CASE REPORT

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A tale of two soles: sociomechanical and biomechanical considerations in diabetic limb salvage and amputation decision-making in the worst of times

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Foot ulcerations complicated by infection are the major cause of limb loss in people with diabetes. This is especially true in those patients with severe sepsis. Determining whether to amputate or attempt to salvage a limb often requires in depth evaluation of each individual patient's physical, mental, and socioeconomic status. The current report presents and juxtaposes two similar patients, admitted to the same service at the same time with severe diabetic foot infections complicated by sepsis. We describe in detail the similarities and differences in the clinical presentation, extent of infection, etiology, and socioeconomic concerns that ultimately led to divergent clinical decisions regarding the choices of attempting diabetic limb salvage versus primary amputation and prompt rehabilitation.

Keywords: *diabetic foot*; *Charcot arthropathy*; *diabetic limb salvage*; *diabetic foot infection*; *amputation*

Diabetic foot infections are among the most common causes of diabetes-associated hospitalization (1–3). The presence of an infected diabetic foot ulcer is the major predisposing factor for nontraumatic foot amputations (4), as it is estimated that 85% of these amputations are preceded by an infection (5–7). It has been strongly suggested that the rate of major amputation can be diminished by 49–85% through implementation of an effective evidence-based prevention program, patient education, foot ulcer treatment by a multidisciplinary team, and periodic surveillance (8, 9). Additionally, teams also appear to have an impact on care of urgent diabetic foot complications, reducing amputation risk, and changing surgery type from reactive and ablative to proactive and preventative (9).

When evaluating Infectious Diseases Society of America moderate to severe diabetic foot infections (10) even in the absence of vascular insufficiency, the surgeon is presented with a potentially difficult decision of selecting which patients are good candidates for limb salvage versus those who would benefit more from a primary major amputation and rapid rehabilitation.

We herein present and contrast two similar patients with severe diabetic foot infections. Although admitted at the same time by the same team, widely different treatment approaches were undertaken. We further describe the treatment course of these patients and outline the rationale for the surgical procedures performed in order to provide them with good long-term results, minimize the risk of recurrent infection, and help them return to full weight-bearing status in a timeframe suitable to each individual.

Patient 1

A 42-year-old Mexican-American man with diabetes presented to the emergency room with a 3-day history of left foot swelling, redness, and pain associated with nausea, fever, and chills. He reported having stepped on a nail 1 month prior. The patient was initially managed with oral analgesics and antibiotics and referral to a wound care center for debridement and dressing changes. His condition failed to improve. The patient was a non-smoker with history of hypertension, and myasthenia gravis. He denied any history of previous ulceration in either foot.

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Physical examination revealed that his foot was exquisitely tender, with copious, fetid purulent discharge. The popliteal pulse and the digital capillary refill time were normal. Pedal pulses were not readily palpable due to edema and exquisite tenderness, which transcended his neuropathy. Nonetheless, he had normal Doppler signals on the dorsum of his foot. He had loss of protective sensation to his feet based on the Ipswich Touch Test (11). An open ulceration of the plantar lateral fifth metatarsal probing to the capsular tissue with a tunneling track toward the proximal porta pedis was noticed. A malodorous purulent draining and deep tunneling lesion at the level of the distal medial arch with fluctuance encompassed the surrounding area. The entire forefoot was erythematous to the level of the midfoot. There were no palpable regional lymph nodes or lymphangitic streaking. The overall musculoskeletal appearance of the foot did not demonstrate any significant abnormalities or structural deformities (Fig. 1A).

Pertinent admission laboratory tests demonstrated a profound leukocytosis, with a white blood cell count greater than 36,000/μl and elevated segmented neutrophils. C-reactive protein (CRP) levels were greater than 25 mg/dl and the erythrocyte sedimentation rate (ESR) was 129 mm/h. The patient's comprehensive metabolic panel was remarkable for severe hyponatremia (122 mMol/l), elevated serum creatinine (2.0 mg/dl) and blood urea nitrogen (43 mg/dl), and serum glucose of 225 mg/dl. Radiographic imaging of the foot revealed periarticular osteopenia about the fifth metatarsophalangeal joint, with subtle periosteal reaction, adjacent soft tissue swelling, and soft tissue gas, compatible with severe infection (Fig. 1B).

