Case study

Application of irrigation and negative pressure wound therapy (INPWT) to treat diabetic foot gangrene: a case report

ABSTRACT

This case study summarises the treatment of a patient with diabetic foot gangrene. By undergoing irrigation and negative pressure wound therapy (INPWT) with moist dressing, foot amputation was avoided. The treatment process included: the comprehensive assessment of systemic and local condition; choosing suitable debridement such as sharp surgical debridement; preventing the spread of infection; applying INPWT to reduce endotoxin absorption; and active treatments of primary disease such as controlling blood sugar and blood pressure, and improving microcirculation and nutrition. After 2 months of vigorous INPWT, the patient's wound bed improved. After the application of a moist dressing, the wound closed and healed successfully at 3 months.

Keywords Diabetic foot gangrene, irrigation, negative pressure wound therapy, moist dressing

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INTRODUCTION

The global prevalence of diabetes mellitus is 8.5%, with roughly 90% of cases being type 2 diabetes[1,2]. Over the last several decades, the prevalence of diabetes has drastically increased worldwide – with rates quadrupling since 1980[2]. This can be attributed to a quickly aging population, general population growth, and increased incidences of obesity. It is estimated that there will be nearly 550 million people with diabetes globally by 2030, making diabetes a key public health issue and a global concern. China currently houses the most diabetics in the world. According to the latest epidemiological survey conducted by the National Health Committee in 2018, 11.6% of the Chinese population has diabetes, totalling 114 million people. Furthermore, China has a low treatment rate (32.2%) and control rate (49.2%), resulting in many incidences of complications, including the risk of heart disease, stroke, blindness, kidney failure and amputation. These complications have serious consequences on the quality of life of patients.

One of the most prevalent comorbidities of diabetes is foot ulcers. The World Health Organization (WHO) classifies a diabetic foot disease as a foot infection, ulcer and/or deep tissue damage related to local nerve abnormality and lower limb distal peripheral vascular pathological changes[3]. The incidence of foot ulcers in individuals with diabetes is 6.3%, with a lifetime incidence of between 19–34% in this population[4,5]. A main concern with foot ulcers in people with diabetes is the prolonged period the wound takes to heal. The likelihood of the wounds healing decreases in diabetics due to a number of factors, including circulatory dysfunction, hyperglycaemia, neuropathy, hypoxia and impaired neuropeptide signalling, as well as comorbidities such as end-stage kidney disease, congestive heart failure and peripheral artery disease[4,6]. Many of these factors contributed to the initial development of the diabetic foot ulcers. Additional factors that

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advance ulcer development include a high body mass index, foot deformity, being of the male gender, prolonged infliction of diabetes, advanced age, and poor foot self-care habits[7].

For individuals with diabetic foot ulcers, the infection rate is over 50%[8]. Infection is a process comprised of invading microorganisms, the body's inflammatory response to the invasion, and tissue degradation and destruction[9]. Factors that contribute to an infection in an individual with diabetic foot ulcers include wounds that last longer than 30 days, deep wounds, wounds that were caused traumatically, and wounds that are comorbid with peripheral arterial disease[8,9].

Additionally, if diabetic foot ulcers become infected they may progress to gangrene[10]. Diabetic foot gangrene is the final stage of diabetic foot disease, which is often comorbid with nerve and vascular lesions of other organs[2]. Infections can include osteomyelitis, cellulitis, abscesses, fasciitis or septic arthritis[11]. These infections can be caused by both fungi and bacteria such as Staphylococcus, Proteobacteria, *Pseudomonas aeruginosa*, Streptococcus and coliform bacteria[10].

Due to infection and slow healing times, diabetic foot ulcers may eventually lead to the need for amputation; individuals with diabetic foot ulcers are 10–20 times more likely to need amputation compared with their non-diabetic counterparts[2,7]. Amputation can lead to additional complications – the 5-year survival rate post-amputation is 30% for individuals with diabetes[4]. One study found that amputation rates were around 46–78% for moderate to severe infections respectively[8].

Infection is generally managed through antibiotic therapy, surgical intervention and wound debridement[8,11]. Other adjunct therapies used with these methods include negative pressure wound therapy (NPWT) and hyperbaric oxygen therapy. Comprehensive treatment and local management of diabetic foot gangrene is therefore important to reduce the amputation rate of patients with diabetic foot disease, to maintain foot function and mobility, and to improve the quality of life for individuals afflicted with diabetic foot disease[12].

