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Review

Evaluation and management of the diabetic foot.

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Diabetes mellitus is rapidly emerging as the new global epidemic. If a diabetic lives long enough he is likely to develop some of its complications including diabetic foot (DF). DF is a major complication of long standing diabetes, accounting for nearly 35% of all hospital admissions in diabetic clinics. It also accounts for nearly 80% of all non-traumatic amputations of the lower limb. Due to its significant morbidity and mortality, DF has a staggering economic impact not only on the individual and his family but also on the society. Foot complications closely related to neuropathy and obstructive peripheral vascular disease, are responsible for more than one (1) million of leg amputations every year. Diabetic foot infections are associated with high morbidity and most diabetic foot infections begin with a wound and once an infection occurs, the risk of hospitalization and amputation increases dramatically. DF is a serious complication of diabetes mellitus and may be the initial presentation of an undiagnosed diabetes mellitus; therefore a proper understanding of how to evaluate and manage this complication of diabetes mellitus is very important. This paper aims to provide a current concept review on the evaluation, diagnosis and management of diabetic foot infections.

Keywords: Diabetes, Diabetic foot,

INTRODUCTION

Diabetes mellitus is a chronic disease with a worldwide increasing trend, and the prevalence of diabetes is expected to double in the next three decades (Gupta and Singh 2012).

With more longevity and more consumption of the Western type of diet especially in the developing world, there is bound to be an increase in the incidence of cardiovascular diseases, diabetes mellitus and many other chronic diseases.

Although a problem with the feet may occur in diabetics at any age, the peak age of patients with this problem is usually in the seventh to the eighth decade of life and most of these patients have had their diabetes for years. Lower extremity ulcers occur in approximately 15% of the estimated sixteen (16) million Americans with diabetes mellitus.

The implication of this is that diabetics with foot problems usually often have associated ischaemic heart disease, renal disease which would invariably complicate their surgical and biochemical management.

Foot infections are a common and serious problem in persons with diabetes. Diabetic foot infections (DFIs)

typically begin in a wound, most often a neuropathic ulceration. While all wounds are colonized with microorganisms, the presence of infection is defined by two classic findings of inflammation and purulence.

Infections could then be classified into mild (superficial and limited in size and depth), moderate (deeper or more extensive), or severe (accompanied by systemic signs or metabolic disturbances) (Lipsky et al., 2013)..

This classification system, along with a vascular assessment, helps determine which patients should be hospitalized, those that may require special imaging procedures or surgical interventions, and those that will require amputation. Foot infection can dramatically increase the risk of lower limb or digital amputations.

The most important risk factors in developing DFI are neuropathy, ischaemia and poor glycaemic control. Therefore early identification of the patient at risk, patient education and implementation of preventive measures are keys to curtailing morbidity and mortality (McInnes 2012).

The pathogenesis of DF is multi-factorial and is related to peripheral neuropathy leading to the insensate foot with foot deformities, peripheral vascular disease and infection in addition to the reduced immunity seen in these patients.

There are three distinct processes involved in the etiology of diabetic foot and these are ischaemia, neuropathy and sepsis. Undetected repeated sepsis is the usual cause of ulceration in diabetic foot. Anaerobic organisms are commonly present in diabetic foot sepsis (Gough et al., 1997).

Patients with DF should be managed by a multidisciplinary team which in addition to clinical specialists should also include a podiatrist and trained nursing staff (Fryberg 1998).

General care of the patient with foot problems must include prophylaxis for deep vein thrombosis and pressure necrosis particularly of the heels.

Early aggressive surgical management reduces the need for major amputation most especially in diabetic patients who have sustained nail puncture wounds.

It is important to realize that after effective intervention to control sepsis, the insulin requirements decrease and have to be adjusted accordingly. In fact hypoglycaemia is the biggest threat to patients with diabetic foot problems when they are in the process of recovery.

Urine glucose levels are not reliable for insulin control unless a correlation has been established with blood sugar levels and neuropathic bladder retention with overflow has been excluded.

Patients may be profoundly hypo-natraemic due to renal impairment and steroid may be required to control this loss of sodium.