After hospital admission and intravenous (IV) rehydration, the patient was taken to the operating room for urgent incision and drainage of deep space abscess in order to control the infection. Immediately upon making the incision, over 20 ml of frank pus was expressed from the wound. An extensive open debridement of the foot was performed extending proximally to the deep plantar tissues and superficial compartments with complete removal of necrotic debris involving cutaneous and subcutaneous tissue as well as muscle and tendon. The incision also required extension to the lateral aspect of the forefoot to the level of the fifth metatarsal head. Sharp debridement of all non-viable and grossly infected

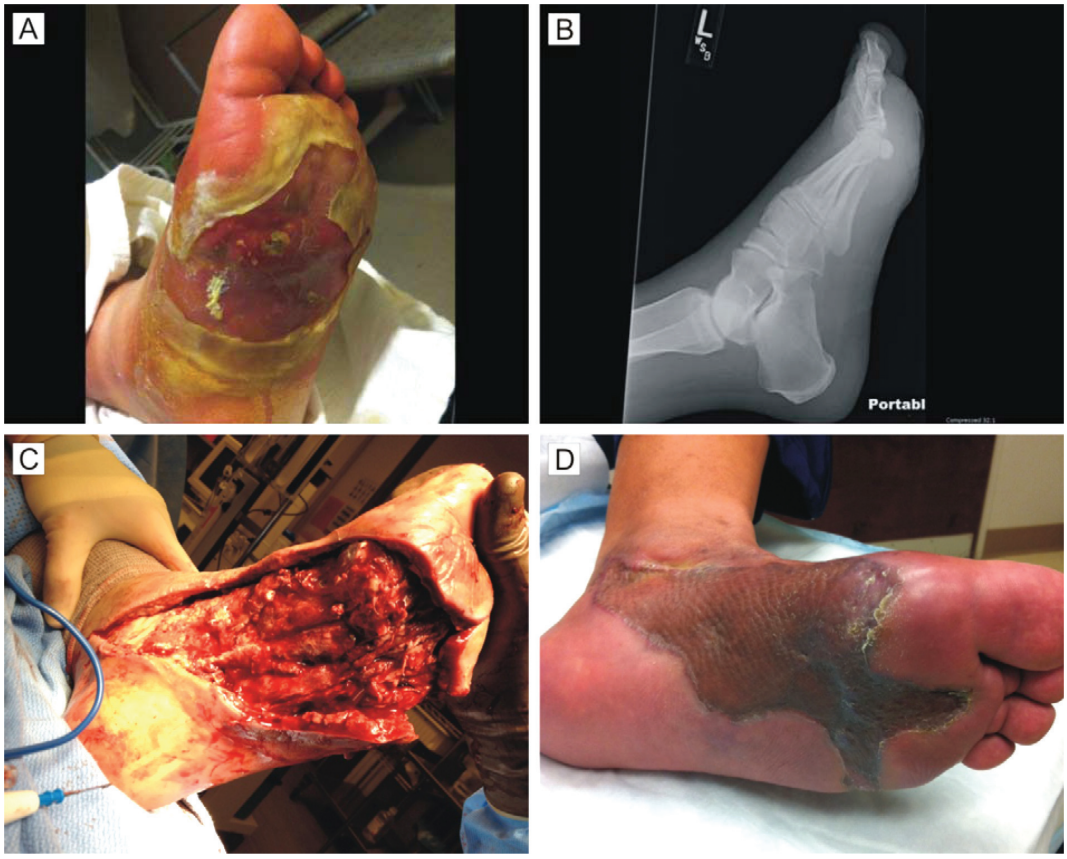

Fig. 1. Initial clinical presentation of the left foot with associated erythema, edema, draining deep abscess (A). Radiographic imagining does not show underlying breakdown of bone suggestive of osteomyelitis or Charcot foot (B). Surgical debridement involving entire medial plantar foot as well as sub-metatarsal soft tissue (C). Clinical appearance of healed tissue following negative pressure wound therapy and split thickness skin graft (D).

