Chronicles of Biomedical Sciences
ISSN:3065-923X
Homepage: https://cbsciences.us/index.php/cbs

Prevention and Management of Diabetic Foot Ulcers

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ARTICLE INFO

Article Type: Review Article
Received on: November 24, 2024.
Revised on: December 17, 2024.
Accepted on: December 19, 2024.
Keywords: Amputation; Diabetes Mellitus; Diabetic Foot Ulcers; Risk Factors; Wound Care.
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ABSTRACT

Diabetes mellitus is associated with various complications, and diabetic foot ulcers being one of the most severe and prevalent. These ulcers contribute significantly to hospitalizations and amputations, with a global incidence of approximately 15%. Risk factors for diabetic foot include neuropathy, peripheral vascular disease, poor glycemic control, and previous foot ulcers. Early detection through regular foot examinations is crucial for preventing ulceration and amputation. The evaluations encompass several key areas, starting with a medical history review and general inspection, followed by a dermatological assessment. This is complemented by a musculoskeletal assessment, which focuses on detecting gross deformities. A neurological evaluation is also conducted using techniques such as monofilament testing and 128-Hz tuning forks. Finally, a vascular assessment is performed, including Ankle-brachial index with Doppler ultrasound. Treatment involves a comprehensive, multidisciplinary approach addressing both local foot issues and systemic factors, with the use of antibiotics, appropriate wound care, and sometimes surgical interventions. Effective management requires patient education, timely medical care, and proper foot care to reduce morbidity and improve outcomes.

Citation: Munir MA, Afzal M, Ahmed Z, Syed R. Prevention and management of diabetic foot ulcers. Chron Biomed Sci. 2024;1(4):28. Available from: https://cbsciences.us/index.php/cbs/article/view/28.

Introduction

Diabetes mellitus (DM) is a prevalent yet potentially devastating condition that has seen a marked increase in prevalence over recent decades, becoming a significant public health challenge of the 21st century [1]. The condition is traditionally associated with complications such as macrovascular diseases, including coronary heart disease, stroke, and peripheral arterial disease, and microvascular complications, such as diabetic kidney disease, retinopathy, and peripheral neuropathy. Additionally, heart failure is a common initial manifestation of cardiovascular disease in patients with type 2 DM, and it is linked to a high mortality risk in individuals with both type 1and type 2 DM [2].

While these traditional complications of DM still pose a significant burden, their prevalence is declining due to advancements in DM management [3]. However, as individuals with DM are living longer, they are increasingly at risk of developing a different set of complications. Population-based studies reveal that vascular diseases are no longer the leading cause of death in people with DM [4]. In some countries or regions, cancer has become the primary cause of death among individuals with DM, and deaths due to dementia have also risen since the turn of the century [5]. In England, traditional complications accounted for over 50% of hospitalizations among people with DM in 2003, but this proportion dropped to 30% by 2018, underscoring the evolving nature of diabetes-related complications over this period [6].

DM poses a serious global threat, with its incidence gradually rising in developing countries. It is

characterized by chronic hyperglycemia resulting from insulin deficiency, resistance, or both. Diabetic foot is among the most severe complications, accounting for approximately half of all diabetes-related hospital admissions and frequently leading to lower extremity amputations. Around 10-15% of diabetic patients develop foot ulcers during their lifetime [7]. DM causes damage to small and large blood vessels as well as nerves, making neuropathy common. Inappropriate footwear in diabetic patients exacerbates intrinsic muscle imbalances, while dramatic changes in microvascular blood flow and arteriolar-venous shunting compromise perfusion and elevate skin temperature. Impaired sweat and oil gland function leads to dry, keratinized diabetic feet prone to cracks and infections [8].

Early detection of diabetic foot risk factors and prompt treatment can significantly reduce morbidity and mortality, emphasizing the importance of proper foot care for both patients and healthcare providers. This review highlights the prevalence, risk factors, foot examination protocols, and treatment approaches for diabetic foot ulcers.

Prevalence

In 2011, an estimated 366 million people globally had DM, a number projected to rise to 552 million by 2030. The global incidence of foot ulcers in diabetic patients is around 15% [9]. Diabetes-related lower-limb amputations occur at an alarming rate of one every 30 seconds. Studies show a higher prevalence of foot ulceration in Europe compared to South Asia [10].

