Complications of diabetes are the leading cause of hospitalization in countries around the world. People with diabetes have a 15% lifetime risk of developing a foot ulcer and a 15- to 46-times greater risk of lower-extremity amputation than those without diabetes.\(^1, 2\) According to the Centers for Disease Control and Prevention, in 1996 there were approximately 86,000 hospital discharges in the United States for diabetes-related nontraumatic amputations.\(^3\) This number has risen over the last decade despite efforts aimed at prevention. Furthermore, survival is poor in diabetic patients after amputation, with higher levels of amputation generally resulting in lower survival rates. Several studies in recent years have indicated that the immediate perihospital mortality of patients receiving high-level amputations is approximately 5%,\(^4, 5\) and the 5-year survival rate after major amputation in this population is less than 50%.\(^6\)

Numerous studies have discussed the importance of peripheral neuropathy in the etiology of diabetic foot ulcers.\(^7, 8\) However, other important risk factors, including biomechanical dysfunction and deformities, trauma, high plantar pressures, limited joint mobility, male gender, duration of diabetes, and elevated glycohemoglobin levels also place the diabetic foot at risk for ulceration. In a study investigating the risk factors and pathways leading to foot ulceration, Reiber et al.\(^9\) found that the critical triad of neuropathy, trauma, and foot deformity was present in 63% of ulcerated patients evaluated. Once patients have had a foot ulcer, they are always at a higher risk for developing another ulcer. Risk factors for amputation are similar to those for ulceration, as 85% of diabetes-related lower-extremity amputations have an ulceration in the causal sequence.\(^10\)

Significant improvements in outcomes have been accomplished through multidisciplinary management of these complex patients. Armed with a better understanding of the etiology of limb-threatening lesions, as well as their appropriate treatments, organized foot care teams and services established at numerous medical centers have dramatically reduced the incidence of recurrent ulceration and amputation.\(^11-16\) Diabetic foot services usually consist of an internist or endocrinologist, podiatrist, vascular surgeon, infectious disease specialist, teaching nurse, and pedorthist, with modifications depending on the needs of the patient population and the resources of the host institution.\(^17\) Prevention plays a key role in the success of any amputation reduction program and it is an integral component of care. Patient education, footwear selection, and provider education are recognized as essential elements of any prevention program.\(^18\)
Ulceration

The Foot Care Council of the American Diabetes Association sponsored a number of sessions at the Scientific Symposium, including oral abstracts, poster discussions, and several themed symposia. The oral abstracts included a presentation from Carrington on data from a 6-year longitudinal study of 169 subjects. The study examined predictive risk factors for ulcers and amputations specifically focused on a variety of neurologic parameters measured at baseline. Within 6 years, 19.5% of the combined diabetes group developed a new foot ulcer, 11.2% had an amputation, and 18.3% died. Several measures of both small- and large-fiber neuropathy were predictive of ulceration and amputation, including pressure, temperature, and vibratory perception thresholds, motor nerve conduction velocity, and previous ulcer. These results, obtained prospectively in a fairly large group, confirm other studies on predisposing risk factors for ulcers and amputations.

In a randomized, controlled clinical trial from Italy, Caravagi introduced the utility of an autologous hyaluronan–based dermal and epidermal tissue-engineered skin implant in treating nonischemic diabetic foot ulcers in contrast to total contact casting alone. Although there was a trend toward faster healing in the treatment group (graft plus cast), except for dorsal ulcers, the results were not statistically significant. This was attributed to the beneficial effect of total contact casting used in both treatments. While this product is not available in the United States, it may have possible indications for dorsal and nonplantar ulcers, or in patients with plantar ulcers who are not treated with contact casting. The study by Caravagi also supported the efficacy of total contact casting in the management of neuropathic plantar ulcers. This was further corroborated in the President’s Poster Session by Armstrong et al.19 who presented the results of a randomized, controlled trial contrasting the effectiveness of total contact casting, removable cast walkers, and half shoes in healing diabetic neuropathic plantar ulcers. In a 12-week trial, 80.5% of the total contact casting group healed their ulcers, and 65% of the removable walker group and 58.3% of the half shoe group healed. The odds of healing in a total contact casting were more than five times greater than in the combined group of patients who were not casted. This was augmented by a significant difference in time to complete healing based on survival analysis. The value and efficacy of total contact casting in the management of neuropathic plantar ulcers is clearly established with this data. In another randomized study of total contact casting and ulcer wound healing, Piaggesi investigated changes in plantar ulcer tissue histology after 20 days of casting. While the study contained several methodological weaknesses, preliminary results in the 20 patients indicate that casting reduces inflammatory or reactive components and enhances reparative processes in chronic ulcers as compared to baseline histologic specimens.