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tissue was carried out utilizing hydro-surgical instrumentation. Once adequate debridement of all compartments of the foot was complete, the underlying bone was investigated for possible infectious involvement. It did not appear intra-operatively that there was violation of the capsular tissue of the fifth metatarsal phalangeal joint necessitating resection. The surgical field was irrigated with pulse lavage of 6 l of antibiotic-laden sterile saline. Perfusion to the soft tissue appeared more than adequate with hemostasis achieved utilizing cauterization and ligation. A soft tissue sample was sent to microbiology for Gram stain as well as culture and sensitivity in order to guide proper antibiotic therapy. The wound was dressed with a moist to dry dressing using 0.25% Dakin's solution. The patient was placed on IV ertapenem 1 g daily. Tissue culture ultimately yielded *Prevotella bivia*.

In the inpatient setting the wound was assessed daily and repeat surgical debridement was performed in the operating room twice more over the following week to remove nonviable tissue and evacuate any remaining abscess formation. The overall debridement involved much of the plantar medial and plantar forefoot area tissue but did not involve removal of bone (Fig. 1C). Once signs of infection abated and the wound ceased to exhibit tissue necrosis, negative pressure wound therapy (NPWT) was begun in preparation for split-thickness skin grafting (STSG). The patient was discharged from the hospital to a rehabilitation center with a peripherally inserted central catheter for continued antibiotic therapy and routine wound care in the form of NPWT dressing changes every 48 h. He was instructed to remain totally non-weight bearing during this time. The patient was evaluated in the outpatient clinic on a weekly basis to monitor the progression of the granulation tissue. Overall, the time from commencement of the NPWT to adequate depth reduction allowing for STSG was 26 days. After surgical application of a STSG taken from the ipsilateral thigh, NPWT was applied over the graft at a reduced pressure setting of 75 mm Hg for 5 days as a bolster to promote graft adherence. NPWT was removed on the fifth day in the outpatient clinic and nonadherent petroleum gauze and dry gauze dressing was placed over the graft site. The patient was able to return home and receive dressing changes every other day as well as weekly clinic visits with the surgical team. This continued until complete healing was observed at 8 weeks (Fig. 1D). The patient was then cleared to return to weight bearing status in a diabetic boot. The total time from initial debridement of the foot to complete healing and return to weight bearing activities was approximately 3 months. The patient was employed as a tile specialist at new home construction which required walking up and down stairs and kneeling on a daily basis.

Patient 2

A 46-year-old Mexican-American man with diabetes, hypertension and hyperlipidemia presented to the emergency department with a 2-week history of acute progressive constitutional symptoms. These symptoms were the result of an infected plantar left foot ulcer that had been noted to have increased swelling, drainage, and foul odor along with the more recent development of an area of black, skin blistering. The underlying ulceration had been present for approximately 1 year and resulted from a skeletal malformation of the foot secondary to long-standing Charcot arthropathy of 9 years duration that left him with a collapsed arch and bony prominence on the bottom of the midfoot. Despite surgical reconstruction of the foot at the time of initial arch collapse and ulceration, the patient had suffered from chronic, intermittent wound breakdown, and repetitive infections requiring hospitalization and IV antibiotics. He did not have a weight bearing offloading device. For the last year, the patient had been unemployed and without health insurance and was therefore self-managing his wounds with a poultice recommended by a family doctor in Mexico. He had, however, just started a new job as a clerk in a deputy sheriff's office, but this position was probationary and he was not yet eligible for health benefits.

Upon evaluation in the emergency room, the patient was febrile with an oral temperature of 39.1°C and otherwise normal vital signs. Laboratory studies were remarkable for a leukocytosis of 24,900/μl and markedly elevated inflammatory markers, with a CRP level of 31.1 mg/dl and ESR of 143 mm/h. The patient's comprehensive metabolic panel was significant for hyponatremia (128 mMol/l), elevated serum creatinine (3.2 mg/dl), blood urea nitrogen (60 mg/dl), and a serum glucose level of 228 mg/dl.

