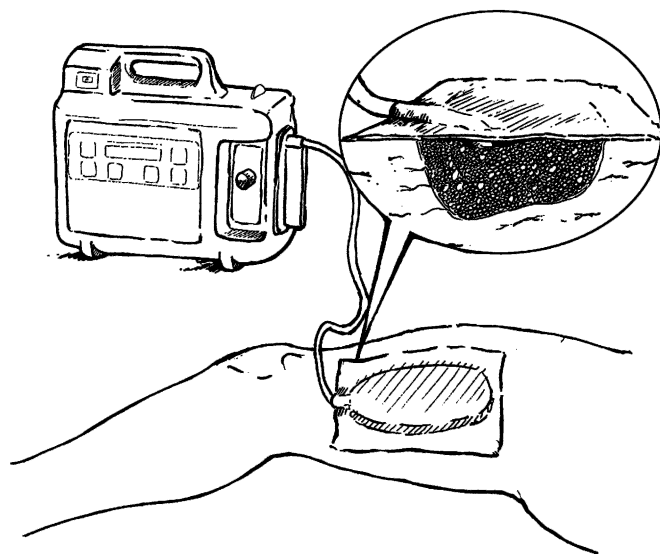
All patients were followed up for 12 to 27 months (median, 19 months). An orthopaedic oncologist (JB) analyzed the clinical records and operative reports. Data on histologic diagnoses, size of soft tissue defects, duration and frequency of dressing change, and complications were retrieved and recorded. We additionally

reviewed a control group of 39 patients with similar postoperative, large soft tissue defects remaining after resection of musculoskeletal tumors, treated between May 1999 and May 2002, before the application of VAC to our services. This control group, treated with daily dressing changes and repeated wound débridements, included 21 men and 18 women who had their wounds located around the pelvic girdle (17), groin (three), thighs (12), and legs (seven). Their data were analyzed for the type of surgical intervention, extent of hospital stay, and outcome.

Statistical analysis included Log rank and Breslow tests, which were used independently to compare cumulative survival data and determine statistical significance. Tests were considered significant if the *p* value was less than 5%.

## RESULTS

The VAC treatment period in the study group lasted from 7 to 19 days (mean, 14.5 days; median, 11.5 days). Ten patients were discharged from the hospital after an average of 4.5 days (range, 4–6 days), and their dressings were changed on an ambulatory basis. Wounds that had exposed



**Fig 2.** A diagram shows application of VAC. Coverage of the polyurethane foam with an adhesive tape extends beyond its margins to create an airtight seal and connects the evacuation tube to the collection canister.



**Fig 3.** A soft tissue defect around the groin remaining after resection of a high-grade sarcoma is shown. The wound edges were approximated with tension sutures.



**Fig 4.** A polyurethane foam is applied to the wound surface, sealed with a tape, and connected via an evacuation tube to the vacuum pump.

bone or tendons in their surface or had been treated previously with radiation required longer ( $p < 0.05$ ) treatment with VAC (average, 14.5 days) compared with wounds that had neither of these two features (average, 9.5 days). The one patient with an open knee had the longest treatment period with VAC (19 days). During dressing changes, none of the study patients had excessive bleeding, experienced substantial pain, or required sedative agents before or during dressing change. None of them had clinical evidence of superficial or deep overt wound infection. At the termination of treatment, all 23 soft tissue defects were covered with a thick and viable granulation tissue. There was an average 25% reduction (range, 10%–35%) in the area of the soft tissue defect in 20 patient; two soft tissue defects around the leg and one sacral defect showed no reduction in size. Primary closure of the soft



**Fig 5.** After 8 days of treatment with VAC, the wound surface is covered with granulation tissue and is ready for primary closure.



