Table 3: Wound etiology in patients (*n* = 66)

Wound etiology	Number of patients
Trauma	2
Wound dehiscence	2
Post-surgical	56
Skin infection	1
Pressure sore	1
Sickle-cell/vascular disease	1
Cutaneous acute lymphoblastic leukemia	1
Purpura fulminans	1
Extravasation injury	1

Table 4: Indication for negative pressure wound therapy (*n* = 66)

Indication	Number of patients
Local wound care	44
Skin graft/Integra fixation	11
Brachytherapy	1
Support of primarily-closed incision	10

Table 5: Anatomic location of wounds, and exposed structures at wound base (wounds = 74)

	Number of wounds
Wound location	
Head and neck	4
Trunk	13
Upper extremity	10
Lower extremity	47
Exposed structures	
Bone	11
Fascia	4
Tendon	7
Nerve	3
Endoprosthesis	2
Skin (incisional wound VAC)	11
Muscle or fat	36

VAC: vacuum-assisted closure

Table 6: Outcomes of negative pressure wound therapy utilization (*n* = 66)

	Number of patients
Mechanism of closure in healed wounds	**(*n* = 60)**
Secondary intention	47
Skin graft/Integra	6
Local flap/tissue closure	4
Delayed primary closure	3
Characteristics of non-healing wounds	**(*n* = 6)**
Wound recurrence	2
Died of primary disease before wound closure	1
Died of necrotizing fasciitis	1
Amputation	2

had NPWT therapy twice: once before reconstruction and again for skin graft fixation. One patient had NPWT applied three times: first, for local wound care; second, for fixation of integra dermal regeneration template (Integra Life Sciences, Plainsborough, New Jersey, USA); and third, for skin graft fixation. Three patients had two separate wounds, requiring two separate wound VACs. In total, NPWT was used 74 times in 66 patients.

Wound etiology is presented in Table 3. Fifty-six patients had surgically-created wounds. Two patients had traumatic wounds. Two patients had wound dehiscence requiring NPWT. One patient had pressure ulcer. There was one case of sickle-cell induced avascular skin necrosis. One case of cutaneous acute lymphoblastic leukemia resulted in full thickness skin loss. One patient with osteosarcoma who was treated with methotrexate developed a case of purpura fulminans that required debridement and NPWT. One wound resulted after debridement of a cutaneous infection. There was one wound that resulted after an extravasation injury. Three patients had amputations that required NPWT; 2 of them for open wounds and 1 for an incisional wound. NPWT was applied immediately in the event of surgically-created wounds, and it was delayed for a range of 1 to 21 days in the remaining patients.

NPWT indication is shown on Table 4. NPWT was used for local wound care in 44 patients, skin graft and/or integra fixation in 10 patients, local wound care in the setting of brachytherapy in one patient, and incisional support in 11 patients. With respect to incisional NPWT, 4 patients had previous external beam radiation therapy, and 2 patients had previous brachytherapy. There were 10 extremity wounds and 1 scalp wound that utilized incisional NPWT. All wounds were healed without complications at the time incisional NPWT was discontinued (5-7 days postoperatively).

Table 5 shows the anatomic distribution of wound NPWT usage. NPWT was used in the head and head/neck in three patients, trunk in 13 patients, upper extremity in 10 patients, and lower extremity in 40 patients. Eleven wounds had bone exposure in the wound bed; four had exposure of fascia; seven had tendon exposure; three had nerve exposure; and two patients had exposure of their endoprostheses. The remaining had either skin, fat, or muscle exposed.

The respective wounds ultimately healed in 60 patients [Table 6]. Wounds healed by secondary intention in 47 patients, skin grafting in four patients, adjacent tissue transfer in three patients, split-thickness skin graft (STSG) and Integra in two patients, local flap in one patient, and delayed primary closure in three patients. Wounds failed to heal in 2 patients who had recurrence of their wound at last follow up, in 1 patient who died of necrotizing fasciitis, in 1 patient who died of primary disease, and in 2 of the 3 patients who required amputation. No patients required free flap to reconstruct their wound.

At the time of their last follow-ups, 2 patients had died of their primary disease. One patient died secondary to necrotizing fasciitis. One patient had a below-knee

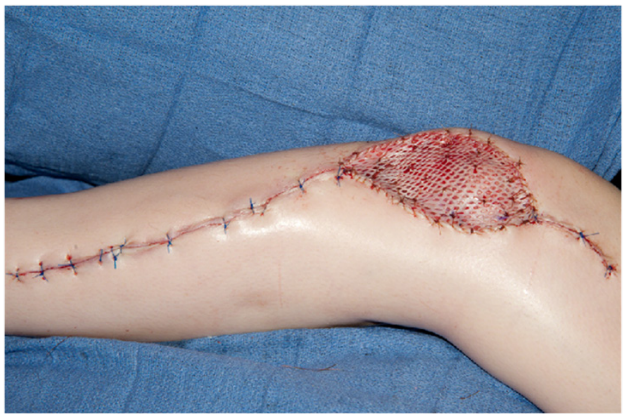

Figure 1: Right leg after limb-salvage procedure, with gastrocnemius muscle flap and skin graft coverage of central wound

