The benefits of working together in diabetic foot care for the vulnerable patient

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This paper was presented as the 2015 Arnold Bloom lecture at the 2015 Diabetes UK Annual Professional Conference held in London

Abstract
The patient with a diabetic foot is extremely complex and vulnerable to tissue necrosis because three great pathologies come together in the diabetic foot: neuropathy, ischaemia and infection. As a result of neuropathy, the signs and symptoms of external physical insults and of infection may be minimal. Nevertheless, the pathology emanating from such insults and infection proceeds rapidly without the body being aware of them and the end-stage of tissue death is quickly reached. Thus, the window of opportunity for intervention is limited and is often missed.

From a practical point of view, the diabetic foot can be divided into two main entities: the neuropathic foot and the ischaemic foot. The neuropathic foot is vulnerable to attack from mechanical forces leading to ulceration and also to bacteriological invasion resulting in tissue necrosis. The diabetic ischaemic foot commonly presents as the neuroischaemic foot which is characterised by both ischaemia and neuropathy leading to ulcers commonly seen on the margins of the foot and toes. These ulcers are also prone to bacteriological invasion, again resulting in tissue necrosis. However, it has been shown that such a vulnerability of the diabetic foot patient to tissue necrosis can be successfully managed by the development of a multidisciplinary diabetic foot team which provides prompt outpatient care in a diabetic foot clinic and inpatient care on the hospital wards.

Such a development has promoted advances in clinical care, research and education, has stimulated the creation of the subspecialty of diabetic foot care, and has shown that most major amputations can be avoided. Copyright © 2016 John Wiley & Sons.

Practical Diabetes 2016; 33(1): 29–33

Key words
diabetic foot clinic; neuropathy; ischaemia; amputations; infection; Charcot foot

Introduction
Arnold Bloom was a considerate and caring physician who worked at the Whittington Hospital in London (Figure 1). He was cherished by his patients and deeply respected by his colleagues. His overriding concern was the care of patients, in which he excelled. He practised the art of medicine with detailed observation and scientific application. This was the ethos at King’s College Hospital in 1979 when I began a research fellowship under the supervision of Dr Peter Watkins who was an inspirational and charismatic expert on diabetic neuropathy. He declared that the ‘the diabetic foot is uncharted territory’.

I have explored this territory for 35 years and conclude that although the patient with a diabetic foot problem is complex and extremely vulnerable to tissue necrosis which may lead to amputation, a multidisciplinary team, working within the subspecialty of diabetic foot care, can be of great benefit to these patients and can prevent major amputation in most cases.

In the first part of this paper I will discuss the vulnerability of the diabetic foot patient to tissue necrosis and then, in the second part, describe the development of a system of multidisciplinary care to manage successfully such vulnerability and to prevent major amputations.

Vulnerability of the diabetic foot patient
Three great pathologies come together in the diabetic foot: neuropathy, ischaemia and infection. From a practical point of view, the diabetic foot can be divided into two main entities: the neuropathic foot and the ischaemic foot. However, in both, there is a swift progression to tissue necrosis which is the fundamental hallmark of the natural history of the diabetic foot.

Neuropathic foot
It is vital to appreciate the important impact of neuropathy in the diabetic foot. The peripheral nervous system is an early warning system and acts to detect both external insults to the body and internal malfunctions.
Neuropathy renders the patient particularly vulnerable to attack from mechanical forces which lead to ulceration and also renders the foot susceptible to bacteriological invasion. The immune system produces inflammation which is recognised by the peripheral nervous system but, in the presence of neuropathy, such inflammation is not detected, host defence activity is impaired and the body is unaware of bacterial invasion. As a result, diabetic foot infections do not always present with the classical signs of local infection. Erythema and pain may be absent. Furthermore, there is a reduced systemic response to infection in the diabetic foot. Leucocytosis is a poor indicator of acute osteomyelitis of the foot in diabetic mellitus. In one series, 51% of patients with acute osteomyelitis had a normal white blood cell count. In a further series of 223 consecutive diabetic patients with deep foot infections, about 50% of patients lacked clinical signs of infection. Thus, the white blood count and body temperature should not be regarded as reliable indicators of infection in the patient with a diabetic foot infection.

The response to bacterial invasion is further weakened by a deficiency in immune function itself. An important part of such immune function is effective neutrophil microbial action which depends on the generation of several oxygen-derived free radicals. These toxic species, which include the superoxide anion, are formed during the respiratory burst activated after chemotaxis and phagocytosis. In diabetes, especially if poorly controlled, deficiencies in neutrophil chemotaxis, phagocytosis, superoxide production, respiratory burst activity and intracellular killing have all been described.

