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The Multidisciplinary Approach to Limb Salvage

B. E. Sumpio, J. Aruny, P. A. Blume

Centers for Vascular Disease and Diabetic Limb Preservation, Yale University School of Medicine, New Haven, CT 96510, USA.

Key words. Diabetic foot ; management ; foot reconstruction.

Abstract. There is considerable morbidity and mortality associated with ulcerations of the lower limbs in patients with diabetes as well as non-diabetic patients. The role of the primary care physician and podiatrist in the evaluation, diagnosis, and management of lower extremity wounds is critical. Careful assessment and management of vascular disease by vascular surgeons and interventionalists, biomechanical foot abnormalities by the podiatrist, wound coverage by the plastic surgeons and aggressive treatment of infections and metabolic derangements by the physicians are required. The multidisciplinary approach provides a comprehensive treatment protocol and significantly increases the chances of successfully healing the ulcer and prevents recurrence. It also provides for increased academic output through publications, participation in clinical trials and educational venues.

Introduction

Ulcers are breaks in the dermal barrier with subsequent erosion of underlying subcutaneous tissue. In severe cases the breach may extend to muscle and bone. The prevalence of leg ulceration in the general population of western nations has been reported to be from 1 to 3.5%, with the prevalence increasing to 5% in the geriatric population (1, 2). The data from these studies most likely underestimate the true prevalence because they do not include patients with leg ulcers that are not known to the health care system. Early recognition of the etiology of these foot lesions and prompt management of the ulcer is essential for good functional outcome. In many cases, successful salvage of an extremity is dependent upon a multidisciplinary team of specialists and timely consultation is warranted.

Materials and Methods

In 1998, we created a Center for Limb Preservation at the Yale Medical Center. We hypothesized that by utilizing appropriate knowledge of risk factors and applying evidence-based multidisciplinary treatment, more than 50% of all foot & leg amputations can be prevented (3, 4). This initially involved the coordination of multidisciplinary clinics of podiatrists and vascular surgeons. This was later extended to a Center for Vascular Disease which included interventional radiologists. The three specialties saw their patients at the same time in a common outpatient location. The algorithm utilized to assess diabetic foot wounds are given on Figure 1. Physical therapists, prosthetists and a staff of vascular lab technologists to perform the physiologic and ultrasound vascular studies were also present in this location. Plastic surgeons and pain specialists were available for immediate consultation. Patients of these specialties were assigned to hospital wards that were adjacent to each other to promote better coordination of care by the service teams. Clinical rotations were created to enable podiatric residents to be assigned to the vascular surgery unit and combined monthly teaching rounds were conducted by the different services. The Vision was to create the pre-eminent center for functional lower extremity care in the region with our mission of providing outstanding patient care and foot salvage in the setting of research and education.

The total number of major vascular procedures, diagnostic radiological procedures and major and minor lower extremity amputations performed at the Yale-New Haven Hospital was ascertained through our data registry prior to the formation of the multidisciplinary center (1995) and in the subsequent years after the establishment of this collaboration (1998, 2001, 2003).

Results

Figure 2 shows the numbers for the major categories of aortic reconstruction. Abdominal aortic aneurysm (AAA) repair remained relatively stable, 55-71 procedures per year. Carotid endarterectomy (CEA) was performed approximately 90-100 times per year. This also remained relatively stable. Of note, however, was that the number of surgical procedures for aorto-iliac occlusive disease (Ao-fem) including aorto-bifemoral, axillo-femoral, ileo-femoral or femoral-femoral bypasses or

