Salvage of the Neuropathic Foot by Using Bone Resection and Tendon Balancing: A Retrospective Review of 10 Patients

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Medical records were retrospectively reviewed for 10 patients (mean age, 48.7 years) who had a chronic, recurrent neuropathic forefoot ulceration or osteomyelitis in the presence of an abnormal metatarsal parabola. Two patients had multiple lesser metatarsal osteomyelitis, 3 patients had chronic ulceration in the presence of an abnormal metatarsal parabola, and 5 patients had previous lesser ray resection or metatarsal head resection. None of the patients had signs of skin breakdown under the first metatarsal. All of the patients were treated with a combination gastrocnemius recession, peroneus longus to peroneus brevis tendon transfer, and resection of the second through fifth metatarsal heads to decrease plantar forefoot pressure and preserve the first ray without increasing the risk of ulceration under the first metatarsal head. All patients achieved a healed plantigrade foot without ulcer recurrence, transfer callus development, or contralateral foot breakdown at a mean follow-up of 14.2 months. Postsurgical complications consisted of dehiscence of various incision sites on 3 individual patients and one local reaction to antibiotic-impregnated beads. This preliminary study suggests that this combination of reconstructive procedures may provide an alternative method of foot salvage to panmetatarsal resection and transmetatarsal amputation. (The Journal of Foot & Ankle Surgery 44(1):37-43, 2005)

Key words: Diabetic foot, forefoot ulceration, limb salvage, tendon transfer, panmetatarsal head resection

Ulcerations under the metatarsal heads commonly lead to infection of soft tissue or bone, and infection and amputation are the eventual sequelae in 14% to 28% of diabetic patients with a foot ulcer (1–5). Long-term rehabilitation is rarely successful in patients who receive above- or below-knee amputation: only 5% of these patients can use a prosthesis to walk outside the home, and most patients remain wheelchair-bound after 5 years (6, 7). For neuropathic patients with transfer forefoot ulceration after partial ray or metatarsal head resection, salvage procedures that provide a plantigrade foot or foot stump may offer a greater possibility of long-term function.

In many cases, isolated partial ray resection is performed to eradicate infected bone and soft tissue affecting a single ray. However, these procedures are complicated and result in a high incidence of transfer ulceration to the remaining rays (8, 9). Transmetatarsal amputation (TMA) and panmetatarsal head resection have been advocated as superior alternatives to isolated partial ray resection (8, 10). Panmetatarsal head resection is more commonly used in rheumatoid patients but has also been advocated for forefoot ulceration in diabetic patients (9, 11). However, TMA and panmetatarsal head resection also carry potential problems. Although they reduce the risk of further breakdown and ulceration, these procedures compromise the normal function of the forefoot, especially the propulsive ability of the first ray (8, 10).

The authors propose an alternative foot salvage procedure that debrides ulcerated and infected soft tissue and bone and reduces risk of ulcer recurrence and further amputation while preserving the first ray. By combining lesser metatarsal head resection with gastrocnemius recession and a peroneus longus to peroneus brevis tendon transfer, forefoot