Physical evaluation of the affected lower extremity revealed palpable pedal pulses, severe foot and ankle edema, and a lack of protective sensation from the toes to the mid-calf. Dermatologic examination revealed a full thickness, 15 cm^2 ulceration of the plantar central midfoot, extending to the bone. Frankly malodorous discharge and sinus tracking to well-circumscribed necrotic gas-filled bulla of the medial foot were also evident (Fig. 2A). Radiographic findings demonstrated gas in the dorsal and medial foot, significant soft tissue edema, and osseous breakdown of the midtarsal bones with osteolytic erosions at the level of the ulceration suggestive of osteomyelitis (Fig. 2B).

Following fluid resuscitation and administration of broad spectrum antibiotics, the patient was promptly transferred to the operating room for surgical incision and drainage. The debridement extended from the area of ulceration down to the underlying bone including a portion of central cuneiform that was sent for culture

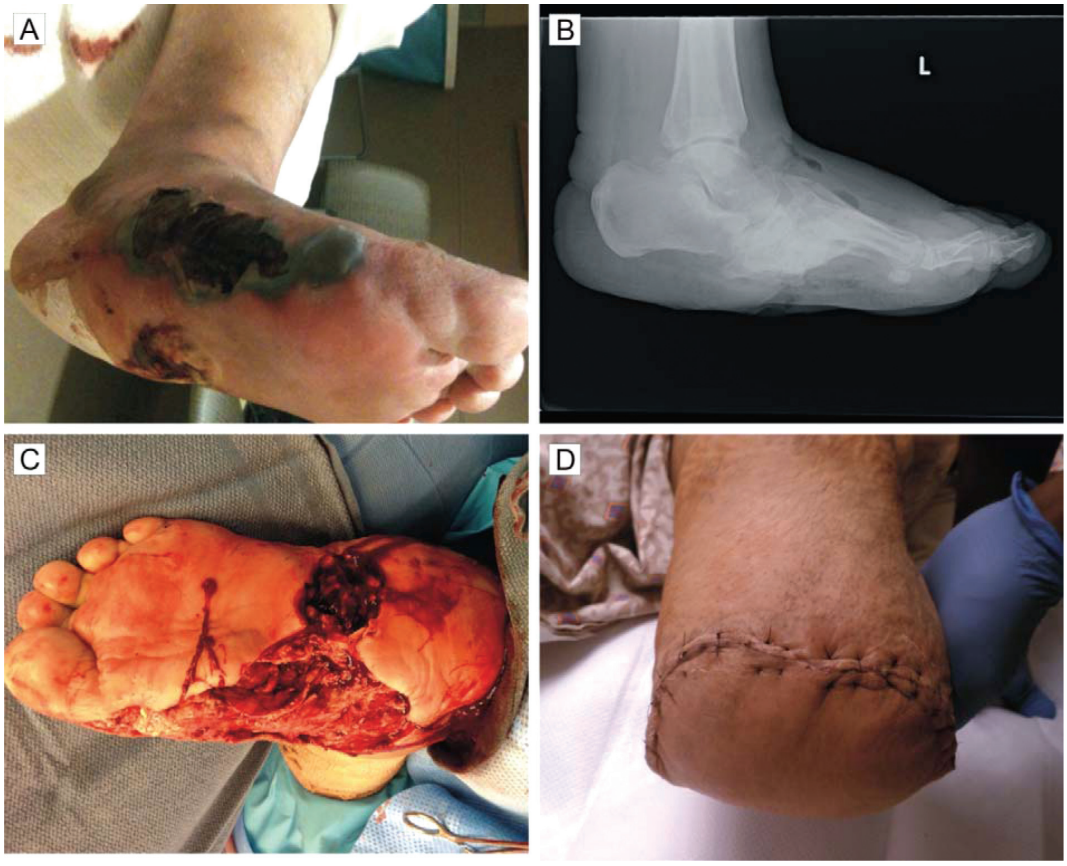

Fig. 2. Initial clinical presentation of the left foot, revealing plantar ulceration and necrotic destruction of the medial skin with gas in tissue (A). Radiographic imagining reveals diffuse gas in tissue and underlying breakdown of bone suggestive of osteomyelitis and Charcot foot (B). Surgical debridement involving the medial and plantar foot including bone (C). Clinical appearance of healing below the knee amputation (D).