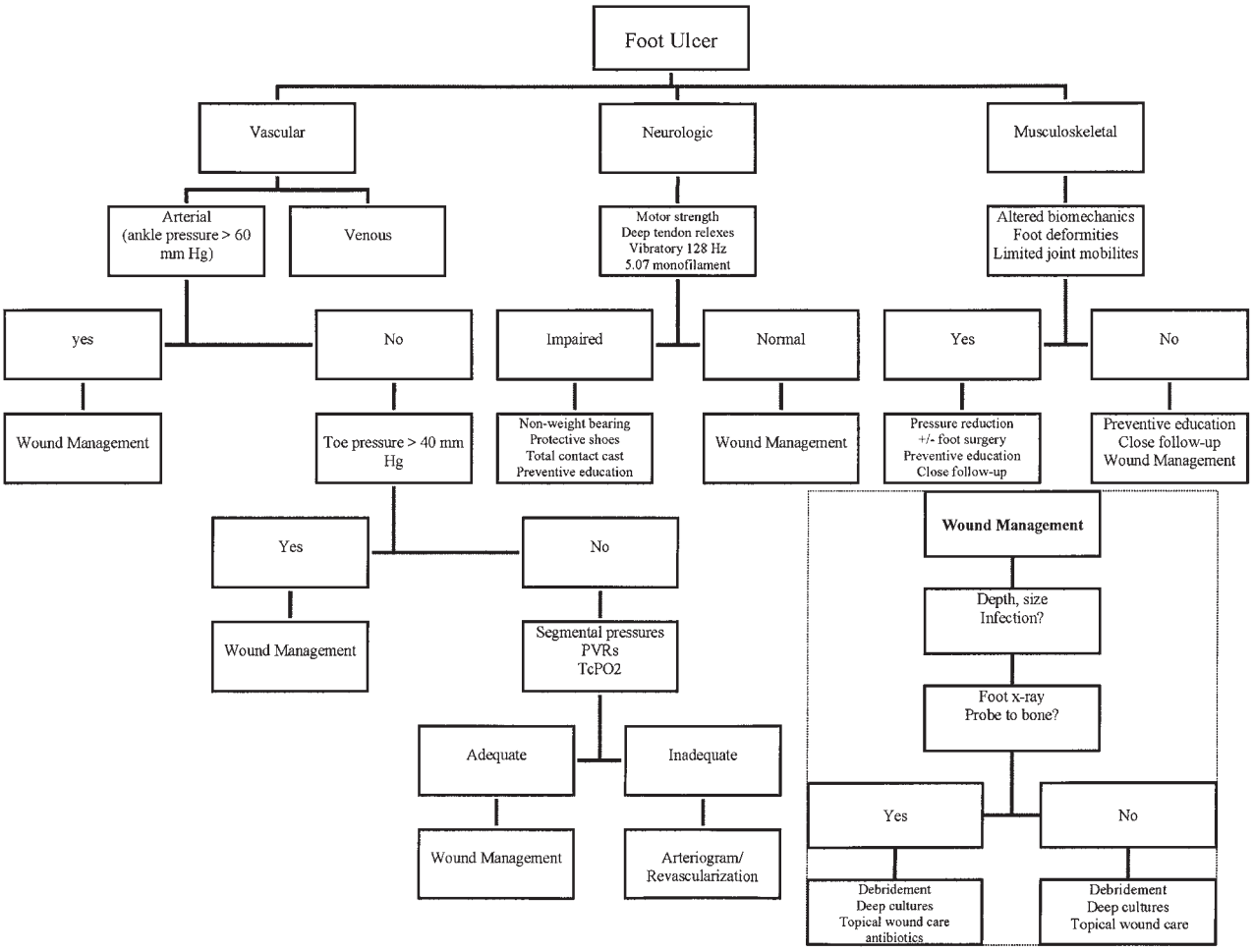

Fig. 1
Algorithm for the multidisciplinary management of diabetic foot wounds

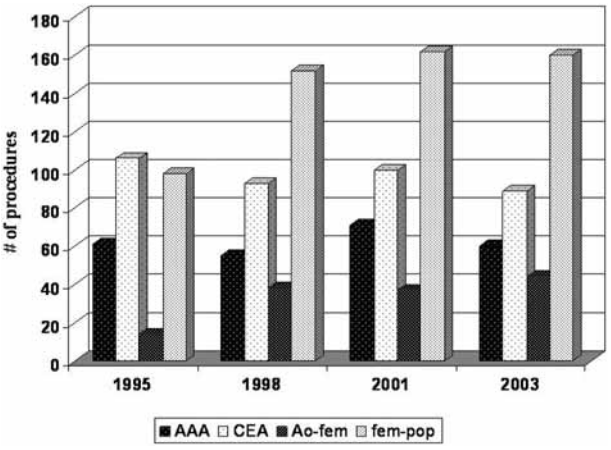

Fig. 2
Major categories of aortic and lower extremity reconstruction. Abdominal aortic aneurysm (AAA), carotid endarterectomy (CEA), aorto-iliac occlusive disease (Ao-fem) including aorto-bifemoral, axillo-femoral, ileo-femoral or femoral-femoral bypasses or endarterectomy, infra-inguinal reconstructions (fem-pop) including, femoraldistal bypass and popliteal-distal bypass operations.

endarterectomy, more than doubled in 1998 and has been sustained at these higher levels. A significant increase in our infra-inguinal reconstructions also occurred. These procedures included, femoraldistal bypass and popliteal-distal bypass operations.