Microvascular Physiology

There has been a great deal of interest recently in nitric oxide and its role in the etiology of metabolic perturbations associated with diabetes mellitus. Using intradermal nitric oxide sensors and laser Doppler flowmetry, Stansberry and Vinik presented an oral abstract that contrasted the physiologic effects of heating on nitric oxide production and skin perfusion between healthy controls, impaired glucose tolerance subjects, type 2 diabetes subjects, and first order relatives to patients with type 2 diabetes. While nitric oxide levels increased equally with heating in all groups, maximum perfusion and nitric oxide sensitivity (perfusion/nitric oxide) was impaired in the three noncontrol groups, suggesting that nitric oxide production is not critically impaired in hyperglycemic states, but sensitivity to nitric oxide (physiologic response) is reduced and is the hallmark of the metabolic syndrome. This is similar to the relationship between type 1 and 2 diabetes, in which type 1 patients do not produce sufficient insulin and type 2 patients often are not adequately sensitized to insulin. The authors also presented a poster investigating the component pathways (nitric oxide and neurogenic) leading to skin vasodilation in response to graded heating. Using both a neuronal blocker and a blocker of all forms of nitric oxide synthase (nitric oxides) at low and noxious levels (44°C) of heating, they found that the neuronal blockade had a greater magnitude of effect on preventing skin vasodilation at less than noxious levels of skin warming. However, at 44°C skin vasodilation occurred despite the blockade of both pathways, suggesting that other unknown mechanisms are invoked during this physiological response to heating.

Amputation

Several abstracts investigating the rates of lower-extremity amputation in diabetes were presented at the symposium. In the President’s Poster Session, Wrobel presented data on geographic variations in rates of major lower-extremity amputation across the United States among Medicare beneficiaries. Age,
sex, and race adjusted annual rates were 10 times higher among diabetic beneficiaries than among people without diabetes \((3.83 \text{ versus } 0.38/1,000 \text{ people with and without diabetes, respectively})\). Furthermore, high regional variations in these rates existed in both populations. Additional investigations are necessary to determine the reasons for these disparities, including access to preventive care, surgical practices, and density of vascular surgical consultants. Vileikyte’s research focused on common sense patients’ nonadherence to preventive foot care practices, and density of vascular surgical consultants. Wunderlich and Lavery presented an abstract on the beneficial effects of a diabetic foot screening and treatment program as part of a disease management model used within a 16,000 member health maintenance organization in Texas. After a 26-month period that followed wide-spread population screening, risk stratification, and treatment intervention, there was a 70% reduction in amputation incidence compared to baseline as well as noted reductions in member hospitalizations and lengths of stay. This diabetes group of 1,700 will continue to be followed prospectively to further ascertain the long-term benefits of a proactive disease management and prevention program. In a retrospective study from Italy, Scionti presented a poster on an 8-year population-based survey on lower-extremity amputation in patients with and without diabetes. Using operating room registries to obtain data from a defined population, the author found a nearly 30-times greater incidence in diabetes-related amputations, as compared to the nondiabetic population. As expected, there were increased rates in older people of both groups, but over the 8-year period there was no significant increase in the number of diabetes-related lower-extremity amputations. However, there was a trend toward performing more distal (minor) amputations than in previous years. These numbers may reflect a recent trend to perform more distal limb salvaging amputations. Unfortunately, National Hospital Discharge Survey data do not provide information on numbers or levels of amputations performed during each hospital admission reported.

**Prevention**

The Scientific Symposium was specifically designed around prevention. Two separate sessions dealt with the prevention of lower-limb complications in diabetes. The first session on prevention of amputation began with a discussion by Vileikyte on the psychological principles and studies useful in understanding patients’ nonadherence to preventive foot care practices. Vileikyte’s research focused on common sense issues that have been incorporated into the Neuropathy Psychosocial Inventory, which is used to assess the determinants of preventive foot care behaviors in diabetic patients with peripheral neuropathy. Although patients in the United States and United Kingdom differed, the two strongest predictors for preventive foot care practices were worry about foot problems and perceptions of the causes of foot ulceration. Lavery spoke on the effectiveness of diabetic foot prevention programs, drawing from experiences in the disease-management model program used in Wunderlich’s managed care model. The prevention strategies included: 1) identification of patients with diabetes; 2) screening for risk factors; 3) risk stratification; 4) prevention strategies (foot care, shoes, education, etc); and 5) acute care protocols. The low tech–high touch approach resulted in a significant decrease in hospitalizations, lengths of stay, amputations, and recurrent ulcerations, with a relatively early return on investment. This exceptionally promising work suggests that a real world model (outside of a large academic institution) may be cost-effective and also save limbs. Lastly, Vinicor spoke on reimbursement issues involving preventive services, emphasizing the 3 “P’s”: 1) Problem: The health issue must be seen as a problem by many people; 2) Policy: Accepted and recognized solutions must have consensus in the diabetes community; and 3) Politics: The three branches of government must agree on the necessity for implementation of preventive programs. Solid research on the efficacy and efficiency of preventive care is necessary before large governmental agencies and systems can be asked to make changes.