NPWT is a form of wound management wherein negative pressure is exhibited across the entire surface area of the wound and is maintained by a dressing that is sealed and connected via a tube to an external vacuum. It acts to bring the edges of the wound together in healing – this promotes granulation tissue formation, reduces oedema, thereby increasing microcirculation, and removes small debris and exudate via suction[13]. This therapy can be combined with other approaches, such as instillation, which delivers a controlled amount of a cleansing solution – such as antiseptics or antibiotics – in order to treat diabetic foot infections[13,14].

In May 2016, a case of Wagner IV diabetic foot gangrene was admitted to our hospital. This paper will explore the clinical history of the patient, patient assessment and treatment. After 3 months of treatment, the patient's wound was healed successfully, and foot amputation was avoided.

CASE REPORT

Clinical history and assessment

The patient was an 88-year-old male who was admitted to the hospital on 22 May 2016. He had experienced polydipsia and polyuria for more than 3 years. Upon physical examination, the patient had a temperature of 37.8°C, pulse of 84 beats/min, and blood pressure of 160/90 mmHg. The patient appeared alert and oriented. The patient had a fasting blood glucose of 11 mmol/L, haemoglobin of 110 g/L, albumin level of 38.1 g/L, and a white blood cell count of 11x109/L.

The right side of dorsalis pedis artery pulse was weak and the front of his right foot appeared black–purple in colour. The patient's first and second toe were missing on the right foot, with toes three, four and five appearing purple–black with necrosis. Tissue was only partially connected with the plantar skin. Yellowish tissue covered 100% of the wound bed, with large amounts of grey, purulent, malodourous exudate at the wound site indicating severe infection. The edge of wound was irregular with oedema, high skin temperature and appeared purple–black. The patient's skin temperature on his right lower limb was higher than that of the left lower limb. The wound was classified as a Wagner Grade 4. On a numeric rating scale, pain was scored by the patient as eight out of 10 on a scale where 0 is no pain and 10 the worse pain.

The patient's admission diagnosis was as follows: type II diabetes mellitus and diabetic foot gangrene and infection; coronary atherosclerotic heart disease with unstable angina, with a chronic non-ST segment elevations myocardial infarction event 2 years previously, arrhythmia, and third stage of paroxysmal atrial fibrillation; hypertension level 3 (high risk); cerebral infarction sequela; and artery plaque formation in double lower limbs. The doctor recommended amputation of the foot, but the patient refused.

In June 2016 the patient was referred to an enterostomal (ET) nurse for foot treatment and wound care. The patient had right femoral artery stenosis (90%) and popliteal artery and posterior tibial artery stenosis (61%, 80%). A right lower extremity artery stent was implanted, which was in place for 5 months, and resulted in positive postoperative arterial blood flow. After a comprehensive assessment, the ET nurse found no contraindications in the patient to NPWT. This is the first case of using irrigation and NPWT (INPWT) in this large hospital to treat diabetic foot ulcer. Factors affecting wound healing in the patient were being of an older age, and having a variety of comorbidities such as diabetes, cardiovascular disease, poor nutrition, long-term chronic disease as well as poor mental health.

Systemic treatment

As outlined above, the treatment process included preventing the spread of infection, as well as active treatments of primary disease such as controlling blood sugar and blood pressure, and improving microcirculation and nutrition.

The goal for wound healing rate is 0.2 cm per week, but when the wound bacterial count is at or above 106/mm^2, healing

Figure 1. Initial stage of wound management (28 June 2016).

speed is expected to decrease to 0.055 cm/week. The more serious a bacterial infection, the slower wound healing is to be expected[3]. It is therefore vital to have systemic infection control practices in place when performing local wound management. The patient was prescribed a peracillin sodium intravenous infusion at a rate of 2.5 g once per 8 hours. Wound cultures showed growth of *Staphylococcus aureus* and *Pseudomonas aeruginosa*, suggesting the need for ofloxacin; therefore, a levofloxacin sodium chloride injection of 0.4 g was given through intravenous infusion once a day for 1 week. The patient's temperature was normal, and his condition was stable.