The total number of major (above (AKA) or below knee amputations (BKA)), and minor amputations (transmetatarsal, forefoot, digits) were recorded (Fig. 3). Since 1998 there was a relative decline in numbers of major amputations with a concomitant increase in number of minor amputations. With the multidisciplinary interactions amongst the podiatric and plastic surgeons, the number of foot reconstructions increased. These included operations with partial bone amputations followed by local flaps to cover defects as well as correction of foot abnormalities (Fig. 4-6). The reconstructions were performed to preserve foot functionality and to maintain the most distal level of amputation.

The total number of diagnostic aortic and/or lower extremity angiograms performed for occlusive disease for the same time period was also determined (Fig. 7).

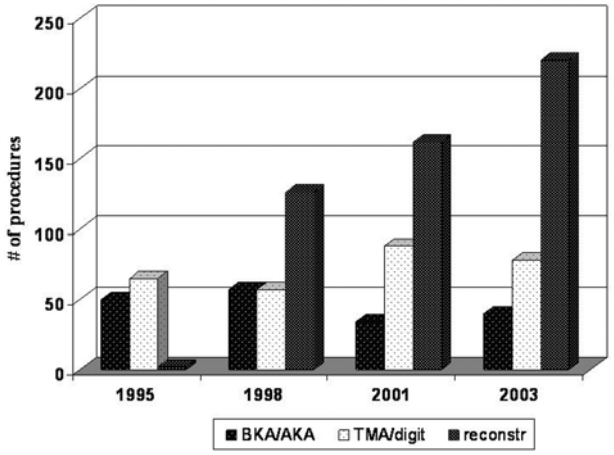

Fig. 3
Total number of major (above (AKA) or below knee amputations (BKA)), and minor amputations (transmetatarsal, forefoot, digits).

There was an overall decrease in angiograms performed while having a relatively unchanged number of interventions for either primary or secondary arterial disease or for promoting patency of lower extremity bypass grafts.

Discussion

Lower extremity ulceration is prevalent throughout the world and poses a major threat to limb integrity. In the United Stated, it accounts for more than 20% of hospital admissions in patients with diabetes, and an estimated annual health care cost of more than $ 2.5 billion (5). Failure of these ulcers to heal lead to lower extremity amputations. In addition, nearly half of all patients who undergo amputation will develop limb-threatening ischemia in the contralateral limb and many will ultimately require an amputation of the opposite limb within 5 years.

The cost of treating leg ulceration is staggering. Epidemiological studies from Sweden estimated annual costs of treatment of lower extremity ulcers at $25 million. In England, the estimated cost of care for patients with leg ulcers in a population of 250,000 was about $130,000 annually per patient. Items factored into the equation include physician visits, hospital admissions, home health care, wound care supplies, rehabilitation, time lost from work, and jobs lost. Adding to the cost is the chronic nature of these wounds, the high rate of recurrence, and the propensity to become infected. It is also evident that a true accounting of the cost is difficult because of the unknown prevalence of disease.

The social cost of leg ulcers also becomes a factor as the disease affects the patients' lifestyle and attitude. The ability to perform their job may be temporarily or permanently affected by the condition. Reduction in their working capacity adds to the total cost. There are also psychological implications. A report in 1994 (6) noted that 68% of patients expressed feelings of fear, social isolation, anger, depression, and negative self-image because of the ulcers. 81% of the patients felt that their mobility was adversely affected. Within the younger population that was still actively working, there was a correlation between lower extremity ulceration and adverse effect on finances, time lost from work, and job loss. In addition, there was a strong correlation between time spent on ulcer care and feelings of anger and resentment. These factors combined to have a negative emotional impact on their lives.