The second session on prevention focused on footwear design and the importance of proper shoe and insole selection to avoid iatrogenic foot lesions. Reiber presented data on a randomized trial involving customized and standard inserts and custom shoes on the development of foot ulcers in 400 diabetic patients over 2 years. The patients were drawn from two health systems in the Seattle area. Although a majority of minor lesions developed in all groups, they were not strictly classified as ulcers. Only 62 ulcers developed over two years and they were equally distributed among the groups. There was a protective tendency against ulcers in the two custom footwear groups as compared to the control group, but the results did not achieve statistical significance. Custom inserts did not provide any additional benefit over standard insoles, and therapeutic shoes did not provide any apparent benefit. As the author discussed, several possible confounding variables could not be controlled across all groups, likely contributing to the negative results of this trial. This highly controlled population received regular attention to foot care and most likely received foot care educa-
tion external to the design of the study. Thirteen percent of the control subjects purchased therapeutic footwear on their own initiative. These circumstances probably reduced the onset of lesions in the control groups to the point that there were not enough outcome events to demonstrate a difference between footwear groups. Clearly, more attention must be given to the methodological issues raised by this study before therapeutic shoes can be dismissed as not beneficial to diabetic patients at risk for foot ulcers.

Wound Classification

Boulton and Schaper presented opposing views on the current debate regarding appropriate classification of diabetic foot wounds. Boulton reviewed the strengths and weaknesses of a number of previously described systems. Stressing the need for simplicity, facilitation of communication, proper description, and assessment for ischemia and infection, Boulton focused on the two validated systems in terms of predicting the possible need for amputation: The University of Texas System and S(AD) System. These classifications incorporate elements of depth, infection, and ischemia that are considered important predictors for outcome and treatment. Boulton concluded that both systems are valuable and should be used in diabetic foot centers worldwide.

Notwithstanding the discussion by Boulton, the Meggit-Wagner System is still the most widely known and used system throughout the world. Schaper reviewed pertinent literature on the subject and discussed objective components for classification. He highlighted the need for proper definition of terms and consistency of use between investigators. Schaper suggested that diabetic foot ulcers are not homogeneous entities, but heterogeneous lesions with clusters of underlying abnormalities. Furthermore, there may be several different and separate ways to classify these lesions based on their etiology (insensitive versus ischemic). The session concluded with a consensus that a modification or amalgamation of currently existing classifications may help to develop a standardized system that the diabetic foot community can adopt.

The Future of Wound Care

In an interactive Meet-The-Professor session, Steed reviewed the present state of diabetic wound care and presented his vision of its future. Chronic wounds of all types represent an $11 billion drain on the US healthcare system, with approximately 6% of patients with diabetes suffering from such complications. This diabetes complication is one that managed care organizations seek to control. Accordingly, there has been a shift away from the inpatient care of these wounds to outpatient clinics, home care, and even telemedicine venues. The future of wound care has already begun with the development and use of various growth factors, tissue-engineered implants, gene therapy, and stem cell therapies. Finally, it was emphasized that good wound care is extremely cost-effective compared to the gangrene and amputation that frequently result from neglect or inappropriate care. It was stressed throughout the conference that primary prevention of wounds should be the ultimate goal of all providers, and that prevention has the greatest impact on reducing the burden of lower-extremity complications of diabetes.

The History of Diabetes Care

In a presidential address that will be remembered for its clarity, quality, and inspirational nature, ADA’s President of Healthcare and Education, Lee J. Sanders, DPM, used stamps as an interesting and brilliant backdrop to discuss the history of diabetes from antiquity to the present and beyond. His description of the incremental discoveries, beginning with guidelines written in hieroglyphics on papyrus to those written in genetic code on proteins, was not only comprehensive, but also thought provoking and emotionally stirring. As a complement to this lecture, Lawrence B. Harkless, DPM, delivered a similarly moving account of his experiences as a mentor and teacher in his Diabetes Educator of the Year acceptance speech.

References