**Fig 6.** The wound is shown 3 months after primary wound closure.

tissue defect was done in seven patients, combined primary closure with skin grafting in 14 patients, and the wounds of two patients healed by secondary intention. In the latter two patients, surgery for the purpose of wound closure was not done because of other medical conditions that precluded additional surgical intervention (pneumonia, myocardial infarction). After wound closure, the patients remained hospitalized for an additional 6 to 11 days (mean, 7.5 days; median, 8.2 days). Overall, hospital stay of the study group was 4 to 30 days (mean, 18.5; median, 20 days). At the most recent followup, all wounds had healed completely with no evidence of wound dehiscence or infection.

Patients who had their soft tissue defects treated with VAC had shorter ( $p < 0.01$ ) hospital stays, lower rates ( $p < 0.01$ ) of surgical wound débridements, and greater rates ( $p < 0.025$ ) of primary wound closure, with or without skin graft, than patients who were not treated with VAC. Hospital stay of the control group was from 15 to 72 days (mean, 37 days; median, 39 days), during which 24 surgical wound débridements were required in addition to the initial 39 surgical procedures. By the end of the treatment period, primary wound closure was done in eight patients, combined primary closure with skin grafting was done in 10 patients, wound coverage with free flap transfer was done in three patients, healing by secondary intention occurred in 15 patients, and lower extremity amputation was done in three patients.

## DISCUSSION

Soft tissue defects after resection of musculoskeletal tumors pose a unique clinical concern; a prolonged and com-

plicated healing process is expected because of the relatively large area of these defects. Moreover, patients with these defects frequently have chemotherapy and radiation therapy, which have consequences associated with the healing process. In addition to the high cost of a prolonged healing process, it also may cause a delay in administration of adjuvant treatments. Our study was designed to evaluate the efficacy and safety of VAC in these patients. It is a retrospective and controlled study, based on a relatively small study group with partially missing data, but differences in outcome are statistically significant.

Compared with repeated dressing change, the use of VAC was shown to be associated with a reduced hospital stay, reduced number of surgical interventions, and greater rates of primary wound closure at the termination of treatment. Wounds that had exposed bone or tendons in their surface required longer treatment with VAC until viable granulation tissue was formed, probably because of the relatively poor blood supply to these regions. Nevertheless, the average treatment period of that group was shorter than the average treatment period of the control group.

The biologic mechanism for accelerated wound healing with VAC has not been defined. Two mechanisms, however, have been suggested to be involved in the facilitated wound healing induced by VAC: (1) removal of interstitial fluids along with inhibitory tissue factors that are assumed to be present, and (2) a decrease of capillary and venous afterload and, consequently, improvement of the delivery of oxygen and nutrients.<sup>1,7,16</sup> Meticulous débridement of nonviable tissue before initiation of VAC is mandatory. That tissue allows the uncontrolled growth of bacteria with production of lytic enzymes, bacterial toxins, and other substances that retard wound healing.<sup>1,7</sup>

Complications associated with VAC are infrequent; when they do occur, they include pain, excessive ingrowth of granulation tissue into the foam, and erosion of neighboring large blood vessels.<sup>1,6</sup> Pain usually is associated with dressing change and is managed easily with oral or intravenous narcotics. Excessive growth of granulation tissue into the sponge was observed when the sponge had been in place for longer than 48 hours.<sup>17</sup> Bleeding from this hypervascular tissue may be encountered during dressing change and usually can be controlled by applying pressure. The protocol of VAC dressing change every 48 hours circumvents the accumulation of large volumes of nonviable tissue and usually prevents overgrowth of granulation tissue into the polyurethane foam and associated pain and bleeding during or after dressing change.

In this small series VAC was a safe and reliable technique in facilitating wound healing and allowing closure with relatively simple surgical techniques. Vacuum-assisted wound closure is easily accomplished by the nursing staff. It is associated with a shorter hospital stay, re-

duced numbers of surgical interventions, and greater rates of primary wound closure. We recommend the approach for patients with soft tissue defects remaining after resection of musculoskeletal tumors.

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