The United States government has promoted The Healthy People 2010 initiative which serves as a roadmap for improving the health of all people in the United States during the first decade of the 21st century and build on earlier initiatives (http://www.healthypeople.gov/). The main premise is that the individual biology and behaviors influence health through their interaction with each other and with the individual's social and physical environments. Policies and actions are implemented to improve health by targeting factors related to individuals and their environments, including access to quality health care. Healthy People 2010 had 28 major areas of focus, of which diabetes was one. Diabetic objectives included the goal to reduce the lower extremity amputations per 1,000 persons with diabetes from 4.1 in 1997 to 1.8 per year, a 55% targeted improvement. Another objective was to increase the proportion of adults with diabetes who have had at least an annual foot examination to 75 percent from the current baseline of 55 percent. However, despite these lofty goals to reduce lower extremity amputations by 40% by the year 2010, United States statistics indicate that the incidence and prevalence of amputations has actually increased (4) . In fact, on a diabetic patient's routine visit to primary care physician, foot exams are only performed 10%19% of the time (7). Of patients admitted to the hospital for diabetic foot complications, less than 14% receive adequate lower extremity evaluations (8).

The pathophysiologic mechanisms underlying diabetic foot disease are multifactorial and include neuropathy, infection, ischemia and abnormal foot structure and biomechanics. It is not surprising then that the management of the diabetic foot is a complex clinical problem, which requires multidisciplinary inputs (Fig. 1). Although peripheral neuropathy has a central role and is present in over 80% of diabetic foot lesions, the vascular specialists maintain a critical management role since inadequate perfusion will always result in a non-healing wound (9). Lack of arterial blood flow decreases tissue resilience, leads to rapid death of tissue, and impedes