In Pakistan, approximately 8 million people have DM, with this number expected to double by 2025. The prevalence and incidence of diabetic foot in Pakistan range from 4% to 10%. The incidence of lower extremity amputation in diabetic patients is 25.8 per 1,000 per year, compared to 1.1 per 1,000 in non-diabetic individuals. Amputation rates in Pakistan range from 21% to 48%, influenced by poor awareness, unhygienic conditions, low socioeconomic status, and late referrals to tertiary care centers [11].

Risk Factors

Early identification of risk factors is crucial for the effective prevention of diabetic foot ulcers. Major risk factors include diabetic neuropathy, peripheral vascular disease, a history of foot ulcers, foot deformities, and the presence of corns or calluses. Additional contributors are diastolic hypertension, dyslipidemia, infection, and inadequate self-care. Diabetic foot complications are influenced by several key risk factors, including poor glycemic control, peripheral neuropathy, and peripheral arterial disease, which collectively impair sensation and blood circulation in the feet. Foot deformities, such as Charcot foot and bunions, increase pressure points that can lead to ulcers, especially in individuals with a history of foot ulcers or amputations. Smoking, prolonged diabetes duration, obesity, and kidney disease exacerbate these risks by further impairing circulation and healing. Vision impairment can delay the detection of foot problems, while inadequate foot care and ill-fitting footwear increase the likelihood of injuries. Preventive measures such as maintaining good blood sugar control, quitting smoking, wearing proper footwear, daily foot inspections, and seeking prompt treatment for minor injuries are essential to minimize complications [12].

Prevention Strategies

Prevention is the cornerstone of reducing diabetic foot complications. Key strategies include glycemic control, regular foot examinations, proper footwear, skin care, smoking cessation, and patient education.

Glycemic Control: Maintaining optimal blood glucose levels reduces the risk of neuropathy and vascular complications.

Regular Foot Examinations: Daily self-checks and periodic professional assessments can identify issues early. *Proper Footwear:* Shoes should fit well, provide support, and avoid creating pressure points. *Skin Care:* Keeping the feet clean, dry, and moisturized prevents infections and cracks. *Smoking Cessation:* Quitting smoking improves circulation and wound healing. *Patient Education:* Teaching individuals about the importance of foot care and early recognition of problems is essential [13].

Components of Foot Examination

The American Diabetes Association (ADA) recommends annual foot examinations for all diabetic patients to identify complications early. The evaluations encompass several key areas: medical history review and general inspection, dermatological assessment, musculoskeletal assessment focusing on detecting gross deformities, neurological evaluation using techniques such as monofilament testing and 128-Hz tuning forks, and vascular assessment, which includes Ankle Brachial Index testing with Doppler ultrasound. Patients exhibiting signs of vascular disease or absent pulses should be referred to specialists. The ADA recommends

ABI testing for all diabetic patients over 50 and for younger patients with multiple risk factors every five years [14].

Infections and Treatment

Diabetic foot infections significantly impact patients, leading to high morbidity, frequent healthcare visits, and potential amputations. These infections require a comprehensive approach, addressing both local (foot) and systemic (metabolic) factors, ideally managed by a multidisciplinary foot-care team, including access to infectious disease specialists. Foot ulceration, often due to peripheral neuropathy, is the main risk factor, with peripheral vascular disease and immunological issues playing a secondary role [14].

The primary pathogens are aerobic Gram-positive cocci, particularly *Staphylococcus aureus*. Chronic wounds or prior antibiotic use may introduce Gram-negative rods, while ischemic or gangrenous wounds may harbor anaerobic bacteria. Diagnosis relies on clinical signs of infection, and microbiological tests are mainly useful in suspected osteomyelitis. Tissue specimens should be obtained for culture before starting antibiotic therapy, except for mild, untreated infections [15].

Imaging is useful for detecting deep tissue infections or bone pathology, with MRI being more sensitive for soft-tissue lesions. Infections should be categorized based on severity, including factors like tissue involvement, arterial perfusion, and systemic symptoms, which guide treatment urgency. Antibiotics are crucial for treating infected wounds but are not necessary for clinically uninfected ulcers. Empirical antibiotic selection should be based on infection severity and suspected pathogens, with culture results refining therapy. Parenteral antibiotics are typically required for severe infections, while oral antibiotics are appropriate for mild-to-moderate cases. Antibiotic therapy should continue until infection resolution, not necessarily wound healing. *Treatment duration varies:* mild infections typically require 12 weeks, moderate-to-severe infections around 24 weeks, and osteomyelitis at least 46 weeks, unless infected bone is removed. If infection fails to respond to antibiotics, further culture and adjustment may be needed. Surgical consultation is essential for complex infections with deep abscesses, significant necrosis, or gangrene, and evaluating arterial supply is crucial [16].