To control blood glucose, phosphate sieglidine tablets at a dosage of 100 mg were given orally once a day. The patient was also prescribed acarbosaccharides (baicana) 50 mg orally three times a day, which helped control his fasting blood glucose at 7 mmol/l and postprandial blood glucose around 10 mmol/l.

To reduce blood pressure, the patient was given amberyl mertolol (betatolak) 47.5 mg orally once a day, mononitrate isosorbate sustained-release capsule (isole) 50 mg orally once a day, and valsartan lodipine (combination of amlodipine 5 mg and valsartan 80) one tablet orally once every 12 hours, which kept blood pressure at 130/80 mmHg.

The patient was given pancreatopeptidase (yi-open) 240 units orally three times daily to increase local blood circulation and promote wound healing. The patient had anaemia, low protein, and other nutritional deficiencies which affected wound healing. To counterbalance this, the patient was given a high protein and high vitamin diet which was distributed via small meals under the precondition of controlling blood sugar.

Wound management process

To manage the wound, the inactivated tissue was removed to prevent the spread of infection. Necrotic tissues and microorganisms were also removed to prevent the absorption of toxins. To promote granulation growth, the patient's dead bone tissue was also excised, and the sinus cavity was closed.

Figure 2. Second stage of wound management (5 July 2016).

Eschar was removed to repair the wound edge and promote epithelium creep. The edges of the wound were trimmed to protect granulation and epithelial tissue. Skin moisturisers were used around the wound to promote blood circulation.

At initial wound management (28 June 2016), an iodine solution was used to disinfect the wound, and a sodium chloride solution was used to rinse the wound. Tissue cultures were taken from the wound to assist in guiding antimicrobial therapy. Surgical debridement was used to remove senescent cells and decrease bacterial burden. INPWT was then applied to the wound. The irrigation liquid that was used was 0.01% iodide normal saline (NaCl 500ml+5% iodide 10 ml), with a speed of 20 drops per min. The negative pressure was kept between 80–125 mmHg (Figure 1).

At the second stage of wound management (5 July), the wound bed was 50% erythematous and 50% yellowish (Figure 2). The wound continued to have a foul odour, with oedema around the wound, dark pigmentation, and edge impregnation. Treatment included continued debridement, and other methods as stated before. INPWT was also continued.

At third stage management (8 July), after the removal of the dead bone, sinus cavities 3.5 cm and 2.5 cm in depth were found in the first and third digits respectively (Figure 3). The total size of wound was 3x7.5 cm. To heal the wounds, conservative debridement was applied, with washing of the

Figure 3. Third stage of wound management (8 July 2016).

Figure 4. Ninth stage of wound management (12 August 2016).

Figure 5. Twelfth stage of wound management (23 August 2016).

sinus cavities and an implanted sponge to ensure that washing fluid reached the bottom of the sinus cavity without leaving a dead cavity. Continued INPWT was used in the treatment.

After roughly 6 weeks of treatment, at ninth stage of wound management (12 August), the sinus cavity in the first toe closed (Figure 4). The wound bed was fully erythematous. The wound was managed with continued conservative debridement using NPWT; however, irrigation was discontinued.

At the 12th stage of wound management (23 August), the wound bed continued to be fully erythematous (Figure 5). The edges of the wound were macerated, and the wound no longer smelled foul. Conservative debridement to remove necrotic tissue was applied. NPWT was stopped and treatment was switched to moist dressings. A hydrocolloid film was applied to the inner later of the dressing to promote epithelisation, while a silicon foam dressing was applied to the outer layer to promote the absorption of exudate.

At the 15th stage of wound management at 3 months (27 September), toes one and three were totally healed through wound care management (Figure 6). Figure 7 shows a comparison of the initial presentation and the wound after 3 months of treatment. Figure 8 shows the fully healed wound in May 2019, some 3 years after initial presentation.

Figure 6. Fifteenth stage of wound management (27 September 2016).

Figure 7. Comparison of treatment from initial presentation to after 3 months of treatment.

Before treatment *Three months later*

Figure 8. Fully healed wound, 3 years after initial presentation (May 2019).