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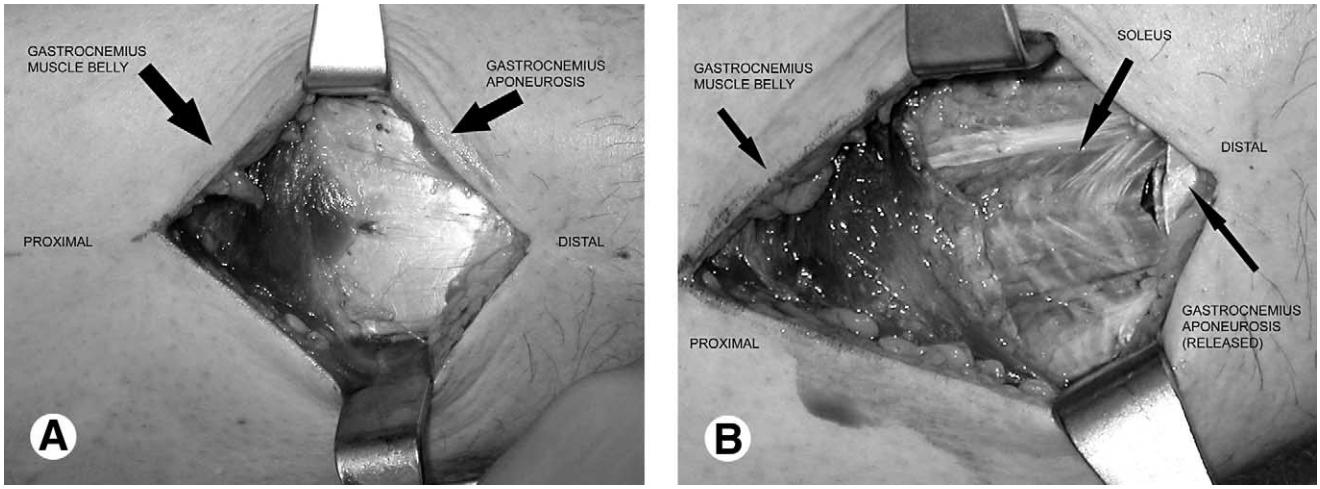

FIGURE 1 Surgical field of high gastrocnemius recession showing medial head of gastrocnemius muscle (*A*) before transection of the aponeurosis and (*B*) after transection. Note intact soleus muscle directly beneath aponeurosis.

pressure can be reduced and redistributed. This report provides a preliminary review of the clinical outcome of 10 patients (12 feet) with recurrent neuropathic foot ulceration who received this combination of procedures.

Methods

This was a retrospective review of the medical and computer database records as well as the pre- and postoperative weightbearing radiographs of 10 consecutive patients (12 feet). These patients were treated between December 2000 and October 2003 for chronic, recurrent, neuropathic forefoot (transfer) ulceration; associated metatarsal osteomyelitis; or both. The following procedure combination was performed on each patient: high gastrocnemius recession, transfer of the peroneus longus tendon to the peroneus brevis tendon, and resection of the lesser metatarsal heads. All patients were followed and examined clinically and radiographically by the respective authors (G.A.H., L.A.F., S.M.R.) who performed the surgical procedures. The study was exempt from Institutional Review Board review.

All patients showed an intact vascular supply in the affected foot as determined by palpable pedal pulse or strong, audible Doppler ultrasonography signals of the pedal arteries. All patients had peripheral sensory neuropathy, defined as the absence of protective sensation with Semmes-Weinstein 5.07 (10 g) monofilament testing and the presence of painless preulcerative skin or ulceration. Each patient also exhibited an isolated gastrocnemius equinus, defined as the inability to dorsiflex the ankle beyond perpendicular with the knee extended and being able to dorsiflex beyond perpendicular with the knee flexed. None of the patients had signs of skin breakdown under the first metatarsal.

Conservative treatment, including any combination of serial debridement, contact casting, the use of external offloading devices, or the use of custom shoes had failed for all patients. All patients were given the option of continued conservative treatment, TMA, panmetatarsal head resection, or the index procedure combination.

A successful outcome was defined as a return to regular activities and the absence of complications after a minimum follow-up of 6 months. Complications were defined as the presence of any forefoot callus, a recurrent or transfer ulceration, the development of metatarsus primus varus or elevatus, postoperative infection, vascular embarrassment, distal or proximal amputation, or a need for any assistive device postoperatively.

Operative Technique

The high gastrocnemius recession was performed first. Lidocaine with epinephrine (1:100,000) was administered along the planned incision line. Beginning at the inferior aspect of the medial head of the gastrocnemius muscle belly, a 4-cm longitudinal skin incision was placed medial to midline, avoiding the sural nerve laterally and the saphenous bundle medially. Sharp dissection was continued to the paratenon, which was incised longitudinally to expose the gastrocnemius aponeurosis (Fig 1A). The surgeon's index finger was used to bluntly dissect the paratenon free from the gastrocnemius fibers and the aponeurosis from medial to lateral. After the underlying soleus fascia was identified and separated from the aponeurosis, the gastrocnemius aponeurosis was sharply transected (Fig 1B). The foot is gently dorsiflexed during recession. The paratenon, subcutaneous tissue, and skin incisions were closed in layers.

