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Reviving a Chronic Wound: Management of a Non-Healing Diabetic Foot Ulcer with Hyperbaric Oxygen Therapy – A Case Report.

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ABSTRACT

Diabetic foot ulcers (DFUs) are a severe complication of diabetes mellitus, contributing to increased morbidity, mortality, and healthcare burden. This case report highlights the use of hyperbaric oxygen therapy (HBOT) in the treatment of a chronic, non-healing diabetic foot ulcer. A 59-year-old male with a 20-year history of diabetes presented with a 2.5-year-old ulcer on the lateral aspect of the right foot. Despite standard care involving antibiotics and dressings, the ulcer worsened, prompting referral to an HBOT centre. Initial transcutaneous oximetry revealed critical hypoxia (<20 mmHg) around the ulcer, which improved significantly with 100% oxygen, confirming HBOT eligibility. The patient underwent 40 sessions of HBOT at 2.4 ATA for 90 minutes each. Post-treatment assessments showed marked improvement in local tissue oxygenation and ulcer healing. Complete epithelialization occurred within two months post-HBOT, with sustained wound closure and no recurrence. This case underscores the role of HBOT as an effective adjunct in managing complex DFUs unresponsive to conventional therapies.
Keywords: Chronic Wound, Diabetic Foot Ulcer, Hyperbaric Oxygen Therapy.

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INTRODUCTION

Diabetic foot ulcers (DFUs) represent a frequent and serious complication of diabetes, affecting approximately 15% of individuals with the condition. They are associated with substantial morbidity, mortality, and financial burden [1]. The five-year mortality risk for individuals with a DFU is 2.5 times higher compared to those without ulcers [2]. About 20% of moderate to severe DFUs may lead to some degree of amputation, and 74% of these patients face the possibility of requiring renal replacement therapy within two years [3]. This elevated mortality rate is further exacerbated by comorbid conditions such as cardiovascular and cerebrovascular diseases.

The underlying mechanisms contributing to DFU development involve a combination of peripheral neuropathy, peripheral arterial disease, and secondary bacterial infections. Neuropathy can result in muscle wasting and structural deformities of the foot, increasing susceptibility to unnoticed injuries [4]. Recurrent trauma and inadequate foot care often lead to deep infections involving fascia, tendons, and joints. Infections contribute significantly to nearly half of major lower extremity amputations. Recent evidence has identified key risk factors for DFU onset, including diabetes duration over 10 years, male gender, advanced age, and the presence of comorbidities such as nephropathy, neuropathy, peripheral vascular disease, and a prior history of foot ulcers [4-6].

Management of Diabetic Foot Ulcers

Managing DFUs poses a significant challenge in clinical settings due to their complexity. Early intervention by a multidisciplinary team is essential to achieve optimal healing outcomes. A structured and timely approach that includes restoring blood flow, managing infections, and relieving pressure from the ulcer is critical for effective treatment [7]. Additionally, several adjunct therapies have emerged as supportive treatment options for DFUs. Over the past decade, advances in basic science have introduced innovative adjuvant treatments such as advanced wound dressings, hyperbaric oxygen therapy (HBOT), and topical growth factor applications for targeted wound healing [8-10].

Hyperbaric Oxygen Therapy (HBOT)

Hyperbaric oxygen therapy (HBOT) has been increasingly recognized as a potentially effective modality for managing diabetic foot ulcers, with the first controlled clinical trial on its use in this context published in *Diabetes Care* more than two decades ago [11]. Proponents of HBOT highlight its various experimentally proven benefits, including enhanced oxygenation of hypoxic wound tissues, improved blood flow, reduced tissue edema, modulation of inflammatory cytokines, and stimulation of fibroblast activity, collagen synthesis, and new blood vessel formation—factors that can contribute significantly to the healing of chronic wounds like diabetic foot ulcers [12, 13]. Additionally, HBOT is considered valuable in treating persistent soft tissue and bone infections by mechanisms such as direct antimicrobial effects, improved leukocyte and macrophage activity, and increased efficacy of antibiotics [14]. While the technology involved in HBOT is costly, its potential to substantially lower the risk of limb amputation in diabetic patients makes it a compelling adjunct therapy.

Case Presentation

A 59-year-old male with a 20-year history of diabetes mellitus, managed with self-administered insulin, presented with a chronic, non-healing ulcer on the lateral aspect of his right foot that had persisted for 2.5 years. He had previously received routine wound dressings and intermittent antibiotic therapy through outpatient services. In February 2025, he was admitted to the orthopaedics department due to an infected wound. During that admission, he was treated with Augmentin and subsequently discharged. However, he was readmitted just three days later owing to increased skin discoloration around the wound, accompanied by escalating foot pain and difficulty walking.

