Fourth-Degree Burns to the Lower Extremity with Exposed Tendon and Bone: A Ten-Year Experience

Brian M. Parrett, MD, Bohdan Pomahac, MD, Robert H. Demling, MD, Dennis P. Orgill, MD, PhD

Fourth-degree extremity burns involve muscle, tendon, and bone, often leading to amputation or significant functional impairment. We report our 10-year experience (1995-2004) at an urban burn center with fourth-degree burns to the lower extremity to characterize treatments and outcomes. Twenty-one patients (40 limbs), mean age of 45 years, were treated for fourth-degree lower-extremity burns with the average extremity burn size of 24% TBSA (range, 2–36%) and a mean fourth-degree burn size of 9% TBSA (range, 2–18%). A mean of eight operations were required for limb salvage. Six free-tissue transfers, 2 fillet flaps, 14 local flaps, and multiple skin grafts were performed. Five patients underwent tibial burring for granulation tissue stimulation, and the subatmospheric pressure device was used in eight patients. Seven limb amputations (18%) were required in four patients, and 76% of patients were ambulatory on follow-up. The mean hospital stay was 76 days with high rates of cellulitis, deep vein thrombosis, and bacteremia. Patients treated with flap closure had a significant decrease in the number of operations required for limb salvage. Fourth-degree lower-extremity burns require multistage reconstructive procedures using multiple levels of the reconstructive ladder but limb salvage is possible in a majority of cases. (J Burn Care Res 2006;27:34–39)

Fourth-degree burns extend beyond the subcutaneous tissue with necrosis of underlying fascia, muscle, tendon, and bone.[1,2] The term fourth degree rarely is found in the literature because it usually is associated with lethal injury; however, recent efforts have been made to better classify these wounds.[2]

Extremity burns present complex reconstructive problems.[1–5] Fourth-degree extremity burns are devastating because skin grafts do not readily take as the result of insufficient soft tissue for graft support, and multistage reconstructions often are required. Nuchtern et al[5] evaluated their treatment of fourth-degree hand burns and found high rates of amputation, functional impairment, and repeat operations.

From the Division of Plastic & Reconstructive Surgery and Division of Trauma, Burns, and Critical Care, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts.
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Address correspondence to Dennis P. Orgill, MD, PhD, Brigham and Women's Hospital, Harvard Medical School, 75 Francis Street, Boston, Massachusetts 02115.

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The reconstructive ladder is the surgical principle of wound closure from the simple to the most complex alternative (secondary intention to free tissue transfer).[6] Multiple levels of the ladder have been used to treat extremity burns. The goal is soft-tissue coverage of bone, tendons and neurovascular structures, and restoration of function. Local flaps into defect areas have been used with success.[7–11] Free-tissue transfer for burns with exposed tendon and bone allows limb salvage in many cases.[12–16] Burring into the outer table of bone to expose vascularized tissue has been used to stimulate granulation with subsequent skin grafting.[17] The vacuum-assisted closure device (VAC®, KCI, San Antonio, TX) has proven useful in treating traumatic wounds, resulting in granulation tissue, even in areas of exposed bone.[18–20] This technology has shown success in preparing burn injuries for grafting.[21]

Multiple treatments are thus available for severe lower-extremity burns. The purpose of this study is to evaluate our treatment of fourth-degree lower-extremity burns to determine outcomes and strategies with the goal of optimizing care and sharing our experience with these difficult injuries.

PATIENTS AND METHODS

From January 1, 1995, to January 1, 2005, 21 consecutive patients with fourth-degree burns to the lower extremity were admitted to Brigham and Women's Hospital Burn Center in Boston, Massachusetts. Charts and operative reports were retrospectively reviewed to collect demographics, record injury severity and extent, and evaluate treatment.

The depth, location, and type of burn, the extent expressed as TBSA, and the percentage of the lower extremity burned (of TBSA) were recorded for each case. All patients with fourth-degree burns to the legs or feet (through fascia and involving muscle with exposed tendon and bone) who survived the initial resuscitation were included. Lower-extremity fourth-degree burn area (of TBSA) was recorded from operative reports. The number of operations for limb reconstruction, type of soft tissue coverage, and use of wound care technologies, including the VAC® device, was recorded.

Outcomes assessed with at least 1-year follow-up were amputations, acute length of stay, complications involving the reconstructed limb, and ambulatory status, defined as the primary means of self-transportation recorded from physical therapy and physician clinic notes. Statistics were performed according to the Student's *t* test for independent samples comparing the number of limb salvage operations between flap closure and nonflap closure patients with a P value $\leq .05$ considered significant.