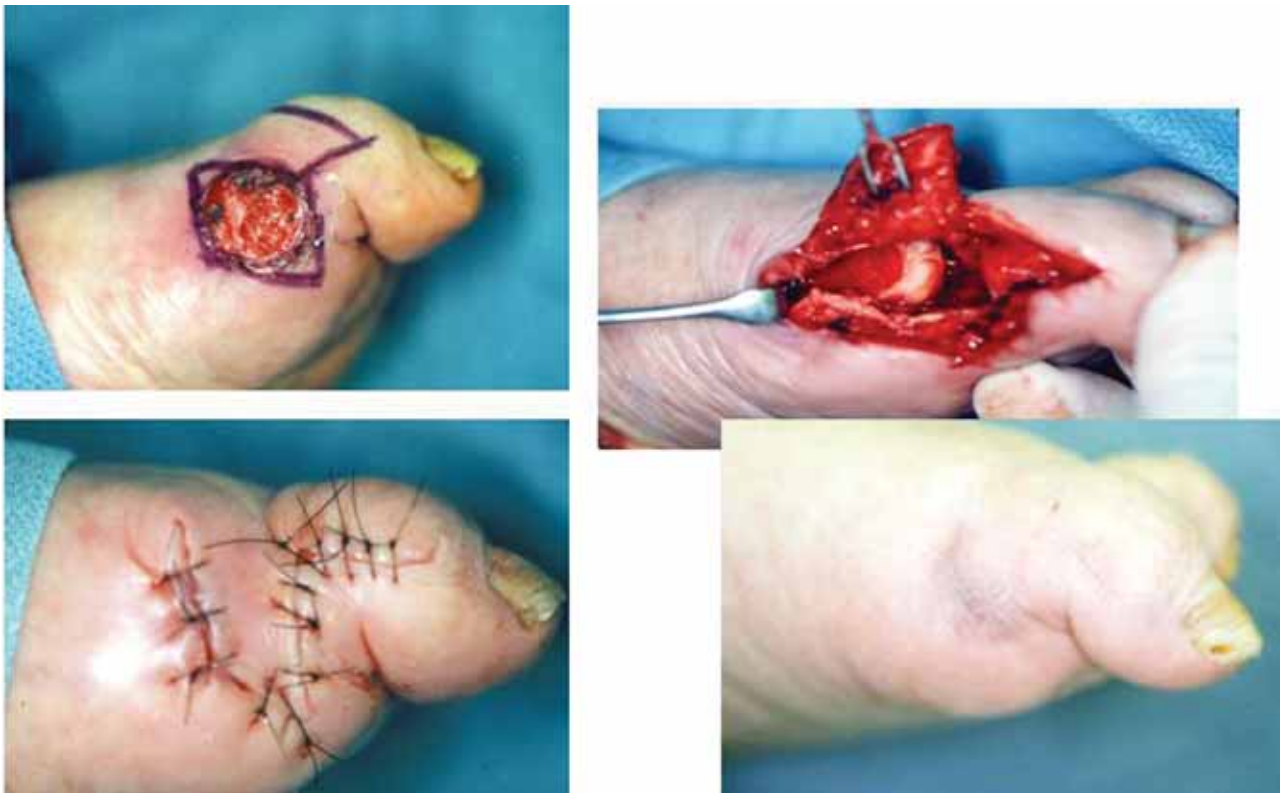

Fig. 4
Resection of ulcer and underlying metatarsal head with preservation of the hallux by use of a rhomboid flap

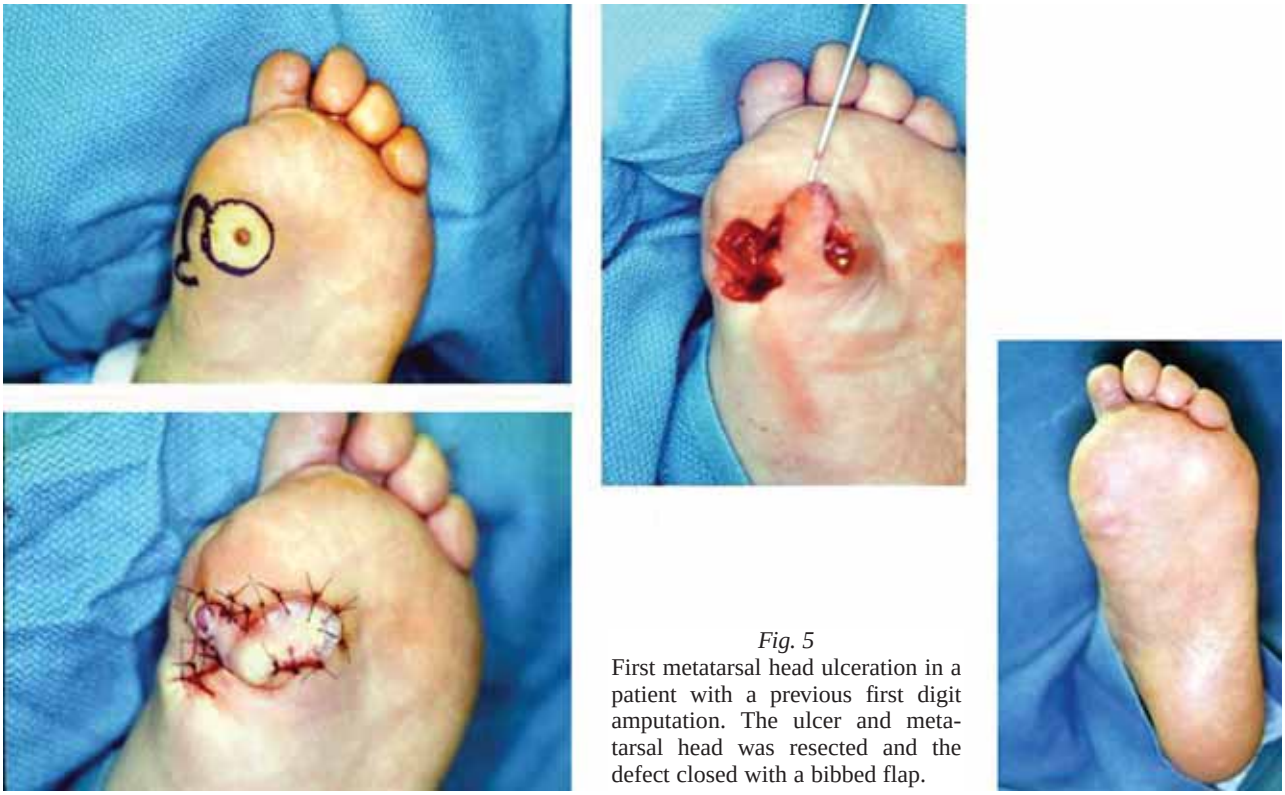

Fig. 5
First metatarsal head ulceration in a patient with a previous first digit amputation. The ulcer and metatarsal head was resected and the defect closed with a bibbed flap.