Clinical Presentation

The clinical presentation may range from the asymptomatic patient who requires nothing more than preventive foot care to the unstable and critically ill patient in whom both loss of limb and death are imminent threats. This wide range of disease severity coupled with inappropriate and untimely use of diagnostic testing contributes to the clinical confusion that often leads to delays in diagnosis and treatment and ultimately to limb loss.

It is important therefore that surgeons caring for diabetic patients develop a simple but comprehensive and orderly approach to diabetic foot problems that can be implemented for any such problems, recognizes the pathogenic roles of neuropathy, ischaemia and infection and emphasizes the initial clinical assessment at the bedside.

The clinical evaluation of any diabetic foot problem begins with a complete history and a careful physical examination so that any immediate threats to life or limb could be identified immediately. It should also be borne in mind that diabetes may affect virtually every organ system in the body so attention must be paid to all body systems.

There should also in addition to the detailed examination of foot deformities and the ulcers to focus on identifying loss of protective sensation using simple clinical tests as well as an examination of the vascular integrity by a simple hand held Doppler device.

The diabetic patient with a septic foot is almost always hyper-glycaemic and patients requiring surgical intervention should have their blood sugar level lowered to about 10-15mmols/dl using insulin.

The diabetic foot usually presents predominantly with a combination of neuropathic and ischaemic features. Diabetic neuropathy presents with sensory disturbances, trophic skin lesions, plantar ulcerations and degenerative arthropathy the so called Charcot's joints. Neuropathic ulcers are deep and painless and are situated on the plantar aspect of the foot or big toe.

Diabetic ulcer of the foot is characteristically punched out (see figure 1 below) and situated over a bony prominence and is often accompanied by neuropathy the evidence of which may be provided by absent ankle jerks and diminished sensations in the toes and foot.

Early identification of infection (see figure 2) and prompt treatment may optimize the patient's outcome and provide limb salvage.

The diabetic foot will invariably become a focus of sepsis especially with poor glycaemic control. Often sepsis begins as a fungal and or mycotic infection, which leads to maceration and ulceration between the toes before

Figure 1 Typical punched out ulcer of the heel

Figure 2 Infection at bony prominence

secondary bacterial infection sets in (Hobizal and Wukich 2012).

Infections are usually anaerobic and surgical management inform of debridement of necrotic tissue especially of the extremities will be necessary in salvaging the limbs from amputations.

The foot after being infected becomes safe haven for pus because of the continuous spread of infection into the foot compartment over a period of weeks or months and the plantar tendons become bathed in necrotic tissue and pus.

If this continues without aggressive and active treatment in terms of diabetic control and surgical debridement the patient can end up either with an amputation, septic shock or even death.

A number of patients with septic foot problems present with renal impairment and hyponatraemia. Urine electrolytes should be determined and if it shows that there is concomitant loss of sodium in the urine, replacement of sodium is often futile. Therefore use of 0.1mg of fludrocortisones daily can control the loss of sodium in the urine and can be withdrawn when the patient is over the acute problem.

Many patients are also hypertensive and beta-blockers should be avoided because of their vasoconstrictor effects.

Diagnosis and Diagnostic Factors

The diagnosis is often easy since the fasting blood sugar estimate is raised.

The ulcers invariably become portal of entry for microbes leading to infections in the surrounding tissues thereby setting up smoldering cellulitis that eventually destroys painlessly the interior of the foot with subsequent necrosis of ligaments, tendons and muscles.

It is imperative that a patient that presents with a leg ulcer should be screened for other possible causes.

A diabetic ulcer creates an unstable state of the art which may eventually cause loss of a foot and this infection should not be allowed to continue; but rapid healing should be the immediate and final objective. Healing is achieved by control of the diabetes and protection of the ulcer from external pressure or by surgery to remove any underlying bony problem and necrotic tissue.

In the compliant patient with no evidence of deep space involvement or systemic infection, treatment may be delivered on an outpatient basis. An oral antibiotic pending culture result is prescribed; patient is instructed to offload weight from the involved extremity and is taught appropriate methods for changing wound dressings. Frequent follow-up is vital and guidelines should be imparted by which improvement or worsening of the lesion can be determined.

However once decision has been made for those that need admission to the hospital the following investigations are requested:

Complete blood count

Complete biochemistry work-up including electrolytes and urea.

Microbiological assessment of the wound and cultures.