and sensitivity to rule out osteomyelitis. From the area of plantar ulceration the incision was extended through the sinus track to the medial arch and area of necrotic tissue. All areas of obvious diseased tissue were removed with the assistance of high pressure water debridement. All compartments of the foot were explored for any residual abscess or gas formation. Once adequate debridement was achieved, the foot was irrigated with copious amounts of antibiotic treated saline solution (Fig. 2C). Necrotic soft issue was sent for Gram stain and culture and sensitivity in order to identify bacterial pathogens for proper antibiotic therapy. The wound was dressed with Dakin's 0.25% solution wet to dry dressing to be changed twice daily. The patient was placed on a broad spectrum course of antibiotics (vancomycin and ertapenem) pending results of tissue and bone cultures. Results of initial blood culture demonstrated *Streptococcus anginosis-constellatus* and the culture results of the bone and soft tissue infection were positive for mixed gram positive and gram negative flora including anaerobic bacteria; at this time antibiotic therapy of piperacillin/tazobactam was continued and other antibiotics discontinued. The patient was followed closely by the surgical team and did not undergo further soft tissue debridement because the open wound did not exhibit ongoing necrosis, the leukocytosis was improving with antibiotic therapy and subsequent blood cultures were negative.

The surgical team had extensive discussions with the patient. Mutually agreed goals of subsequent therapy were to enable the patient to ambulate; to prevent recurrence of this wound and infection that had been plaguing him for nearly a decade; and, to allow him to return to his current probationary position as a deputy sheriff so that he would have a means of support and health benefits. After weighing the limb salvage options including significant bone debridement to remove residual bone infection, external fixation, delayed soft tissue coverage, prolonged recovery phase and even if successful, the lifetime risk of re-ulceration, he elected to proceed with primary below the knee amputation in order to facilitate timely discharge and progression to a weight bearing status in a prosthesis that would permit him to return to his job. He also was concerned that prolonged treatment and convalescence that prevented early return to work could result in loss of his new-found employment.

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One week after the initial surgical incision and drainage, the patient underwent a below the knee amputation. The patient was discharged on oral amoxicillin 4 days following surgery having been in the hospital a total of 10 days. He was sent home after working with physical therapy and able to ambulate with a walker and having been instructed on transferring abilities. Two weeks after the amputation, healing was unremarkable, and the skin sutures were removed (Fig. 2D). He returned to work within 4 weeks and was ambulatory with a prosthesis at 6 weeks postoperatively.

Discussion

The intent of this report was to juxtapose the rationale used to determine which treatment strategy best suited two similar patients with severe diabetic foot infections, and outline the subtle differences in each patient's clinical presentation, disease history, socioeconomic status, and life needs and expectations that helped guide the decision-making process. Although such decisions impact the patient not only physically, but also economically, socially, and emotionally, they are all too often made on the basis of what is easiest for the surgeon. As with many decisions in medicine, sufficient doctor-patient communication must take place concerning how particular treatment options will influence the patient's life in both the short-term and the long.

This report describes two patients who at first glance might seem quite similar. Their ages, cultural and ethnic backgrounds were nearly identical. They each had a diabetic foot ulcer complicated by severe infection. From a technical and purely surgical standpoint, limb salvage was quite possible in each patient. On more careful inspection, distinct differences pertaining to the underlying cause, disease duration, bony involvement and architecture, workplace needs, and socioeconomic realities resulted in the divergent decision pathways to move forward with a limb salvage approach in one patient and a below the knee amputation in the other.

In patient 1, the clinical history was that of an active tile layer and roofer who developed ulceration secondary to a puncture wound while on the job. There was neither an underlying bony abnormality nor ulceration due to repetitive stress. Prior to this insult one could have classified this patient's foot using American Diabetes Association standards as a grade 1, relatively low risk foot for amputation. (12). When determining a treatment approach for this patient we decided to follow the recommendations of surgery in the diabetic foot based on the risk-based classification for diabetic foot surgery developed by Armstrong et al. (13). This was considered a class 4 surgical emergency, which involves rapid surgical intervention to decrease complications regardless of perfusion to the limb. Even though there was an extensive amount of debridement and repeat operations in order to remove all infection from the foot, the patients overall skeletal structure was uncompromised. This meant that bone resection was avoided and if the patient were to heal this wound he would be able to return to a functional type diabetic work boot and be highly likely to maintain employment as a roofer for a construction company. This patient was very emotionally optimistic about being able to heal and return to his lifestyle given this was a first 'foot event' for him. He had sufficient sick leave to be able to afford the time necessary for wound stabilization, granulation and eventual STSG.