Table 1. Patient and burn profile

Patient	Age (Years)/Sex	% Extremity Burns (TBSA)*	% TBSA Burns
1	23/M	10/8	20
2	40/M	29/18	90
3	30/F	36/6	36
4	70/M	8/6	8
5	39/M	6/5	6
6	31/M	36/10	80
7	70/M	27/10	56
8	44/M	25/15	25
9	36/M	36/10	90
10	22/M	23/6	60
11	18/F	36/10	65
12	49/M	28/14	28
13	64/M	2/2	2
14	44/M	20/18	20
15	82/F	15/7	15
16	36/M	36/6	90
17	62/M	28/8	28
18	42/F	20/8	20
19	67/M	12/9	12
20	37/M	30/12	30
21	40/M	36/10	40

*Percent lower-extremity burned of TBSA (second- to fourth-degree inclusive)/% lower-extremity fourth-degree burns expressed as TBSA.

RESULTS

The authors treated 21 patients with fourth-degree burns to 40 lower extremities who were, on average, 45 years of age (Table 1). Mechanisms of injury included 16 flame, 3 contact, 1 electrical, and 1 chemical burn. The mean TBSA burned was 39%. The average lower-extremity TBSA burned was 24%, and six patients sustained total bilateral lower-extremity burns (36% TBSA). The mean lower-extremity fourth-degree burn area with exposed muscle, tendon, and bone was 9% of TBSA.

Table 2 summarizes the procedures performed for limb salvage. A mean of eight operations per patient were required for limb salvage. A majority of patients (71%) underwent immediate burn débridment on hospital day 1 followed by multiple excisions with skin grafting. Split-thickness skin grafts (STSGs) were performed as early as the first débridment, with an average of six grafts per patient. More-advanced reconstruction was performed when wounds appeared stable.

Twelve patients underwent flap closure. Fourteen local flaps were performed, including seven fasciocutaneous, three gastrocnemius, two anterolateral thigh, and two soleus flaps. No local flaps failed.

Six free flaps were performed: a radial forearm flap for coverage of an exposed Achilles tendon and calcaneous bone (patient 3), three transverse rectus abdominus flaps for coverage of exposed foot bone and tendon (patient 5) and exposed tibias (patients 8 and 21), a latissimus dorsi flap for coverage of an exposed patella (patient 11), and an anterolateral thigh flap for coverage of an ankle joint (patient 20). One flap developed ischemia (patient 21) and was salvaged after two repeat operations. The average time from burn injury to free flap closure was 60 days (range, 7–121 days).

Two fillet flaps using viable foot tissue, one as a free flap and the other as a pedicle flap, were performed in patient 14 to salvage bilateral below-knee amputation (BKA) sites. The right fillet flap became infected and was removed with subsequent débridment.

Because of extensive TBSA burns and inadequacy of tissue for flap closure in patients 2, 6, 9, and 16,

Table 2. Operative course and outcomes

Patient	LOS (Days)	No. Operations	Flap Type	Amputation	Ambulation*	Complication
1	36	4	Bilateral anterolateral thigh	–	Independent	–
2	170	13	–	Bilateral BKA	Wheelchair	Bacteremia
3	30	6	Free radial forearm	–	Independent	Cellulitis
4	21	2	Three Fasciocutaneous	–	Support	–
5	37	3	Free rectus abdominus	5 left toes	Independent	–
6	57	16	–	–	Support	Cellulitis
7	49	9	–	–	LTF	–
8	30	8	Soleus, gastrocnemius,free rectus abdominus	Bilateral BKA	Independent	Bacteremia, cellulitis
9	97	16	–	–	LTF	Cellulitis
10	96	9	–	–	Independent	–
11	137	10	Free latissimus dorsi	3 left toes	Support	Cellulitis
12	41	4	Soleus, gastrocnemius	–	Support	bacteremia
13	10	3	–	–	Independent	–
14	52	6	Pedicle fillet foot, free fillet foot	Right AKA, Left BKA	Wheelchair	Free fillet flap necrosis
15	137	9	–	–	Wheelchair	DVT
16	232	16	–	–	Support	–
17	105	11	–	–	Independent	DVT, cellulitis
18	35	2	Gastrocnemius, fasciocutaneous	–	Support	DVT
19	13	5	Three fasciocutaneous	–	Independent	–
20	95	5	Free anterolateral thigh	Right BKA	Independent	Bacteremia
21	114	16	Free rectus abdominus	–	Independent	Flap ischemia and infection

LOS, length of acute hospital stay; *BKA*, below-knee amputation; *AKA*, above-knee amputation; *LTF*, lost to follow-up; *DVT*, deep-vein thrombosis. *Ambulation: independent (without need for assistance), support (cane or walker needed), or wheelchair (primary transportation via wheelchair).

wound coverage was accomplished with a variety of procedures, including dressing changes, tibial burring, and VAC® device application until granulation tissue developed for grafting. The VAC® device was first used in 2001 in patient 14 and has been used in each case since that time, resulting in granulation tissue for skin grafting. Burring of the outer table of bone to expose bleeding tissue was used in cases 2, 6, 7, 9, and 21 with significant granulation tissue formation for skin grafting but mandated multiple operations.