Prevention

Diabetic foot is prone to relapse after healing or may reoccur in the other foot. Therefore, prevention is of vital importance. The patient needs to control their blood sugar levels and blood pressure, refrain from smoking, and participate in a consistent exercise regime. Moreover, the patient needs to diligently preform self-checkups on the problematic foot daily, practise proper foot care, wear comfortable diabetic shoes, practise regular foot hygiene, and visit the hospital for annual checkups. If any issues should arise, the patient must contact a diabetic podiatrist for examination and early treatment.

DISCUSSION

This case report indicated that INPWT can be used to treat diabetic foot ulcers when combined with other therapies to promote wound healing. The total treatment process lasted for 3 months and cost 27,500 RMB. The success in wound treatment prevented foot amputation which could negatively impact patient health and quality of life. In addition, life-threatening infection and sepsis were prevented. The patient and their family were very satisfied with the effectiveness of the treatment.

Managing a wound in a diabetic foot is a clinical challenge – it requires multiple care strategies which are interdependent in order to reach the ultimate goal of wound healing. The literature suggests that the treatment process of a diabetic foot ulcer is lengthy, expensive and has a low curation rate[12]. However, this case study adds to the growing body of knowledge about utilising INPWT and adjunct therapies to heal advanced diabetic foot ulcers.

In the case of our patient, INPWT, managing patient comorbidities, and good nutrition played key roles in successfully healing his wound. The INPWT used a water bath therapy combined with closed aspiration. The main principle of INPWT is to bathe the infected wound in the cleansing solution to dissolve debris such as liquefied necrotic tissue or bacteria, inflammatory mediators, and purulent secretions. Debris can then be removed from the wound bed through a suction device. When an abundance of irrigation solution is utilised, the concentration of harmful cellular debris and metabolic by-products is effectively lowered, thus efficiently eliminating harmful substances on the surface of the wound.

Fully draining the wound secretions also reduced the wound burden and promoted local blood circulation, speeding up growth of granulation tissue[15]. Draining is an important process as bacterial by-products – such as endotoxins and metalloproteases from cellular metabolism during the colonisation process – can interfere with wound healing at various stages. This interference can occur through increased metabolic demands, negative microcirculatory changes, and can signal an inflammatory response. INPWT acts to produce mechanical stress on cells, removes interstitial fluid, and stimulates new cell proliferation. Meanwhile, the irrigated solution enhances these affects or introduces antimicrobial properties[16].

The successful healing of our patient's wound matches other research findings regarding INPWT. Gabriel et al.[16] found that instillation of an irrigation solution in combination with NPWT enhanced wound healing through autolytic processes, prevention of glycocalyx establishment, mechanical debridement, and increased the viscosity of wound exudate which allowed for easier removal through the INPWT system. Additionally, Zelen and colleagues[14] found that INPWT was effective at closing both small and large wounds resulting from diabetic neuropathy by promoting epithelialisation and granulation at the wound.

Our patient's case was of greater complexity as he had many comorbidities alongside a severe wound infection. In addition to managing the patient's local wound, emphasis was therefore placed on systemic treatment such glycaemic control, blood pressure reduction, improving microcirculation and ensuring better nutritional status. These strategies are in alignment with the *Practical guidelines on the management and prevention of the diabetic foot 2011*[17] which notes the importance of proper nutrition and maintaining blood sugar levels at less than 8 mmol/L.

Another study highlighted the importance of good nutrition for preventing amputation in individuals with diabetic foot ulcers. Their findings illuminated how nutritional status has a significant impact on limb preservation. The proposed mechanism through which poor nutritional status impacts wound healing is multi-faceted. Nutrients are lost in wound exudate, and comorbidities can impact nutrient uptake which are major concerns due to the metabolic requirements for the products of wound healing such as collagen formation and fibroblast proliferation[18]. Thus, if nutrition is inadequate, wound healing can be delayed or severe progressions in the ulcer can develop and lead to the need for amputation. Through comprehensive treatment, the patient's wound healed successfully, and amputation was avoided. A plethora of research has demonstrated that amputation will drastically decrease quality of life, therefore avoiding amputation was of vital importance for the patient[19].

CONFLICT OF INTEREST

The authors declare no conflicts of interest. The patient consented to the usage of the photographs in this article.

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