The prevention of foot ulceration and amputation in the patient with diabetes is crucial. The Society for Endocrinology, Metabolism and Diabetes of South Africa (SEMDSA) will soon issue guidelines on this important topic. This review hopes to cover some of the essential facts pertinent to these guidelines.

**The importance of the diabetic foot**

**Burden of disease**

The annual incidence of foot ulcers in the general diabetes population is just over 2% in the UK and Netherlands.\(^1\) Neuropathic patients may have annual incidence rates between 4% and 7%. More than 5% of diabetic patients have a history of foot ulcers and the cumulative lifetime incidence may be as high as 15%.\(^3\)

**Costs**

Shearer *et al.*\(^4\) confirmed that diabetic patients with neuropathic risk factors (reduced vibration perception) incur five times more direct medical costs for ulcers and amputations, and live for 2 months less than individuals without neuropathy.

In the USA average inpatient costs in 1997 were: foot ulcers $16 580, toe or toe and other distal amputations $25 241, and major amputations $31 436. The average outpatient cost for one diabetic foot ulcer episode has been estimated at $28 000 over a 2-year period.\(^5\) Costs of foot ulcer patients outstrip those of non-foot ulcer patients by a factor of approximately 1.5 - 2.4 times in the year before diagnosis and by 5.4 times in the year following diagnosis, and remain 2.8 times greater in the second year.\(^6\)

**Impact on quality of life**\(^7\)

In a study by Meijer *et al.*,\(^8\) 14 patients with a previous or current (but clinically stable) diabetic foot ulcer were compared with 24 controls without ulcers, matched for age, sex, and duration of diabetes. The investigators concluded that an existing or previous foot ulcer had a negative influence on the physical and social aspects of their subjects’ quality of life.

These findings are supported by a study that used the Markov state transition model to estimate the cost effectiveness of several approaches to the diagnosis and treatment of foot infection and suspected osteomyelitis in diabetic patients. To adjust life expectancy for quality of life as an outcome measure, scores from 1 738 diabetic patients on three subscales of the Short Form-36 were used to calculate weighting factors for the decision model. Compared with diabetic controls, both those with ulceration and those who had amputation rated their quality of life as significantly poorer for physical functioning ($p < 0.001$). Mean scores for the ulceration group (44.13) were lower than for those who had amputation (49.1). The location of the amputation was also important — patients with foot ulceration had poorer scores than those who had toe, transmetatarsal, and below-the-knee amputation, but they had better scores than those who had above-the-knee amputation.

Studies of patients with foot problems other than amputation also provide information on the consequences of foot complications. For example, a study of patients with peripheral neuropathy who developed ulcers over a 10-month period found that they had a more negative attitude toward their feet and less belief in the efficacy of medical advice than those with existing ulcers, Charcot neuroarthropathy, or diabetic controls. In this study, neuropathy and negative attitude toward feet predicted development of a first ulcer. These data may reflect the complex relationship between depression and neuropathy.\(^9,11\)

**Causal pathways**\(^3\)

Amputations are preceded by foot ulceration in more than 85% of cases. Foot ulcers result from the interplay of various risk factors, typically neuropathy plus disturbed foot mechanics/anatomy plus or minus vascular compromise, with minor trauma resulting in ulceration. Neuropathy is the most important contributor in the pathway. Peripheral ischaemia resulting from proximal arterial disease is a component cause in 35% of cases.\(^2\) Risk factors for ulceration are shown in Table I.

**Prevention of foot ulceration and amputation**

A simplified pathway underlying lower-extremity amputation can be visualised as: neuropathy $\rightarrow$ ulceration $\rightarrow$ amputation. Early detection of neuropathy (and other risk factors) and appropriate
management of foot ulcers are therefore vital to reduce amputation rates.

Screening diabetic patients to identify the foot at risk

Both feet of diabetic patients should be screened at least annually and examined at every visit if found to be at risk (Table II).

Obviously the foot risk increases as the number of positive factors related to risk increase (neuropathy with or without bony abnormalities or ischaemia or previous ulcer or amputation). The patient is deemed at risk for ulceration if any of the following are present: loss of protective sensation, both pedal pulses absent in any given foot, foot deformity, history of foot ulcer or prior amputation. Calluses may also put the patient at risk and should be treated (if possible by a podiatrist).