Following these developments, he was referred to our Hyperbaric Oxygen Therapy (HBOT) Centre for further evaluation and management. Initial transcutaneous oximetry monitoring (TCOM) revealed critical hypoxia around the wound, with oxygen tension readings below 20 mmHg. Upon administration of 100% oxygen, the values significantly improved to over 100 mmHg, indicating a positive response and suitability for HBOT.

The patient underwent a total of 30 HBOT sessions, each conducted at a maximum pressure of 2.4 ATA for 90 minutes. Repeat TCOM assessments showed improved and sustained oxygenation, with average values exceeding 30 mmHg. The treatment was discontinued on Day 64 after substantial wound improvement and normalization of oxygen levels.

Daily wound care continued at the general outpatient clinic. The ulcer fully healed within two months following the completion of HBOT. At subsequent orthopaedic follow-ups, the patient showed complete recovery with a well-healed wound, no residual callus formation, and no pain.

Table 1: TCOM assessment results

TCOM/Sensor	Day 1 (mmHg)	Day 49(mmHg)	Day 70(mmHg)	Day 85(mmHg)
1	5	33	23	24
3	9	44	36	33
4	46	45	44	57
5	44	42	41	41
6	17	41	50	45

Remarks: Sensor 1, 3, 4, 5, 6 are sensors around similar place of the wound. Reading <20: Critical hypoxia; 20–30: Hypoxia; 30–40: Mild hypoxia; >40: normal.

Figure 1: (a) Wound Status Day 1of treatment; (b) Wound Status Day 15 of treatment; (c) Wound Status Day 30 of treatment

(a) **(b)** **(c)**

DISCUSSION

Chronic diabetic foot ulcers (DFUs) that do not heal and are accompanied by recurrent infections are a common complication in individuals with long-standing diabetes. Around 13% of diabetic patients experience one or more episodes of DFU, and 59% of those cases recur within five years [15-17]. DFUs significantly impact health-related quality of life, negatively affecting both the physical and psychological well-being of patients and their caregivers. Additionally, the management of DFUs and diabetes-associated lower limb amputations incurs substantial healthcare costs [18].

The Diabetic Foot's Challenging Triad: Pathophysiology of DFU

Three key factors consistently contribute to the development of chronic diabetic foot ulcers (DFUs): deformity, deep infection, and ischaemia–hypoxia. This challenging combination, often termed the "troublesome triad," along with neuropathy as an indirect factor, tends to delay patients in seeking timely medical care [19]. Structural deformities in the lower limbs contribute to ulcer formation due to corresponding biomechanical stress. Shear forces acting tangentially on the skin surface, when coupled with deformities and bony prominences, increase the risk of ulceration. Oxygen plays a critical role in numerous cellular activities, including collagen synthesis and antimicrobial defense. Processes such as fibroblast proliferation, collagen production, and angiogenesis are highly oxygen-dependent and are essential for wound healing [20-22]. Effective bacterial clearance by phagocytes requires a local tissue oxygen tension of at least 30 mmHg(23). At this oxygen level, neutrophils can destroy up to 70% of bacteria, but in the absence of oxygen, their killing efficiency drops to 37% [24]. Prompt antibiotic therapy, when paired with oxygen-rich environments, enhances bacterial elimination [25].

Approaches to Diabetic Foot Ulcer Management

The primary goal in managing DFUs is to optimize the wound bed environment. Debridement remains a cornerstone of treatment and includes techniques such as sharp, autolytic, enzymatic, pulsatile lavage, and biological debridement. Correcting deformities through procedures like osteotomy, ostectomy, or tenotomy is essential. Removal of necrotic tissue must be thorough. Subsequently, the wound must be protected and stabilized using padded dressings, splints, removable walkers, or fixators to foster optimal healing conditions. Glycaemic control, with targeted glucose and HbA1c levels, is vital, along with the evaluation of cardiac, renal, and nutritional status. Appropriate dressing selection is crucial and should be tailored to the ulcer's stage, infection status, and exudate level. Finally, focus should shift to perfusion and oxygenation of the wound [26].