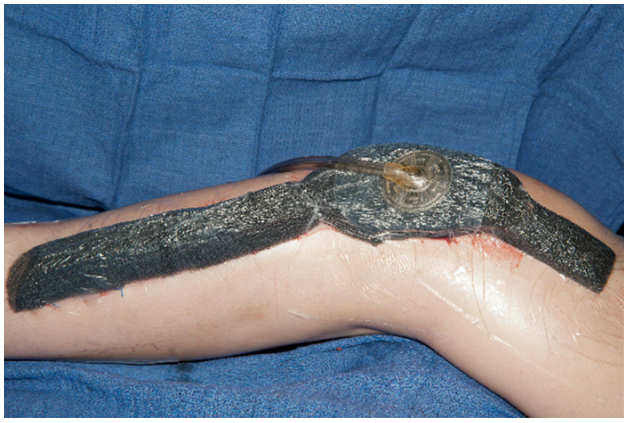

Figure 2: Surgical site with wound vacuum-assisted closure in place

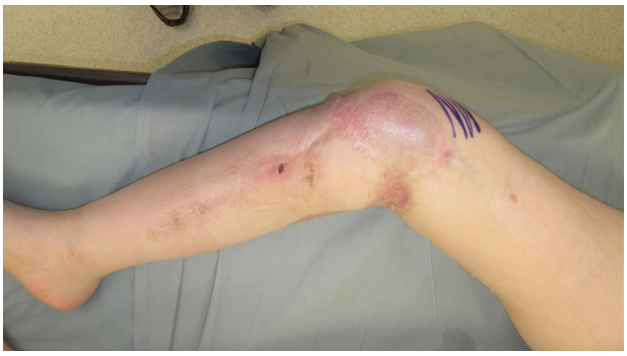

Figure 3: Surgical site after wound has healed

amputation secondary to intractable pain, unrelated to his wound. Three patients had above-knee amputations: 1 secondary to local tumor recurrence; 1 due to a failed free flap reconstruction; and 1 from implant failure.

NPWT was applied with a negative pressure of 125 mmHg, except in 1 scalp case in which the negative pressure was set to 75 mmHg. NPWT was used under continuous pressure except in 1 patient where intermittent pressure was used for a cheek wound. The regular black Granu-foam sponge was used in all but 11 cases. Silver-impregnated Granu-foam sponges were used in 7 cases, and 1 case used the White-foam sponge for an open abdominal wound. The average wound size was 36 cm^2 (median, 27 cm^2; range, 4-250 cm^2). The average number of days to achieve wound closure was 39 days, with a median of 21 days and a range of 3 to 236 days.

In general, patients tolerated NPWT with minimal morbidity. One patient who had NPWT for fixation of STSG developed cellulitis under the sponge secondary to methicillin-resistant *Staphylococcus aureus*. The cellulitis resolved after the discontinuation of the NPWT and healed completely with no further interventions. Seven patients developed maceration of the skin under the wound VAC dressing, requiring temporary discontinuation of NPWT.

DISCUSSION

Wound issues are not uncommon in the oncology population due to various factors including radiation, chemotherapy, and decreased immunity.[16-19] NPWT has showed some promising results in the pediatric population.[12-15] Our study assesses the safety and efficacy of NPWT therapy in the pediatric oncology population.

NPWT therapy offers several advantages over traditional wound care. Because dressing changes are only done every two to three days, the often painful dressing change experience is less traumatic, simplifying wound care for both the patient and the provider. Drainage of the wound is contained in a transparent container, and wound leakage is far less likely compared to traditional wound care. These factors help improve compliance and reduce patient anxiety regarding wound care.

In this study, most wounds were managed successfully with NPWT. The wound VAC was applied in all our patients without any problems regardless of the patient's age or the location or size of the wound.

Of the total 66 patients treated with NPWT, 69% of the wounds healed completely with no intervention, and 20% required delayed surgical closure. NPWT was discontinued temporarily secondary to skin maceration or cellulitis in 12% of patients. Wound care was converted to traditional saline wetted gauze in those cases, and all wounds subsequently healed completely without surgical intervention. No problems of retained sponge material, device malfunction, or inability to apply the wound NPWT were reported in our study. Complications were seen in 12% of the patient population.

The indications for NPWT have expanded since its first introduction. We started using NPWT directly on primarily-closed incisions in the setting of previous radiation therapy, reoperation, and chronic steroid use in 2009. Initially described in patients with multiple comorbidities, this technique was met with moderate success and has resulted in the introduction of NPWT