It is important to understand that bacterial invasion can lead to a septic vasculitis of the digital and small arteries of the foot. The walls of these arteries are infiltrated by polymorphs leading to occlusion of the lumen by septic thrombus. This is mainly responsible for the tissue necrosis and the classical diabetic gangrene of the diabetic foot.

**Ischaemic foot**

It should be noted that the diabetic ischaemic foot is different from the non-diabetic ischaemic foot. It is not just an ischaemic foot in a patient who happens to have diabetes. It commonly presents as the neuroischaemic foot which is characterised by varying degrees of ischaemia together with neuropathy leading to ulcers commonly seen on the margins of the foot and toes, often at sites of pressure from poorly fitting shoes. Such ulcers are very prone to bacterial invasion which again leads to a septic vasculitis and tissue necrosis. Furthermore, in the neuroischaemic foot, reduced arterial perfusion to the foot resulting from occlusive disease of the leg and foot arteries is also an important contributing factor to tissue necrosis. A less common presentation of the diabetic ischaemic foot is the critically ischaemic foot which is characterised by a severe reduction of perfusion which of itself results in tissue necrosis, often initially in the absence of infection. Intermittent claudication and rest pain may be absent in the patient with a diabetic foot because of neuropathy and the distal distribution of the arterial occlusive disease.

**The multidisciplinary diabetic foot team**

The second part of this paper describes the development of a diabetic foot service to manage the vulnerability of the diabetic foot patient, stressing the crucial role of the multidisciplinary diabetic foot team in providing outpatient care in the Diabetic Foot Clinic and inpatient care on the hospital wards. Such a development has promoted advances in clinical care, research and education, and stimulated the creation of the subspecialty of diabetic foot care.

**Diabetic Foot Clinic**

After recognising the distinctive lesions of the neuropathic and ischaemic foot and the rapid deterioration to tissue necrosis, it was concluded in 1981 that there was a need for coordinated intensive care of these patients with input from several disciplines, including podiatry, orthotics, nursing, diabetology, and orthopaedic and vascular surgery. Such care needed to be put in place rapidly because of the propensity for rapid worsening of the diabetic foot.

Mary Blundell, the chiropodist at King’s College Hospital at that time, proposed that these disciplines could see patients together in her Chiropody Clinic and her inspired suggestion led to the development of a multidisciplinary Diabetic Foot Clinic which opened in May 1981 and brought together a multidisciplinary diabetic foot team comprising chiropodist (otherwise known as a podiatrist), nurse, orthotist, surgeon and diabetologist. The development of the Diabetic Foot Clinic was further supported by a British Diabetic Association Development Grant in 1983. The clinic facilitated immediate and rapid communication between these disciplines such that therapeutic interventions by these disciplines, often jointly, could be put in place rapidly. The multidisciplinary team worked closely together, within the focus of an outpatient Diabetic Foot Clinic, but also extended its work to the inpatient location of wards. Over three years, from 1981–1984, healing
was achieved in 204 out of 238 (86%) neuropathic ulcers and 107 out of 148 (72%) ischaemic ulcers and the number of major amputations was reduced by 50% (Figure 2). This work underpinned the lower limb recommendations of the St Vincent Declaration. This was made in 1989 by a group of patient representatives, governmental representatives and diabetes experts who convened in St Vincent, Italy, at a meeting which was organised under the auspices of the World Health Organisation and the International Diabetes Federation, to discuss the growing problem of diabetes across Europe. It specified that the number of limb amputations for diabetic gangrene should be reduced by 50% over five years.5

Aware that the diabetic foot could deteriorate with alarming rapidity, and mindful that delay can cause serious problems, an open-access service was an important feature of the Diabetic Foot Clinic. This allowed patients to attend in an emergency without an appointment and be seen on the same day or within 24 hours.6 Furthermore, such a service supported local health care professionals who came to know where to seek urgent help and advice about their patient

Inpatient care
Patients with severe foot problems were admitted to hospital under the care of the most appropriate clinician (diabetologist, vascular or orthopaedic surgeon) but continued to be managed by the multidisciplinary diabetic foot team. From 1981–2015, the inpatient care has become increasingly complex and diabetic foot practitioners (podiatrists experienced in diabetic foot care) have become important members of the multidisciplinary foot team, particularly in the coordination of inpatient care through joint diabetic foot/orthopaedic and diabetic foot/vascular rounds and multidisciplinary meetings involving physiotherapists, occupational therapists, nurses and doctors. Other important roles of the practitioners are wound debridement, relief of mechanical pressure, surveillance of infection and liaison with the microbiology department. The diabetic foot practitioners also work closely with plastic surgeons and have developed a negative pressure wound therapy service for large postoperative diabetic foot wounds. To facilitate early discharge, patients continue such therapy at home led by community nurses who have received training from the diabetic foot practitioners. Furthermore, a service for the insertion of PICC (peripherally-inserted central catheter) lines has been developed to allow early discharge from hospital and administration of intravenous antibiotics at home.