The peroneus longus tendon was then transferred to the

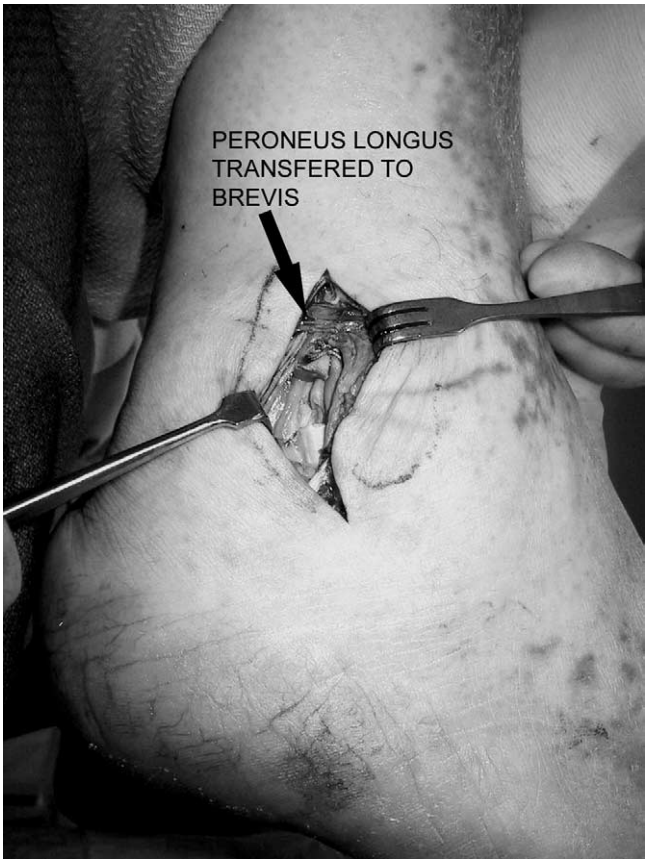

FIGURE 2 Intraoperative photograph showing peroneus longus tendon after transfer to peroneus brevis tendon.

peroneus brevis tendon. A small incision was made posterior to the lateral malleolus directly over the peroneal tendons. The peroneal sheath was incised linearly to expose the tendons. The peroneus longus tendon was transversely transected, and the first ray was manipulated to a more dorsiflexed resting position. This position was determined intraoperatively by manipulating the first metatarsal to the level of the lesser metatarsals. The proximal peroneus longus tendon stump was sutured to the peroneus brevis tendon with 2-0 nonabsorbable suture (Fig 2). In the new resting position, the distal peroneus longus tendon stump was sutured to the peroneus brevis tendon. The incision was then closed in layers.

The remaining lesser metatarsal heads were resected using two dorsal longitudinal incisions placed in the second and fourth intermetatarsal spaces. The metatarsal heads were resected so that the distal ends of the shortened metatarsals defined a smooth arc (Fig 3A and B). All dorsal incisions were closed, and plantar ulcers were then debrided.

Ulcers were allowed to heal by secondary intention. The limb was placed into a nonweightbearing splint with modified Robert Jones compression dressing until suture removal. A total-contact cast was then used until the ulcers completely epithelialized.

Results

Data regarding surgical indications, comorbid conditions, surgical complications, and outcome are summarized in Table 1. The mean patient age was 48.7 years (range, 31–63 years). This condition was secondary to diabetes in 7 patients, Charcot-Marie-Tooth disease in 1 patient, alcoholism in 1 patient, and an idiopathic peripheral neuropathy in 1 patient. Nine patients had two or more comorbid conditions. Five patients had a previous lesser ray resection with chronic transfer ulceration, osteomyelitis, or both. Two patients had osteomyelitis in multiple lesser metatarsal heads, and the remaining three patients had chronic preulcerative calluses or full-thickness ulceration under the second and third metatarsal heads in the presence of an abnormally long second and third metatarsal with a short first metatarsal.