Cardiovascular assessment including electrocardiography (ECG) and Echo-cardiography if needed.

X-ray of the foot (Di-Gregorio et al., 1997) to rule out osteomyelitis (see figure 3 and 4 below) and sometimes Magnetic Resonance Imaging (MRI) scan might be needed

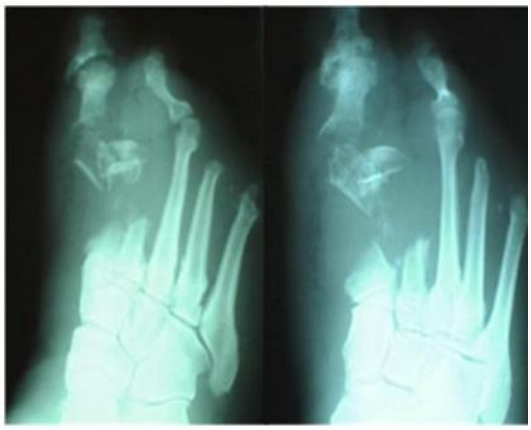

Figure 3

Figure 4

in some cases for diagnosing osteomyelitis of the underlying bone (Croll et al., 1996).

Doppler sonography to assess the state of the vessels both visually and by the measurement of the ankle-brachial index which could provide useful guide in terms of prognosis is necessary.

Angiographic assessment should only be done if surgical reconstruction is being contemplated.

Management

General Management.

The old adage that prevention is better can cure is better illustrated in the management of the diabetic foot than anywhere else in medicine.

Management of diabetic foot is a multidisciplinary team organization; however general care of the patient with foot problems must include prophylaxis for deep vein thrombosis and pressure necrosis particularly of the heel.

Patients should be given detailed advice on foot care and they should have rapid access to specialist care for even minor lesions such as nail puncture wound that would normally not cause problem in non-diabetic patients.

The need for a detailed history and urologic, vascular, metabolic physical examination, accurate assessment of neurologic, metabolic status and addressing the etiological factors involved are all essential since diabetes is a multi-system disease (Caravaggi et al., 2013).

Blood sugar control

The diabetic with a septic foot is almost always hyperglycaemic and such patients are best treated using soluble insulin either by intermittent dose or with continuous infusion.

Normal blood sugar levels need not be achieved before any expected surgical intervention, but to realize that after effective intervention to control sepsis; their insulin requirement decrease requiring adjustment accordingly.

During recovery phase they could even go into hypoglycaemia and therefore it is important to watch out for this. In fact hypoglycaemia is the biggest threat to patients with diabetic foot problems when they are in the process of recovery.

Renal disease

Some of these patients present with renal impairment and sometimes hyponatraemia as a result of concomitant sodium loss in the urine, the use of 0.1mg of fludrocortisones daily can control this loss of sodium and this can be withdrawn when the patient is over the acute phase (Walrond 2000).

Deep venous thrombosis prophylaxis

This is an essential part of the treatment for these patients. They should wear anti-embolic support stockings on the

Figure 5

Figure 6

uninjured leg and encourage movement of the legs within the limits of the illness.
Use of subcutaneous low dose heparin of 5000IU 12 hourly is of tremendous help.
Use of low dose aspirin should also be considered in patients with evidence of ischaemic heart disease.

Protection of pressure points

Bony points especially the heels should be adequately protected (see figures 5 and 6 above).
This is necessary since these patients are neuropathic and damage could easily be done without them realizing this problem so as to prevent increase in further amputation.

Analgesia

One should be cautious with the use of non-steroidal anti-inflammatory (NSAID) agents especially in those patients with renal disease but otherwise other analgesics could be used when necessary. Factors such as age consideration for the patient and previous gastrointestinal disorders should be looked into before administering analgesic agents.

Antibiotic therapy

Evaluation for and treatment of infection is the first priority in the management of any diabetic foot problem and its presence is usually made on the basis of clinical findings.

The use of antibiotic agents should be guided by the organism expected and by culture results when available (Hartemann-Heutier et al., 2000; Edmonds 1999).

The microbiology of the diabetic foot varies according to the depth and severity of the infection and the nature of the patient's environment whether hospitalized or managed as an out-patient.

Mild localized and superficial ulcerations particularly in out-patients are usually caused by aerobic gram-positive cocci such as staphylococcus aureus and streptococci.