If the foot is identified to be ‘at risk’ the patient must be educated regarding foot care and footwear (Table III). It is also essential that such a patient’s feet be examined at every visit. According to the National Institute for Clinical Excellence (NICE) guidelines there is randomised controlled clinical trial evidence that educational interventions can improve foot care knowledge and behaviour in the short term (up to 18 months).

If needed non-ulcer pathology should be appropriately managed by a podiatrist and/or orthopaedic surgeon.

A patient with both pedal pulses absent in any foot should be referred for evaluation of possible peripheral arterial disease (ankle brachial or toe brachial index plus or minus arterial wave forms).

<table>
<thead>
<tr>
<th>Table I.</th>
<th>Risk factors for foot ulceration</th>
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<tbody>
<tr>
<td>Neuropathy</td>
<td>Peripheral vascular disease</td>
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<tr>
<td>Foot deformities</td>
<td>Plantar callus formation</td>
</tr>
<tr>
<td>Duration of diabetes</td>
<td>Increased plantar foot pressure</td>
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<tr>
<td>Other microvascular complications</td>
<td>Peripheral oedema</td>
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<tr>
<td>Previous foot ulcer or amputation (most predictive)</td>
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</table>

Table II. Components of the foot examination

| Inspection | Skin: Ulcer, callus, fissures, fungus |
| Nails: Fungal infections, ingrown toenails |
| Bone: Claw toes, hammertoes, bunions |
| Palpation: Pedal pulses |
| Neuropathy assessment 10 g monofilament |
| 128 Hz tuning fork (vibration sense) |
| Assessment of footwear Shoes appropriate width with no sharp or hard seams or edges |

Table III. Education of the ‘at risk’ patient should cover the following:

- Daily inspection of both feet, including areas between the toes
- If the patient cannot inspect his/her feet, someone else should do so
- Regular washing of feet with careful drying, especially between the toes
- Feet should not be soaked in warm water
- Temperature of the water should always be tested with the elbow to ensure that it is not too warm
- Avoid walking barefoot indoors or outdoors and avoid wearing shoes without socks
- Chemical agents or plasters to remove corns and calluses should not be used
- Daily inspection and palpation of the inside of the shoes
- If vision is impaired, patients should not try to treat the feet (e.g. nails) by themselves
- Lubricating oils or creams should be used for dry skin, but not between the toes
- Daily change of stockings/ socks
- Wear stockings or socks with seams inside out or preferably without any seams at all
- Cut nails straight across
- Corns and calluses should not be cut by patients, but by a health care provider
- The patient must ensure that the feet are examined regularly by a health care provider
- The patient should notify the health care provider within a week if a blister, cut, scratch or sore develops
Monofilament assessment to detect neuropathy

Various modalities exist to detect neuropathy. International (and soon local) guidelines advise the use of the 10 g monofilament. This simple-to-use, reproducible technique has been shown to predict ulceration (if the monofilament is not felt). The guidelines of the International Working Group on the Diabetic Foot advise testing at 3 sites (test each site in random order, using 3 tests per site with 1 sham per site included). The patient must have 2 out of 3 correct responses for sensation to be intact at a given site. Absence of sensation at any site means the foot is at risk for ulceration (Figs 1 and 2).

Management of diabetic foot ulcers (adapted from references 12 and 14 - 16)

A number of recent reviews have described protocols for management of diabetic foot ulcers. Two core issues in the assessment are: (i) presence of peripheral vascular disease (e.g. ankle brachial index (ABI) < 0.9 or > 1.2) requiring further evaluation and possible revascularisation; and (ii) the presence of infection.

If foot pulses are absent, Doppler studies should be performed (some units will do this routinely on all patients with foot ulcers).

Infection must be diagnosed clinically, e.g. systematic signs (fever, chills, leukocytosis — which can be absent in someone with diabetes), purulent secretions, or more than 2 local clinical signs or symptoms of inflammation (warmth, redness, pain/tenderness, induration). In chronic wounds delayed healing, abnormal colour, friability or foul odour may indicate infection.

Diagnosing foot osteomyelitis is notoriously difficult. Clinical evaluation should include gently ‘probing to bone’ (positive predictive value 90%).