A healed plantigrade foot was achieved for all patients. The mean postoperative follow-up was 14.2 months (range, 6–28 months). The mean time to incision healing was 31.3 days (range, 14–102 days). The mean time for complete ulcer healing was 42.6 days (range, 28–102 days). After the surgical sites healed, all patients could ambulate independently wearing custom or extra-depth diabetic shoes with a polyethylene foam insert. Three patients required a cane postoperatively but had also required a cane preoperatively. The remaining 7 patients ambulated without any assistive device either pre- or postoperatively. At the time of review, no patient developed a recurrence or transfer of ulceration. No calluses or contralateral foot breakdown developed postoperatively. No patient developed hallux valgus or first ray elevatus.

Postsurgical complications developed in 4 patients; in 3, dehiscence developed at various incision sites: at all incisions (1 patient), at the gastrocnemius incision site (1 patient), and at the dorsal foot incision site (1 patient). All 3 patients were successfully treated with local wound care and oral antibiotics. In the fourth patient, who had antibiotic beads placed in the forefoot to augment osteomyelitis treatment, a local reaction to a prominent bead and a sterile sinus developed. The wound healed uneventfully after bead removal.

Discussion

The goals of lower limb salvage procedures are to adequately control infection or ischemia and to create a plantigrade platform on which the patient can adequately bear weight and ambulate. Adjunctive procedures may be needed to reduce risk of further foot breakdown and the risk of amputation (8, 12, 13).

FIGURE 3 (*A*) Preoperative dorsipalmar (DP) radiograph showing resection of the fifth metatarsal head; (*B*) postoperative DP view. Note appropriate smooth arc defined by lesser metatarsals.

The choice of the combined procedures in this study is based on three anatomic and biomechanical principles: 1) equinus causes increased forefoot pressure, a contributing factor to diabetic ulcers; 2) the peroneus longus can cause increased pressure under the first metatarsal head; and 3) the first ray stabilizes the foot and is essential for propulsive gait. In this study's patient set, the initial goal was to decrease the pressure under the ball of the foot in the presence of multiple or recurrent forefoot ulcerations. Instead of performing a panmetatarsal head resection that would produce an apropulsive foot, only the lesser metatarsals were resected. A gastrocnemius recession also was performed to further decrease the pressure on the ball of the foot. Finally, the peroneus longus was transferred to the peroneus brevis to reduce pressure and breakdown under the preserved first metatarsal while still maintaining its integrity.

DiGiovanni et al (14) compared maximum ankle dorsiflexion with the knee extended in 34 otherwise healthy patients who had metatarsalgia or other forefoot or midfoot symptoms with ankle dorsiflexion of a control group who had no forefoot symptoms. Approximately three quarters of the symptomatic group showed an isolated gastrocnemius contracture, and the remainder showed combined gastrocnemius-soleus contracture. Similarly, equinus has been implicated as a contributing factor in forefoot ulcers and complications with the stump after amputation (15, 16). Laboratory gait studies showed substantially reduced forefoot pressure after percutaneous lengthening of the Achilles tendon in diabetic patients (15). This procedure has also been associated with higher healing rates. Several other authors believe that addressing equinus is an important component of diabetic limb salvage (16–19). A prospective comparison of total-contact cast application with or without lengthening the Achilles tendon reported that the patients who received tendon lengthening had a fourfold lower ulcer recurrence rate (17). In a study of 30 patients (33 feet) who had both TMA and Achilles lengthening procedures, the healing rate was 91% (19).