In contrast, deeper ulcers and generalized limb-threatening infections are usually polymicrobial. Apart from gram-positive cocci, potential causative organisms include gram-negative bacilli such as Escherichia coli, klebsiella, enterobacter aerogenes, proteus mirabilis and pseudomonas aerugenosa and anaerobes such as bacteroides fragilis and peptostreptococci.

Also clostridia perfinges which cause gas gangrene could be responsible which fortunately is uncommon and can be recognized by the rapid spread of sepsis, gas in the tissue with crepitus, foul smelling and possible toxic state of the patient (Gough et al., 1997; El-Tahawy 2000).

The antibiotic chosen should reflect on knowledge of the likely organisms and their local sensitivity pattern. In many cases broad spectrum penicillin is good to start with but if there is allergic reaction to it, erythromycin could be substituted; however this regime can be modified based on culture results whenever they are obtained.

The choice of antibiotic agent and the duration of therapy are dependent on the extent of the infection. In the absence of osteomyelitis, antibiotics should be continued until the wound appears clean and all surrounding cellulitis has resolved. If osteomyelitis is present treatment should

include both surgical debridement and a prolonged 4-6 weeks course of antibiotic therapy.

Also antibiotic therapy should take into account their complications such as renal impairment and possibility of drug interaction.

Dressings

Wounds should be kept moist with wet-to-wet dressings avoided in favour of normal saline wet-to-wet dressings and they should be applied logically (Bardwell 1997; Hanft et al., 1997; Gonzalez and Oley 2000).

Saline dressing alone is only suitable in cases where both infection and necrosis have been controlled and the wound is kept moist and it has to be applied several times a day.

Various adjunctive wound treatments are also available including enzyme debridement agents suitable for necrotic wounds where surgical debridement is considered inadvisable because of inadequate line of demarcation from viable tissue and newly developed growth factors can also be used.

Antiseptic preparations or topical antibiotics should be used where there are surface organisms and in the prevention of infection in cases of dry gangrene while awaiting demarcation.

Granulation promoting agents are most suitable when both necrosis and infection are under control.

New therapies for stimulating the healing process are being evaluated (Muha 1999; Walrond and Ramesh 1998).

Other dressings such as Aloe Vera and negative-pressure wound therapy (NPWT) have being used but require randomized trials to validate their continuous use.

NPWT is a therapeutic technique using a vacuum dressing to promote healing in acute or chronic wounds and enhance healing of first and second degree burns usually but it appears to be useful for diabetic ulcers.

A 2010 systematic review found consistent evidence of the benefit of NPWT in the treatment of diabetic ulcers of the feet (Xie et al., 2010).

NPWT promotes wound healing by applying a vacuum either continuously or intermittently through a special sealed dressing.

The continued vacuum draws out fluid from the wound and increases blood flow to the area. Typically, the dressing is changed two to three times per week.

It must be remembered that some of these newer agents may offer a slight additional benefit in terms of improved healing but must realize that they are expensive and blanket use of these costly modalities is therefore not encouraged.

Failure of wound healing in the diabetic foot is usually attributable to unrecognized ischaemia, ongoing infection, or poor conventional wound care but not as a rule to the absence in the use of the above sophiscated wound therapy agents.

Orthotic foot wear and Prosthetic devices

These devices can greatly promote the healing of neuropathic ulcers and their recurrence if the devices are tailored to the needs of the individual patient. Similarly the ability to fit an effective prosthesis is the hallmark of rehabilitation of the amputee; however many diabetics are treated at centers where such facilities are either poorly developed or not available.

Nutrition

It must be remembered also that hyperglycaemia and malnutrition are common in hospitalized diabetic patients with foot ulceration, and both can adversely affect wound healing; therefore correction of these abnormalities should begin early and continue throughout the wound-healing period.

Surgical Management

Early and aggressive surgical management reduces the need for major amputation in patients with diabetic foot problems, however some authors have even suggested prophylactic diabetic foot surgery (Armstrong et al., 1996; 2Tan et al., 1996), but this has not been substantiated to be beneficial.

Surgery is beneficial in the following situations.

