**Pathophysiology of foot ulceration**

**Introduction**

Ulcers can occur on any part of the foot; approximately half develop on the plantar side (including toes) and half on other areas. In general, diabetic foot ulcers can be divided into neuropathic, neuro-ischaemic, and solely ischaemic lesions, with partly overlapping pathophysiology. Diabetic foot lesions frequently result from a combination of two or more risk factors occurring together. Pathways to ulceration are displayed schematically in Figure 1. In diabetic peripheral neuropathy, all fibres (sensory, motor and autonomic) are affected. Sensory neuropathy is associated with a loss of pain, pressure awareness, temperature and proprioception. Due to the loss of these modalities, damaging stimuli or trauma are either perceived less well or not at all, which may result in ulceration.

Generally, it is accepted that motor neuropathy results in atrophy and weakness of the muscles of the leg, resulting in an abnormal walking pattern and abnormal loading of the plantar aspect of the foot. Moreover, patients with neuropathic foot ulcers frequently have foot deformities, such as flexion deformity of the toes. These deformities will result in areas of increased pressure, eg under the metatarsal heads. Due to clawing of the toes, pressure ulcers can also develop interdigitally or on the dorsal and plantar sides of the toes (see Practical Guidelines on the Management and Prevention of the Diabetic Foot, Figure 2). Autonomic neuropathy results in reduced or absent sweat secretion leading to dry skin with cracks and fissures. Furthermore, blood flow through arteriovenous shunts is increased, resulting in a warm, sometimes oedematous foot with distended dorsal foot veins.

**Joint mobility**

Joint mobility can become limited in patients with diabetes, probably due to glycation of proteins in joints, soft tissue and skin. In plantar ulceration, foot deformities, abnormal walking patterns, and limited joint mobility will all result in an altered biomechanical loading of the foot, with elevated plantar foot pressures and probably increased shear forces. Due to the loss of protective sensation, the repetitive trauma of walking is not perceived and, as a normal physiological response, callus forms. Unfortunately, callus functions as a foreign body at the skin surface and may further increase local pressure. Consequently an ulcer may develop, often preceded by a subcutaneous haemorrhage. Also, ulcers frequently result from factors extrinsic to the insensitive foot, such as an external trauma, often in combination with intrinsic factors such as increased foot pressure.
Peripheral arterial disease

Signs of peripheral arterial disease (PAD) can be found in approximately half of patients with a foot ulcer. In PAD, ulcers usually develop in conjunction with minor trauma or trivial injury. These may result in a painful, purely ischaemic foot ulcer. However, PAD and neuropathy are frequently present in the same patient. It is likely that a reduction in skin blood-flow, due to macrovascular disease, renders the skin more susceptible to elevated biomechanical stress, impairs wound-healing and decreases local immunity, which can lead to severe infections. It should be noted that it is unlikely that occlusive microvascular disease is a direct cause of ulceration; microangiopathy causes thickening of the basement membrane and endothelial swelling in the capillaries, but it does not cause blockage. It should also be noted that end arteries are responsible for the arterial supply of the toes. Relative minor oedema - caused, for example, by trauma, septic thrombosis or infection - can result in total occlusion of already compromised end arteries, resulting in gangrene of the toe.

Infection

Infection is seldom the direct cause of an ulcer. However, once an ulcer is complicated by an infection, the risk for subsequent amputation is greatly increased, particularly in the case of ischaemic and neuro-ischaemic ulcers.

Shoe-related trauma is the most frequent event precipitating an ulcer, although several of the pathophysiological pathways described above can combine to produce diabetic foot ulcers. An understanding of these pathways should enable the development of strategies for identifying high-risk patients, and prevent the potentially dangerous interactions which frequently result in ulceration. However, it has become increasingly apparent that, despite the implementation of such strategies, ulceration remains a common complication. Recent research has emphasized the role of psychosocial factors in the development of diabetic foot ulcers. Studies have shown that the foot-care practices of people with diabetes can be affected by their perceptions of their own risks based on symptoms, and their beliefs in the efficacy of self-care.

Further reading


Figure 1:
Diabetes Mellitus

Neuropathy

Motor

Sensory

Autonomic

"Limited joint Mobility"

Postural and coordination deviation

Decreased pain sensation and proprioception

Diminished sweating

Dry skin fissures

Foot deformities, stress and shear pressures

Callus

Trauma

Inadequate foot wear, Non-compliance, Neglect, Unawareness, Lack of patient and staff education

Foot ulcer

Infection

Amputation

Angiopathy

Micro-angiopathy

Peripheral vascular disease

Ischemia

Gangrene

Development of a plantar ulcer caused by mechanical stress

Different stages in the development of a plantar ulcer caused by mechanical stress.