Cohen et al (8) showed that both panmetatarsal head resection and TMA had significantly higher clinical success rates compared with solitary partial ray resection. With a successful result defined as no reulceration or reinfection beneath adjacent metatarsals, success rates were 77.8% for solitary fifth ray resection, 36.4% for the first ray, 16.8% for the third ray, 14.3% for the second ray, and 0% for the

TABLE 1 Characteristics of and outcomes for 10 patients with peripheral sensory neuropathy who had foot salvage with bone resection and tendon balancing

Age (yr)	Indications for Index Operation	Previous Foot Surgery	Complications	Time to Healing (day)	Follow-Up (mo)	Comorbid Conditions
52	Ulcer metatarsal head 2	Partial third through fifth ray amputation	None	14	26	CRF, HTN, IRDM
55	Ulcer metatarsal heads 2, 3	None	Dehiscence at gastrocnemius incision.	102	12	CAD, COPD, CRF, HTN, IRDM, P/S CABG
31[a]	Ulcer metatarsal head 2; osteomyelitis metatarsal heads 2, 3	Incision and drainage	Antibiotic bead required removal	56	28.5	HTN, hyperlipidemia, IRDM, obesity, renal
63	Ulcer metatarsal head 3	Partial ray amputation 4, 5	None	20	12	CHF, HTN, NIDDM, obesity
62	Ulcer metatarsal head 2	Partial third ray amputation	None	21	17	CHF, COPD, hyperlipidemia, HTN, NIDDM, obesity
50	Ulcer metatarsal heads 3, 5	Fourth metatarsal head resection, fifth metatarsal osteotomy	None	23	15	CHF, CP, hypothyroidism, IRDM
32[a]	Ulcer metatarsal head 2; osteomyelitis metatarsal heads 2, 3	First ray bunionectomy	None	21	10	Idiopathic peripheral neuropathy, MCTD, psoriatic arthritis, RA, SLE
46	Ulcer metatarsal heads 2, 3	None	None	14	9.5	Hypercholesterolemia, Hyperlipidemia, IRDM, obesity
42	Right foot: ulcer metatarsal heads 2, 3	Right foot: partial ray resection 4, 5	Superficial dehiscence dorsal fourth ray	14	6	HMSN (CMT)
	Left foot: ulcer metatarsal heads 3, 4	Left foot: clawtoe correction		14		
54	Left and right foot: preulcerative lesions metatarsal heads 2-4	Hammertoe correction	Dehiscence of all incision sites; oral antibiotics	28	6	Alcoholic neuropathy, cigarette addiction, RA

Abbreviations: CAD, coronary artery disease; CHF, congestive heart failure; CMT, Charcot-Marie-Tooth disease; COPD, chronic obstructive pulmonary disease; CP, cerebral palsy; CRF, chronic renal failure; HMSN, hereditary motor sensory neuropathy; HTN, hypertension; IRDM, insulin-requiring diabetes mellitus; MCTD, mixed connective tissue disease; NIDDM, non–insulin-dependent diabetes mellitus; P/S CABG, poststatus coronary artery bypass graft; RA, rheumatoid arthritis; SLE, systemic lupus erythematosus.
[a]In this patient, infection of 2 bones necessitated bone resection and tendon balancing.

fourth ray. This yielded an overall success rate of 37.1% for isolated partial ray resection with an even lower rate of 10.4% for isolated central ray resection (8). Similarly, Gianfortune et al (9) found a low overall success rate for isolated ray resection (34%). Therefore, if an isolated central ray resection is necessary or if the patient has already received an isolated lesser ray resection, simply resecting the remaining lesser metatarsal heads and establishing an even parabola may be more prudent.

Panmetatarsal head resection is an attractive alternative to TMA, not because the resultant foot is more functional but rather for the psychosocial benefits of preserving a relatively normal appearance of the foot. This procedure was first used for rheumatoid arthritis patients with protruding metatarsal heads causing pain that was unresponsive to conservative treatment (19). In 1982, Jacobs (11) used the Hoffman-Clayton panmetatarsal head resection procedure to treat chronic foot ulcers in diabetic patients. Panmetatarsal head resection creates a shorter metatarsal parabola, a configuration that relieves forefoot pressure and redistributes pressure evenly.