Table 2 summarizes outcomes. There were seven limb amputations (18% of limbs) in four patients including six below-knee, one above-knee, and no midfoot amputations (Figure 1). There was a significant decrease in the mean number of operations needed for limb salvage from 11 in the nonflap closure patients to 6 in the flap closure patients ($P = .009$), despite no significant difference in extremity burn area. The acute hospital stay was long, averaging 76 days; in comparison, for all patients with 40% TBSA burns at our burn center during the past 10 years, the average length of stay was 18 days.

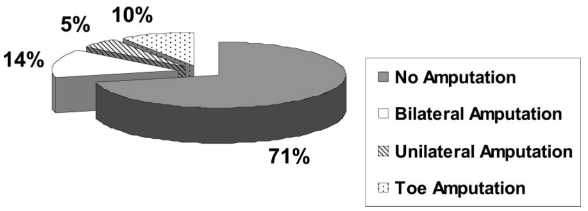

Figure 1. Percent of patients (n= 21) who underwent amputations.

With at least 1 year of follow-up, 48% of patients were ambulating independently, 29% depended on a cane or walker, 14% required wheelchairs, and 10% were lost to follow-up. There were high rates of lower-extremity cellulitis and infections (33%), bacteremia (19%), and deep vein thrombosis (14%). The following three cases are reviewed.

Case 1

Patient 8, a 44-year-old man, sustained 25% TBSA flame burns to his bilateral lower extremities. Two excision and grafting procedures revealed 15% fourth-degree burns. As the result of sepsis and necrosis of the bone and tendons of his feet, the patient underwent bilateral BKAs. Because of inadequate local tissue, patient had bilateral exposed tibias, greater on the right. To prevent above-knee amputations (AKA), on hospital day 15, the patient underwent a local right soleus muscle flap and a left gastrocnemius muscle flap to cover exposed tibias. Two débridments revealed additional right exposed tibia, which was treated with dressing changes until the wound stabilized. Seventy-four days after his initial burn, he underwent a left rectus abdominis myocutanous free flap to his right BKA stump. The free flap and two local flaps provided full bone coverage and prevention of AKAs. At 8-year follow-up, he ambulates independently 2 miles daily with bilateral prostheses.

Case 2

Patient 20, a 37-year-old man, sustained self-inflicted 30% TBSA sulfuric acid burns to his bilateral lower extremities (Figure 2, left panel). His wounds were immediately irrigated and débrided of necrotic tissue and bone in several areas; 12% TBSA was fourth-degree burns. The tendons, bones, and neurovascular structures of the right foot and ankle were necrotic, and he underwent a right BKA. The patient underwent additional débridment and grafting resulting in an exposed left ankle and multiple areas of exposed tibia bilaterally. Hospital course was marked by renal failure, respiratory failure, pneumonia, and sepsis. VAC® foam was placed until the patient stabilized, and on hospital day 18, a right anterolateral thigh free flap was performed to cover his left exposed ankle joint (Figure 2, center and right panels). The VAC® foam was maintained for 50 days and granulation tissue grew into remaining areas. Patient underwent two STSG procedures resulting in total wound coverage. At 1-year follow-up, patient ambulates independently with a prosthesis.

Case 3

Patient 21, a 40-year-old man with diabetes and a 20-pack-year smoking history, lit his bed on fire, sustaining 40% TBSA burns to his bilateral legs, groin, and buttocks. He immediately underwent bilateral escharotomies. Nine excision and grafting procedures revealed 10% fourth-degree burns with tibial exposure bilaterally. As the result of poorly controlled diabetes, smoking, and malnutrition, his wounds were treated with VAC® foam at a rehabilitation facility after 114 days of acute hospitalization. The patient's nutritional status and glucose control improved, he quit smoking, and he returned for tibial coverage (Figure 3, left panel). The patient underwent a free rectus abdominus muscle flap to his left leg complicated by ischemia and infection, but with revision of the flap anastomosis there was full flap survival (Figure 3, center panel). Because of the patient's reluctance to have another free flap, tibial burring was