Plain radiographs should always be obtained in patients with an infected foot ulcer (radiographic changes take at least 2 weeks to be evident). Repeat radiographs in a couple of weeks may be more cost-effective than sophisticated imaging.

However, if available, various types of scans may be useful. Bone scans (e.g. Tc-99) are sensitive (~85%) but too nonspecific (~45%). Leucocyte scans are more specific (~75%). Magnetic resonance imaging (MRI) is usually the diagnostic procedure of choice, with a sensitivity of > 79% and specificity of > 80%.

Definite diagnosis of osteomyelitis requires obtaining a specimen of bone (open or transcutaneous without transversing the open wound).

Importantly, non-infected ulcers should not be treated with antibiotics.

Core issues of management are: (i) adequate debridement of all necrotic and infected tissue; (ii) removal of pressure; and (iii) appropriate wound care.

General diabetes care

General diabetes care involves optimal glucose control and smoking cessation.

Wound preparation

Debridement is crucial. Sharp debridement (rather than medical) has been more thoroughly evaluated. Weekly sharp debridement ensures more rapid healing than less frequent debridement. Treatment of local oedema (pneumatic compression) may also be beneficial.

Removal of pressure

There is clear evidence regarding the benefit of removing pressure from the neuropathic foot ulcer. Of all methods the use of a total contact cast has been shown to be superior. A walking cast may be made unremovable by wrapping it in plaster. The application of the total-contact cast requires a degree
of expertise and can be time-consuming (it often needs to be changed weekly) and is the reason why other methods of off-loading are being evaluated.

**Wound dressing**

The use of various dressings is best summarised by the NICE from the UK.2 ‘In the absence of strong evidence of clinical or cost-effectiveness, health care professionals should use wound dressings that best match clinical expertise, patient preference, and the site of wound and consider the cost of the dressing (level D evidence) (evidence, or extrapolated recommendation from category I, II or III evidence). There is insufficient evidence to support the effectiveness of any type of protective dressing or topical application, over any other for treating diabetic foot ulcers (level Ib evidence).’ (For levels of evidence see McIntosh et al.;15 I represents meta-analysis or randomised clinical trial, and IV represents evidence from expert committee reports or opinions and/or clinical experience of respected authorities.)

An essential component of wound care is to provide an adequate moist environment. Saline dressings may not be adequate and newer dressing containing a cellulose-modulating framework (Promogran, Johnson and Johnson — available in South Africa), or hyaluron-containing dressing (Hyalofill, Convatec, USA), or hydrocolloid dressing (Comfeel, Coloplast — available in South Africa) have been developed.

**Biological therapy and growth factors**

Diabetic foot ulcers exhibit decreases in both angiogenic response and production of growth factors within the wound. Cell therapy, also called biological therapy, presents an appropriate treatment option in some cases. Accelerating healing time decreases the risk of wound infection. Cultured epidermal autografts can provide permanent coverage of large areas. The US Food and Drug Administration (FDA) approved 2 cell therapies to accelerate the closure of non-healing ulcers. These 2 commercially available products are fibroblasts in a vicryl mesh, called Dermagraft (Smith and Nephew), and Apligraf (Organogenesis, East Hanover, NJ), also known as human skin equivalent, which contains both fibroblasts and keratinocytes.26 Of these only Dermagraft is available in South Africa.

A growth factor such as recombinant human PDGF-BB (Regranex; Ortho-McNeil, Raritan, NJ) is a homodimer produced through recombinant DNA technology by inserting the gene for the B-chain of PDGF into the yeast *Saccharomyces cerevisiae*. The biological activity of becaplermin is similar to that of naturally occurring PDGF produced through recombinant DNA technology by (Regranex; Ortho-McNeil, Raritan, NJ) is a homodimer containing a cellulose-modulating framework (Promogran, Johnson and Johnson — available in South Africa), or hyaluron-containing dressing (Hyalofill, Convatec, USA), or hydrocolloid dressing (Comfeel, Coloplast — available in South Africa) have been developed.

**Conclusion**

Health care providers should have a clear strategy on how, when and where to screen in order to identify patients at risk, and they should also have a management plan once such patients are identified. It is also vital to stress that the prevention and management of the diabetic foot requires a multidisciplinary approach (diabetes educator, physician, surgeon, vascular surgeon, orthopaedic surgeon, wound care nurse, orthotist and podiatrist).