Puncture wounds

Puncture wounds could be fraught with danger and can lead to severe destruction of the surrounding tissues if treated conservatively as is done in non-diabetics. Therefore to avoid this destruction, puncture wounds in diabetics should be excised as a matter of urgency. The resultant wound takes about 1-2 weeks to heal (see figures 7 and 8 below) but saves months of treatment and possible loss of the limb.

Dry gangrene

Dry gangrene of a digit or patch of skin without infection is best treated conservatively until demarcation and separation of the dead tissue starts.

If vascular reconstruction is being contemplated and the patient is willing, this is the period to consider this type of treatment especially at this waiting period.

Figure 7

Figure 8
Same wound as figure 7 after debridement

Figure 9

Figure 10

Figure 11

Infection

The hallmark of surgical treatment in a diabetic with septic foot is the debridement of all necrotic tissue (see figure 9, 10 and 11 above).This must be done well and thoroughly in removing all dead tissues. Such debridement should be considered under tourniquet control so that all necrotic tissue is recognized and should be carried out in anatomical fashion.

After effective debridement, the wound might look extensive and will possibly take several weeks to granulate properly; but this procedure is necessary before the residual wound could be skin grafted (Mitchell and Masson 2000; Sinacore 1998).

Osteomyelitis

Unless infected bone is debrided, it can lead to persistent infection as well as sinus formation.

Appropriate long term antibiotic might be needed to avoid recurrence of the infection. Inserted orthopaedic devices should be used with caution in such patients.

Use of hyperbaric oxygen

This can be used as an adjunct therapy in some cases and may prevent further extension of necrosis and eventual loss of a limb (Faglia et al., 1996).

Deformity correction

Deformities such as hallux valgus, hammer toes in neuropathic limb should be considered for correction to prevent the occurrence or reduce the incidence of ulceration; however patients with such deformities and previous ulcerations are more likely to develop a post-

Figure 12

Figure 13

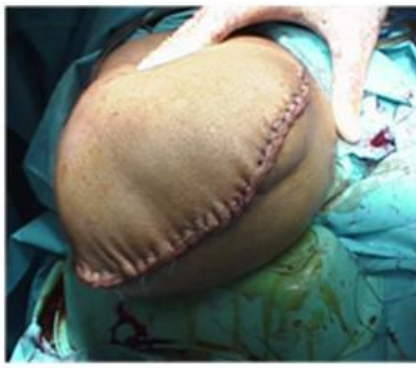

Figure 14

operative infection and should be covered by the appropriate antibiotic therapy.

Vascular reconstruction

This procedure is made more difficult in diabetics in view of the fact that the small vessels of the feet are also affected by the diabetes making distal reconstruction difficult since these vessels are close to the area of the necrosis (Mohan et al., 1996).

Amputation

Amputation of the digits should be done in a manner which allows for reconstruction of the arch of the foot if possible. Trans-metatarsal amputations are usually not very effective except for the few cases where the disease spreads transversely rather than along the path of the tendons.

Below knee amputation is the procedure of choice, which allows the patients to be better rehabilitated with prosthesis and they are more mobile in a chair or a bed with an intact knee joint.

However many will not achieve primary healing with a below knee amputation and may eventually end up with an above knee amputation (see figures 12, 13 and 14 above).

The open amputation is advisable when there is cellulitis at the level of the amputation. Flaps could be fashioned for delayed closure before contraction sets in. It must be remembered that stumps closed with skin grafts may not be suitable for fitting of prostheses (Sinacore 1998; Zafar 2001).

Foot Care

Once the foot has healed, preventive measures should be initiated to prevent future ulceration.

Foremost among these measures is patient education, focusing on general hygiene (Fryberg 1998; Uloko et al., 2008; Esposito et al., 2012), such as daily washing and moisturizer use and daily inspection of the feet. Walking barefoot, employing heat pads, wearing thong sandals and using caustic over-the-counter foot medications should all be strongly discouraged.

Neuropathy continues to be one of the most common causes of diabetic foot ulceration, so every attempt must be made to assess and follow all these patients. In addition abnormal pressure points secondary to mechanical deformity of the foot should be identified and appropriate treatment given.

In conclusion management of diabetic foot is a multidisciplinary approach which includes early hospitalization, effective glycaemic control, aggressive surgical debridement and patient education in foot care because all these will significantly minimize diabetic foot disease complications.

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