Fig. 6
Lateral column ulceration in a patient with a Charcot foot deformity. The ulcer and fifth metatarsal head was resected and the wound reconstructed with a double Z rhomboid flap.

wound healing. In addition, correction of hypoxia improves cutaneous micro circulation in the neuropathic diabetic foot resulting in retardation of the progression of neuropathy. Non-interventional management of patients with lower extremity ischemia consists of general wound care measures and use of pharmacologic agents, such as anticoagulants and thrombolytic therapy. As a rule, however, severe ischemia of the lower limb generally requires an interventional approach. The method of revascularization of the affected limb is dependent upon several factors ; among the most important being the indications for surgery, the patients' risk factor, arteriographic findings and available graft material.

The podiatric surgeon also plays a key role. Four foot-related risk factors have been identified in the genesis of pedal ulceration : peripheral neuropathy, evidence of increased pressure, altered biomechanics, and limited joint mobility, bony deformity or severe nail pathology (4). Successful management of foot ulcers involves recognition and correction of the underlying etiology as well as appropriate wound care and prevention of recurrence. Off-loading strategies such as total contact casting or removable walkers, has resulted in significant decreases in healing times. The stresses placed upon the foot can be intrinsic or extrinsic in nature. These external forces can result from inappropriate footwear, traumatic injury, and/or foreign bodies. Shoes that are too tight or too shallow are a frequent, yet preventable component to the development of neuropathic ulcers. A variety of shoe modifications such as rocker sole design and different types of insoles, have shown that it is possible to reduce plantar foot pressures thus decreasing risks of ulceration.

Reconstructive foot surgery may often become the conservative treatment in order to avoid major amputations in chronic neuropathic wounds. The endpoint for chronic diabetic foot wounds should include reduction in the number of major amputations, prevention of infection, decrease probability of ulceration, maintaining skin integrity, and improvement of function. Open wounds can be treated in one stage and are primarily closed with pre-morbid tissue using local flap reconstruction (Fig. 4-6) and soft tissue repair (10). Reconstructive surgery can range from simple metatarsal head resections to subtotal calcanectomies. Local flaps that are often difficult to elevate and inset are more easily mobilized and incised when concomitant bone resection is achieved at the time

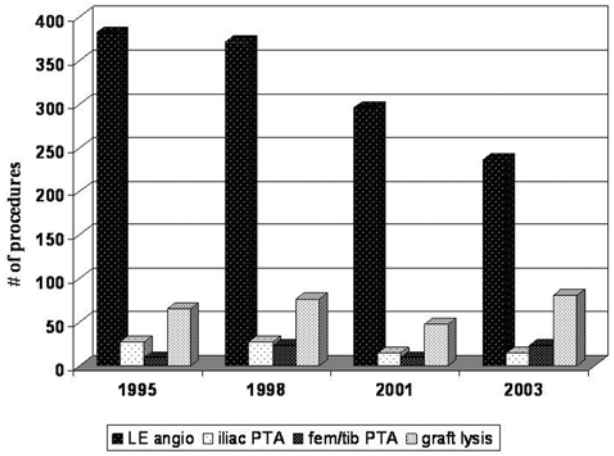

Fig. 7
Total number of diagnostic aortic and/or lower extremity angiograms performed for occlusive disease (LE angio) and the interventions for either primary or secondary arterial disease (iliac PTA and femltib PTA) or for extending patency of lower extremity bypass grafts (graft lysis).

of flap creation. In addition, a local flap will result in greater exposure and direct visualization of the underlying osseous structures compared to a single linear or semielliptical incision. The implementation of local random flaps can eliminate the need for additional incisions often deemed necessary to gain access to a forefoot, midfoot, or rearfoot bony defect. Plastic surgical repair of these wounds can help avoid the production of inelastic scar tissue over weight bearing surfaces. Extrinsic pressures and intrinsic pressures can be further neutralized with post-op accommodative shoe gear.