On the other hand, panmetatarsal head resection also destroys the essential mechanical properties of the first metatarsophalangeal joint. Both the hallux and the first ray are considered essential for normal gait (20–24). One function of the toes is to increase the weightbearing surface area and effectively dissipate pressure (23). The center of load during the walking cycle progresses from the heel to the medial forefoot through the first metatarsal head and moves to the plantar aspect of the hallux at pushoff (25). The hallux

bears more than twice the load of all the other toes combined (26). In a study of 160 normal subjects, Hughes et al (23) found that walking can exert pressure on the toes similar to that exerted on the metatarsal heads and concluded that every effort should be made to preserve toe function. In a biomechanical study of patients who had hallux amputation for thumb replacement, Mann et al (27) stated that removal of the hallux at the metatarsophalangeal joint resulted in instability of the medial foot and observed decreased arch height after hallux amputation.

The hallux is essential to the foot's stability, probably because the plantar fascia inserts into the proximal phalanx. The plantar fascia acts as a truss to stabilize multiple joints and the arch (25, 28, 29). The fact that the windlass mechanism is more effective in the first metatarsophalangeal joint than in the lesser metatarsophalangeal joints emphasizes the importance of the hallux over the lesser toes (25).

Leaving the first metatarsophalangeal joint intact while eliminating the lesser metatarsophalangeal joints probably subjects the first joint to increased pressure and possible ulceration. Factors likely to cause excessive pressure at the first metatarsophalangeal joint include traction by the Achilles and peroneus longus tendons. The deforming force of the Achilles tendon has been implicated in the need for foot amputation in diabetic patients, and this force is commonly reduced during limb salvage procedures (13, 15, 17, 18). Influence of the peroneus longus muscle on function of the first ray in the presence of panmetatarsal head resection, however, is not fully understood. Contraction of the peroneus longus muscle is believed to plantarflex the first metatarsal, evert the forefoot, and plantarflex the ankle; these actions probably cause increased pressure under the first metatarsal head, a result supported by recent cadaveric studies (30, 31).

Imbalance between a normal peroneus longus muscle and a weakened tibialis anterior has been implicated in plantarflexion deformation of the medial forefoot in patients with Charcot-Marie-Tooth disease (32). Peroneus longus tendon lengthening has therefore been advocated as an adjunctive procedure in cavus reconstruction to alleviate plantar angulation of the first metatarsal (33). Hansen (personal communication, Sigvard T. Hansen Jr, MD, September, 1999) performs peroneus longus to peroneus brevis transfer to alleviate pressure under the first metatarsal in athletes with sesamoid fractures or during forefoot cavus reconstruction. The authors believe that, following lesser metatarsal head resection, decreasing the potential force of the peroneus longus is crucial to minimize excessive pressure on the intact first metatarsophalangeal joint. Peroneus longus tendon transfer combined with gastrocnemius recession minimizes the chance of increased pressure and ulceration under the first metatarsophalangeal joint. We are unaware of any studies that have analyzed pressure under the first metatarsal head after lesser metatarsal head resection.

The results of the present retrospective study suggest that the proposed procedure combination can result in satisfactory healing and ambulation in some patients with recurrent forefoot ulcers in the presence of a disrupted metatarsal parabola. The contention that patients showed a good functional result is based on our observations that this procedure combination successfully produced a plantigrade foot.

Interpretation of this study's results is limited by the small number of patients who underwent the combined procedures. Furthermore, because our data were gathered by simple observation, some observer bias could have occurred. In addition, given the maximum follow-up period of 28.5 months with 2 patients followed up for only 6 months, a longer follow-up is required to show maintenance of these good results. Finally, pre- and postoperative laboratory gait analysis would be needed to substantiate our theory that combined lesser metatarsal head resection and tendon balancing provides a more functional, propulsive foot and more even distribution of pressure than panmetatarsal head resection or TMA.

Conclusion

Although more studies are needed to assess the long-term efficacy of this treatment, the early findings are encouraging. Combining high gastrocnemius recession, transfer of the peroneus longus tendon to the peroneus brevis tendon, and resection of the second through fifth metatarsal heads may provide surgeons with an alternative to solitary ray resection, TMA, or panmetatarsal head resection in the salvage of the unbalanced, ulcerated forefoot of a neuropathic patient. Specific indications for this procedure combination include patients with multiple lesser metatarsal head osteomyelitis or recurrent ulcers on the ball of the foot after partial amputation of the lesser ray or clinically significant disruption of the metatarsal parabola.

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