Development of the subspecialty of diabetic foot care
The evolution of the multidisciplinary diabetic foot team and the Diabetic Foot Clinic has fostered the growth of the subspecialty of diabetic foot care which has three main aims: firstly, to promote advances in clinical care of both the neuropathic and ischaemic foot; secondly, to research into the pathogenesis of diabetic foot problems; and, thirdly, to teach patient and health care professionals how best to care for the feet of patients with diabetes.

Care of the neuropathic foot
Advances have been achieved in both the care of the neuropathic ulcer and the Charcot foot.

Neuropathic ulcer. The Diabetic Foot Clinic at King’s was one of the first to pioneer the use of the total contact cast as the most efficient way to offload neuropathic ulcers. Ali Foster, who succeeded Mary Blundell as Lead Podiatrist in 1985, learnt the technique from Paul Brand in the National Leprosarium in Carville, Louisiana, and the practice of plaster casting has been continued by her successor Maureen Bates who also pioneered the teaching of casting in specific instructional courses. Patients with deformity and non-healing ulcers that do not respond to offloading are seen in a joint diabetic foot/orthopaedic clinic where a decision to proceed to deformity correction and reconstruction is made.7 The most frequent complication of the neuropathic ulcer is infection which usually responds well to aggressive antibiotic therapy and prompt surgical debridement. As well as offloading the ulcer and aggressive treatment of infection, podiatric debridement is crucial in the management of neuropathic ulcers, and such an approach is successful even in diabetic patients with a renal transplant and on immunosuppression.8

Charcot foot. Three major advances have been made in the management of the Charcot foot.

Firstly, considerable progress has been made in the early recognition of the acute Charcot foot when the X-ray is still normal (stage 0 or incipient Charcot foot). Recent advances in imaging modalities have enabled the detection of initial signs of inflammation and underlying bone damage before overt bone and joint destruction, as seen on the X-ray, has occurred. It is now possible to diagnose the Charcot foot while the X-ray...
is still normal. Imaging modalities include: single photon emission computed tomography combined with conventional computed tomography (SPECT-CT); magnetic resonance imaging (MRI); and positron emission tomography–computed tomography (PET-CT) scanning. Casting therapy remains the mainstay of medical treatment of the acute Charcot foot and, if timely instituted, offloading can arrest disease activity and prevent foot deformity. Secondly, surgical reconstruction of the mid- and hindfoot has constituted a major advance in the management of Charcot foot deformities. We have reported recently on the outcomes of 20 patients (21 feet) with Charcot foot who underwent correction of deformities of the ankle and hindfoot using retrograde intramedullary nail arthrodesis. All were treated with reconstructive surgery and seven underwent simultaneous midfoot fusion. Limb salvage was achieved in all patients and all but one patient regained independent mobilisation. Thus, in cases with severe deformity, modern surgical techniques can correct the unstable deformity and promote improved functional outcome and limb survival.

Thirdly, increased understanding of the pathogenesis of this condition has been achieved. Emerging studies carried out by Nina Petrova at King’s College Hospital have identified aberrantly activated osteoclasts as key players in the pathological bone destruction of the acute Charcot foot. These newly-formed osteoclasts derived from patients with acute Charcot foot exhibited an enhanced response to the receptor activator of nuclear factor kappa-B ligand (RANKL), an osteoclast activator. Their aberrant resorbing activity was modulated by the proinflammatory cytokine, tumour necrosis factor alpha (TNF-α). This has resulted in an improved understanding of the mechanisms involved in the process of rapid bone destruction which is essential for the improved management of this condition.