The overall treatment regimen and clinical outcome correlate closely with that of a recent study by Kim et al. who sought to determine the efficacy of a management algorithm that includes NPWT in diabetic limb-threatening infections (14). There are similarities in the number of surgical debridement's (3 vs. 2.4 ± 1.3 days) of NPWT application (26 vs. 26.2 ± 14.3 days), and complete wound healing (90 vs. 104 days). The conclusion of the retrospective case series was that a management algorithm including NPWT application following debridement and early vascular intervention (if applicable) was beneficial in treating severe diabetic foot infections. The successful attempt to salvage our patient's limb using a similar algorithm also demonstrates the effectiveness of postoperative NPWT along with an early and aggressive surgical approach.

In patient 2, the initial surgical approach to limit the progression of life and limb threatening infection was nearly identical to that used for patient 1. Thereafter, subtle issues led to the divergent recommendation of primary limb amputation, an option that many limb salvage centers such as our own often hesitate to even seriously consider. Patient 2 had a 10-year history of Charcot arthropathy that yielded a rocker-bottom foot even after a remote attempt at surgical reconstruction 10 years ago. This residual deformity predisposed him to recurrent ulcerations (secondary to repetitive stress rather than isolated external trauma from a nail) and infections that resulted in multiple hospital admissions and nearly constant wound management for repeat ulcerations. This burden of constant morbidity ultimately cost him his job and further limited his ability to receive the care needed to prevent ulceration and infection. He had, however, recently acquired a position with the local Sheriff's department, but was in probationary status. Any prolonged time away from the job would have resulted in further unemployment. He admitted to being physically and emotionally exhausted dealing with this chronic problem limb, and had a much more positive outlook about the idea of amputation being likely to rid him of a source of infection and allow him to start rehabilitation promptly so that he could return to work and resume his clerical responsibilities.

As a team with a significant predisposition to a locally aggressive approach to debridement, reconstruction, and healing, we strongly contemplated the aggressive approach of salvaging the limb in this relatively young man and proceeding in a similar direction to that pursued in the first patient. Because of wound chronicity and the severe underlying bony deformity, however, it became apparent that even if we attempted to pursue limb salvage in this case, the outcome would likely not be favorable. Sohn et al. reported that the amputation risk in diabetic patients with an ulcer and Charcot arthropathy is 12 times higher than in patients with Charcot arthropathy without ulceration (15). Outcomes are worse in such patients in the presence of bone infection and a deep wound. Yesil et al. found that osteomyelitis and ulcer depth increased the risk for major amputation in a retrospective observational study that included 574 foot ulcer episodes (16).

In patient 2, had a limb salvage approach including removal of infected bone and Charcot foot reconstruction were been attempted, final wound healing and a complete return to weight bearing status would most likely have been 6–12 months. This approach likely would have led to the patient's loss of current employment and subsequent inability to financially cover costly procedures, devices, shoe gear, and ancillary services such as home health care. Ultimately the decision to perform below-the-knee amputation was made jointly by the patient with the surgical team. The patient recovered uneventfully from the amputation. He was able to return to work within 4 weeks. At a recent visit with patient, he stated his gratitude for the procedure and stated how much more emotionally positive he has been not having to 'deal' with the overwhelming burden of a complicated limb. A below the knee amputation in our first patient would have been devastating to his current job, as he would have had significant difficulty kneeling or repeatedly climbing stairs throughout the day.

Conclusion

The decision to attempt salvage or amputate a limb in the face of diabetic foot infection is always a difficult one. Using an initially algorithmic surgical approach combined with understanding the highly specific nonsurgical, socioeconomic, and emotional needs of the patient can help with this determination. In fact, this additional risk factor is so important to us, we have coined the term 'sociomechanics'. Sociomechanics and biomechanics are each important consideration and contribute to a realistic definition of a successful outcome.

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