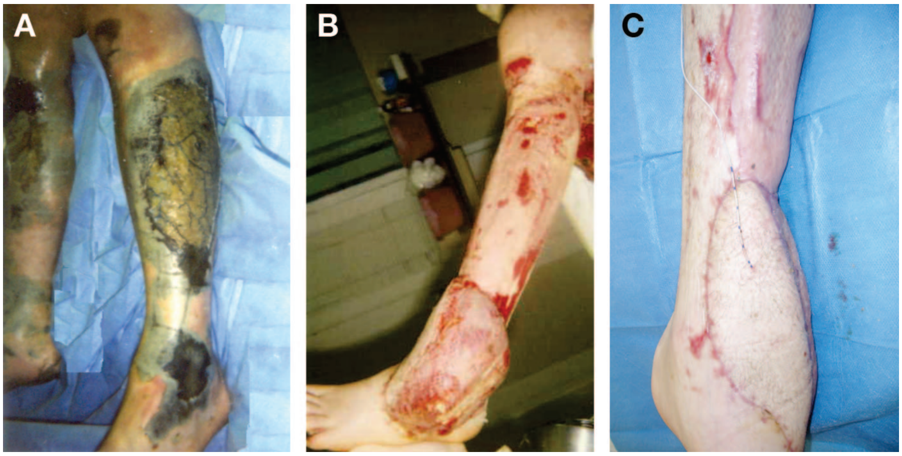

Figure 2. Patient 20 with fourth-degree sulfuric acid burns. Left panel, the left leg with full-thickness tissue loss before débridment. Center and right panels, left leg with total wound coverage 4 days and 1 month after split-thickness skin grafting and a free anterolateral thigh flap to cover an exposed ankle joint.

Figure 3. Left, patient 21 with exposed tibias after multiple excisions and graftings. Center, left leg 3 months after a free rectus flap with complete tibial coverage. Right, right leg after tibial burring and Vacuum-Assisted Closure device® foam placement resulting in partial granulation tissue coverage of the exposed tibia.

performed on the right leg with VAC® placement, resulting in granulation tissue and a residual area of exposed tibia (Figure 3, right panel). At 1-year follow-up, patient ambulates independently and continues with dressing changes to his left leg.

DISCUSSION

This retrospective study details our 10-year experience with fourth-degree lower-extremity burns, demonstrating the use of multiple levels of the reconstructive ladder to salvage these severely injured limbs. Only 18% of limbs were amputated, and only four patients underwent amputations with follow-up demonstrating that nearly 50% of patients were ambulating independently.

Our center treats severe lower-extremity burns with early excision[22–24] and immediate coverage of viable tissue with STSG, skin substitutes, allografts, or VAC® foam. Our goal is to remove devitalized tissue while maintaining as much healthy tissue as possible. This process is repeated until wounds are clean, and we then focus on coverage of exposed structures.

Soft-tissue coverage depends on TBSA burned, availability of healthy tissue, and comorbidities. In patients with exposed bone who are seriously ill, unstable, or have no donor sites, VAC® foam is placed and changed three times per week. Future coverage depends on clinical status and tissue availability and, over the course of time, granulation tissue often forms for grafting. Comorbidities decreased our willingness to perform flaps; nonflap closure patients had higher TBSA burns (57% vs 24% in the flap patients), uncontrolled diabetes (patient 6), severe chronic obstructive pulmonary disease and coronary artery disease (patient 7 and 15), and an aortic transection and subarachnoid hemorrhage (patient 10). In patients with adequate tissue and the ability to tolerate longer and more complex procedures, we chose flap coverage of exposed structures because they are reliable and significantly decrease the number of operations, allowing quicker wound coverage. For example, in patient 21, the flap treated limb resulted in total bone coverage whereas the burr hole and VAC®-treated wound had residual bone exposure after multiple procedures. Local and free flaps were performed, on average, 50 and 60 days respectively after the acute burn; VAC® foam is placed until this time, allowing the zone of injury to be determined and for the patient to stabilize. Blood supply for free flaps is assessed preoperatively with Doppler and physical examinations; angiograms rarely are performed.

Our reconstructive efforts focus on preventing amputation while preserving function. Patients with amputations suffer physical and psychological disabilities,[25] decreased return to work,[26] and low independent ambulation rates.[27,28] Some studies have shown worse physical outcomes in patients with amputations vs those with successful limb salvage after trauma.[29] Once amputation is necessary, our goal is preservation of maximal limb length[30,31] and prevention of bilateral amputations. AKAs are avoided because of high rates of nonambulation and decreased use of prosthesis compared with BKAs[26,32–34]; flaps often are used to cover a BKA site to prevent an AKA, as in patient 8s and 14. Bilateral amputations have a poor prognosis for ambulation,[35,36] and only one third of our bilateral amputees were ambulatory. In this study, 29% of patients require assistance with ambulation and 14%

need a wheelchair, thus reflecting the disability associated with these burns.

Lower-extremity fourth-degree burn care involves multiple surgeries and long in-patient care, but salvage of a functional limb can be successful. Flaps expedite soft tissue coverage but are not always clinically feasible, yet combinations of other levels on the reconstructive ladder can lead to wound coverage. Long-term follow-up of functional status will be useful in determining the ultimate effects of our efforts.

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