**Care of the ischaemic foot**

From 1981–2015, the diabetic ischaemic foot has become an increasingly important problem and a joint diabetic foot/vascular fast-track service has been developed. This consists of a twice-weekly joint diabetic foot/vascular clinic, a once-weekly joint multidisciplinary vascular radiology conference, and a joint diabetic foot/vascular ward round held once weekly. The joint diabetic foot/vascular clinic provides rapid access, speedy investigations carried out by clinical vascular scientists in the vascular laboratory, priority treatment and urgent follow up for patients with diabetic ischaemic foot. Patients with diabetic foot problems are usually admitted to the medical wards under the care of the diabetologist, but when there is an overt vascular problem they are admitted directly under the vascular surgeons. In the joint diabetic foot/vascular ward round held weekly patients are seen together, both on the medical and surgical wards. On these rounds, the diabetic foot practitioner, diabetologist and vascular surgeons together with a microbiologist make joint clinical decisions, with a view to avoiding any delays and achieving discharge as quickly as possible.

Service coordination is accomplished within the organisational framework of a multidisciplinary vascular radiology meeting attended by vascular surgeon, interventional radiologist, clinical vascular scientist and diabetologist. Angiograms are reviewed and joint decisions are made on the suitability of angioplasty (often performed as a day case procedure) or, alternatively, of arterial bypass after careful evaluation of the patient’s comorbidities. Angioplasty and bypass are regarded not as competing but as complementary treatments. Also, a recent study has shown that both distal and ultra-distal bypass have comparable outcomes regardless of the comorbidities. After either angioplasty or bypass, patients are followed up closely in the Diabetic Foot Clinic to assess the clinical outcome and the need for further intervention. Diabetic ischaemic foot patients with end-stage renal disease are the most difficult to treat.

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**Table 1. Weekly timetable of the Diabetic Foot Day Unit. Emergencies are seen throughout the day as they present, and by Casualty at weekends**

<table>
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*State of the art lecture*

The 2015 Arnold Bloom lecture
The patient with a diabetic foot is complex and extremely vulnerable to tissue necrosis because three great pathologies come together in the diabetic foot: neuropathy, ischaemia and infection.

The neuropathic foot is vulnerable to attack from mechanical forces which lead to ulceration and also to bacteriological invasion resulting in tissue necrosis.

The ischaemic foot commonly presents as the neuroischaemic foot which is characterised by both ischaemia and neuropathy, leading to ulcers commonly seen on the margins of the foot and toes which are prone to bacteriological invasion also resulting in tissue necrosis.

The vulnerability of the diabetic foot patient to tissue necrosis can be successfully managed by the development of a multidisciplinary diabetic foot team which provides outpatient care in a diabetic foot clinic and inpatient care on the hospital wards.

The multidisciplinary diabetic foot team has promoted advances in clinical care, research and education, has stimulated the development of the subspecialty of diabetic foot care, and has shown that most major amputations can be prevented because of diffuse arterial disease including greater involvement of the distal and pedal vessels and extensive tissue necrosis. However, angioplasty and bypass can be performed safely and effectively in a dialysis-dependent patient population.17

Development of multidisciplinary Diabetic Foot Day Unit

The natural history of the diabetic foot has become increasingly aggressive and complex. To counteract this, the multidisciplinary Diabetic Foot Clinic has recently evolved into a multidisciplinary Diabetic Foot Day Unit, which delivers an emergency open access system for patients, with a ‘one-stop’, same day service in which investigations are performed, results reviewed and treatment implemented. It provides joint clinics with vascular and orthopaedic surgeons and, recently, plastic surgeons with expertise in wound healing, and also specialised clinics for casting of complex neuropathic feet, and for the administration of intravenous or intramuscular antibiotics on the same day. The weekly timetable for the service is shown in Table 1.22

Education of patients and health care professionals

From its inception in 1981, the Diabetic Foot Clinic has been a centre for education. The main form of teaching is a practical, patient-based teaching which is carried out while patients are treated in the Diabetic Foot Clinic. The team teaches individual health care professionals who attend for training in diabetic foot care to enable them to set up their own diabetic foot clinic. Visitors have been welcomed from all over the world. The diabetic foot team has employed various forms of teaching, including instructional courses on total contact casting which are held twice yearly, and also organises an annual educational ‘Masterclass’ meeting which attracts between 250 and 300 health care professionals. It has also organised specific meetings for patients entitled ‘Diabetic Foot Care for the 21st century: What every patient has the right to expect’.

Conclusion

The patient with a diabetic foot problem is complex and extremely vulnerable to tissue necrosis but a multidisciplinary diabetic foot team, working within the subspecialty of diabetic foot care, which is focused in the Diabetic Foot Clinic, can treat these patients successfully and avoid major amputation in most patients.

Acknowledgements

I am very grateful for the assistance of Dr Nina Petrova in the preparation of this paper.

Declaration of interests

There are no conflicts of interest declared.

References