Effective wound care, including proper cleansing, debridement, and pressure off-loading, is essential for healing. There is no consensus on specific wound dressings, but early follow-up ensures treatment effectiveness. Adjunctive therapies like granulocyte colony-stimulating factors and hyperbaric oxygen therapy may help in severe or non-responsive infections. Diagnosing osteomyelitis requires clinical and imaging tests, with bone biopsy providing definitive identification and antibiotic susceptibility. The intersection of tuberculosis and DM also poses a significant global health challenge, with each condition exacerbating the other's clinical course and outcomes. Therefore effective management of tuberculosis-diabetes comorbidity requires an integrated approach in such cases [17].

Further research is needed to refine diagnostic systems, optimize antibiotic regimens, and better understand the role of surgery in osteomyelitis treatment.

Clinical Manifestations

Patients with diabetic foot may present with neuropathic ulcers, ischemic ulcers, mixed ulcers, and infections. *Neuropathic ulcers:* Often painless with a punched-out appearance, frequently located on weight-bearing areas. *Ischemic ulcers:* Painful ulcers with poor granulation and surrounding skin discoloration. *Mixed ulcers:* Features of both neuropathy and ischemia. *Infections:* Ranging from superficial cellulitis to life-threatening conditions such as necrotizing fasciitis and osteomyelitis [18].

Diagnosis

A thorough clinical assessment includes history and physical examination, neurological testing, vascular evaluation and wound swabs and imaging.

History and physical examination focus on risk factors such as long-standing diabetes, poor glycemic control, and smoking.

Neurological testing, including monofilament and vibration perception, helps assess neuropathy. *Vascular evaluation* may involve ankle-brachial index, Doppler studies, or advanced imaging like CT angiography.

Wound swabs and imaging (e.g., X-rays or MRI) are crucial for detecting infections and underlying osteomyelitis [17].

Management

Management strategies are prevention, wound care, infection control, revascularization and amputation. *Prevention:* Education on foot care, appropriate

footwear, and glycemic control are cornerstones of prevention.

Wound care: Includes regular debridement, dressing changes, and pressure offloading using devices like total contact casts.
Infection control: Empirical antibiotics targeting common pathogens like *Staphylococcus aureus* and gram-negative bacteria are often required, tailored based on culture results.
Revascularization: For ischemic cases, endovascular or surgical interventions may be necessary. *Amputation:* While a last resort, it remains necessary for extensive tissue damage or systemic complications [18].

Prognosis and Outcomes

Despite advancements in treatment, the prognosis of diabetic foot remains guarded. Recurrence rates for ulcers are high, and untreated cases can lead to amputations and reduced quality of life. Multidisciplinary care models have shown promise in improving outcomes.

Conclusion and Recommendations

Early identification of risk factors, patient education, timely hospitalization, and appropriate medical or surgical treatment can reduce diabetic foot-related morbidity and mortality. Many diabetic patients lack adequate knowledge and practices regarding foot care, with literacy significantly influencing awareness.

Raising awareness about self-care can help reduce diabetic foot ulceration and amputation rates, particularly in developing countries like Pakistan. Patients must maintain good glycemic control, avoid foot injuries, wear suitable footwear, perform self-examinations, and seek regular check-ups. Healthcare providers should be trained to screen for neurological, vascular, dermatological, and musculoskeletal complications and focus on high-risk conditions for effective management.

Emerging therapies include the use of growth factors, stem cell treatments, and novel wound dressings such as bioengineered skin substitutes. Advances in wearable technology and artificial intelligence also offer new avenues for early detection and personalized management.

Authors' contributions

ICMJE criteria	Details	Author(s)
1. Substantial contributions	Conception, OR Design of the work, OR Data acquisition, analysis, or interpretation	1,2 1,2 3,4
2. Drafting or reviewing	Draft the work, OR Review critically for important intellectual content	2,3 1,4
3. Final approval	Approve the version to be published	1,2,3,4
4. Accountable	Agree to be accountable for all aspects of the work	1,2,3,4

Acknowledgement

None

Funding

This research study received no specific grant from any funding agency.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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