Prophylactic diabetic foot surgery is becoming an increasing option in preventing recurrent ulceration and reducing the risk of major amputations. Surgical biomechanics, plastic and soft tissue reconstruction, as well as appropriate off loading are all essential to creating a stable platform from which to keep these difficult patients free from tissue breakdown, and as functional as possible. Successful outcomes for diabetic foot reconstruction should result in less intrinsic pressures via minor amputations, arthroplasties, osteotomies, chondylectomies, exostectomies, tendon procedures, and joint arthrodesis.

The creation of a truly multi-disciplinary center enables the hospital to link and coordinate a multidisciplinary team of specialists to effectively manage patients with complex disease of the peripheral vasculature and diabetic neuropathy. It also provides the participants with a leadership role in the dissemination of information regionally and nationally and it enables the medical center to be at the forefront in the development of new information and strategies for both the prevention and treatment of limb threatening disorders. When done in the setting of an academic institution it also provides for the utilization of the infrastructure to design and implement clinical research trials.

One benefit for the physicians seen in our data is that the establishment of a distinct, readily identified "center" resulted in an incremental increase in patient referrals especially from primary care physicians and podiatrists in the region. Utilization of the multidisciplinary teams attracted industry-supported clinical trials involving algorithms for optimum management for functional foot salvage and new technology in wound healing and orthotics. We have participated in 11 clinical trials to date : 3 involving antibiotics, 3 in wound healing medications, 1 for cardioprotection during vascular procedures, 2 in perfusion measurement devices and 1 instrument for wound healing.

Conclusion

An aggressive multidisciplinary approach to foot disease involving the primary care provider, medical specialists, interventional radiology, podiatric, plastic and vascular surgeons will provide optimal medical and surgical care. The principles of care are actually simple including correction of systemic factors such as blood glucose control, cardiovascular risk factor management, smoking and local factor correction such as debridement, pressure relief, infection control and revascularization when indicated. Assessment of the ulcer consists of determining the size and depth of the wound, and inspection of the surrounding area for local signs of infection or gangrene. Peripheral vascular disease is highly treatable if intervention is instituted in a timely and collegial fashion. Early aggressive drainage, debridement, and local foot amputations combined with liberal use of revascularization results in cumulative limb salvage of 74% at 5 years in high-risk groups. Support for education based programs for the region not only enhances the identity of our academic institution as a health leader but provides good will among the regional primary care and specialty physicians. Innovative use of technology already being developed and utilized in the medical center expedites the dissemination of information and the design and implementation of clinical research programs.

Acknowledgement

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References

1. Sumpio B.E. Foot ulcers. *N Engl J Med*, 2000, **343** : 787-793.
2. Sumpio B., Blume P. Contemporary management of foot ulcers. *In* : Pearce W., Matsumura J., Yao J. (eds.). Trends in Vascular Surgery. Chicago, IL : Precept Press, 2002 : 277-290.
3. U.S. Department of Health and Human Services National Diabetes Fact Sheet. 1998.
4. American Diabetes Association. Preventive foot care in people with diabetes (position statement). *Diabetes Care*, 2003, **26** : S78-79.
5. Knox R., Dutch W., Blume P., Sumpio B. E. Diabetic Foot Disease. *Int J of Angiology*, 2000, **9** : 1-6.
6. Phillips T. Chronic cutaneous ulcers : etiology and epidemiology. *J lnvest Dermatol*, 1994, **102** : 38S-41S.
7. Bailey T. S., Yu H. M., Rayfield E. J. Patterns of foot examination in a diabetes clinic. *Am J Med*, 1985, **78** : 371-374.
8. Edelson G. W., Armstrong D. G., Lavery L. A., Caicco G. The acutely infected diabetic foot is not adequately evaluated in an inpatient setting. *Arch Intern Med*, 1996, **156** : 2373-2378.
9. Collins K. A., Sumpio B. E. Vascular assessment. *Clin Podiatr Med Surg*, 2000, **17** : 171-191
10. Blume P., Partagas L., Sumpio B., Attinger C. Single stage surgical treatment of noninfected diabetic foot ulcers. *J Plastic Reconst Surg*, 2002, **109** : 601-609.

Bauer E. Sumpio, M.D., Ph.D.
Professor of Surgery and Radiology
Chief Vascular Surgery
Yale University School of Medicine
333 Cedar Street
New Haven, CT 06520
E-mail : bauer.sumpio@yale.edu.