Patient Eligibility for Hyperbaric Oxygen Therapy

Appropriate patient selection is key to maximizing the benefits of hyperbaric oxygen therapy (HBOT). A comprehensive evaluation involving a vascular team is recommended to assess the need for intervention, manage neuropathic ulcers, control infection, and optimize systemic conditions. HBOT should be considered as an adjunct in cases of reversible tissue hypoxia. In patients with acutely infected Wagner Grade 3 DFUs who require surgical intervention and present with hypoxic tissue, HBOT should be initiated promptly. Postoperatively, tissue hypoxia typically worsens during the initial 3–4 days, and HBOT can help reoxygenate compromised tissue. According to the UHMS Clinical Practice Guidelines, HBOT is also indicated for chronic wounds persisting beyond 30 days despite optimal care, particularly Wagner Grade 3 DFUs [27]. In the case presented, the patient had a chronic ulcer unresponsive to conventional wound care and vascular evaluation, with no further surgical options available. HBOT represented the final therapeutic option.

Transcutaneous Oximetry (TCOM)

TCOM measures tissue oxygen levels (in mmHg) and approximates arterial capillary oxygen pressure. Normal values range between 40–90 mmHg depending on the anatomical site. It serves multiple functions, such as screening for vascular disease, assessing healing potential, guiding amputation level decisions, selecting HBOT candidates, and monitoring oxygenation during treatment. Tissues with hypoxia (TCOM < 20 mmHg) are unlikely to heal spontaneously. However, wound healing potential also depends on other factors such as infection and nutrition. A pre-treatment TCOM is vital. If an oxygen challenge test reveals a TCOM increase above 100 mmHg, it suggests that the wound may respond favorably to HBOT [28].

Scientific Basis for HBOT in Diabetic Foot Ulcers

HBOT is particularly effective for wounds that are ischaemic or hypoxic. By increasing the oxygen diffusion gradient, HBOT enhances oxygen delivery to poorly perfused tissues. The amount of oxygen diffused correlates directly with the partial pressure of oxygen [29]. HBOT also mitigates ischaemia-reperfusion injury, activates circulating stem cells, enhances neutrophil bactericidal activity, and generates reactive oxygen and nitrogen species. It promotes angiogenesis by recruiting and differentiating stem progenitor cells [20]. Moreover, HBOT increases the production of various growth factors, including vascular endothelial growth factor (VEGF) and platelet-derived growth factor (PDGF) [31, 32]. It has been shown to speed up epithelialization by around 30% [28].

By correcting underlying hypoxia and promoting growth factor production, HBOT targets the key pathophysiological factors in diabetic foot ulcers (DFU). Various studies have demonstrated its effectiveness. A 2018 efficacy study(33) evaluated HBOT in DFU patients classified by Wagner grade. Among those treated, healing was observed in 35 patients (87.5%) with grade 3 ulcers and 11 patients (84.6%) with grade 4 ulcers, resulting in an overall healing rate of 60 out of 71 patients (84.5%). Subgroup analysis revealed no significant differences for grades 2 and 5, but showed greater efficacy for grades 3 and 4. A 2021 systematic review [34] and meta-analysis reported that pooled data demonstrated a significant effect of HBOT on complete healing of diabetic foot ulcers (OR = 0.29; 95% CI 0.14–0.61; I^2 = 62%) and on reducing major amputations (RR = 0.60; 95% CI 0.39–0.92; I^2 = 24%). HBOT did not significantly affect minor amputation rates (RR = 0.82; 95% CI 0.34–1.97; I^2 = 79%), and the standard treatment group experienced fewer adverse events (RR = 1.68; 95% CI 1.07–2.65; I^2 = 0%). A systematic review published in 2022 [35] found that HBOT increased the healing rate of diabetic foot ulcers (relative risk = 1.901; 95% CI 1.484–2.435; $p < 0.0001$), shortened healing time (mean difference = −19.360 days; 95% CI −28.753 to −9.966; $p < 0.001$), and lowered the incidence of major amputations (relative risk = 0.518; 95% CI 0.323–0.830; $p < 0.01$), compared with control.

CONCLUSION

This case demonstrates the potential effectiveness of hyperbaric oxygen therapy as an adjunctive treatment in managing chronic diabetic foot ulcers, particularly when standard wound care and antibiotics fail. The patient's positive response—marked by restored tissue oxygenation, infection control, and complete wound healing—supports the utility of HBOT in selected patients with critical hypoxia and prolonged ulcer duration. Early identification of non-healing wounds and timely referral to a multidisciplinary care team including HBOT can significantly improve outcomes and reduce the risk of limb amputation in diabetic individuals.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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