Efficacy Analysis of the Treatment of Grade 3 Diabetic Foot Cases by Minimally Invasive Toe-preserving Combined with Regenerative Medical Technology

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Abstract: This study delves into the research conducted by the Hainan District People's Hospital in Wuhai City on the application of regenerative medical technology in the treatment of chronic refractory wounds, with a specific focus on a case study involving toe-preserving therapy for diabetic foot. The treatment protocol adopted a combined approach of minimally invasive surgery and regenerative medical technology for toe preservation in diabetic foot cases. The significance of this research lies in the application of this integrated strategy, which utilizes minimally invasive techniques alongside regenerative medical technology to treat diabetic foot wounds. This approach ensures hemostasis, prevents damage to normal tissues and blood vessels, avoids reperfusion injury, and accelerates wound healing. After 45 days of treatment, the stability, integrity, and aesthetic appearance of the patient's left fifth toe were successfully preserved.

Keyword: Minimally Invasive; Regenerative Medical Technology; Grade 3 Diabetic Foot; Rifampicin; Moist Exposed Burn Ointment

1. Case Report

Diabetic foot syndrome manifests in diabetic individuals as lower extremity infections, ulcerations, and/or profound tissue damage, stemming from neuropathic complications and variable degrees of vascular pathology. The underlying causes of diabetic foot ulcers encompass neuropathic, neuroischemic, and purely ischemic origins. This condition represents a prevalent chronic ailment in Chinese clinical settings, marked by insidious onset, protracted duration, and an unfavorable prognosis [1-3], coupled with a high incidence of amputations. Within the framework of this research initiative, a case of grade 3 diabetic foot was managed through a synergistic "minimally invasive toe-preserving" strategy, amalgamating the merits of minimally invasive surgery and regenerative medical technologies, as elucidated hereinafter.

2. Case Data

The patient, a 55-year-old male, presented to our hospital with a one-month history of ulceration on the fifth toe of his left foot, which had worsened over the past three days. His medical history included hypertension, type 2 diabetes mellitus, and stage V diabetic nephropathy, for which he was undergoing dialysis treatment. Physical examination revealed a 1cm×1cm wound on the medial aspect of the fifth toe of the left foot, with undermining extending 1.5cm at the 12 o'clock and 6 o'clock positions. The fifth toe of the left foot was swollen, with elevated skin temperature, but not significantly tender to palpation. Local tissue edema was observed, along with destruction of the joint capsule. The flexor digitorum brevis and extensor digitorum longus tendons were necrotic, with necrosis extending proximally. The flexor digitorum longus tendon was partially necrotic, and the middle phalangeal joint was destroyed, appearing gray with purulent discharge and a foul odor, accompanied by crepitus. The skin surrounding the wound was dark purple, with slow capillary refill upon pressure, weak dorsalis pedis artery pulse, and poor distal circulation. Auxiliary examinations showed: X-rays of the left foot in anteroposterior and oblique views revealed bone destruction in the fifth toe of the left foot (as shown in Figures 1 and 2); general bacterial culture of the wound secretion indicated Staphylococcus aureus; fasting blood glucose was 7.6 mmol/L, creatinine was 365 umol/L, and urea nitrogen was 83 mmol/L. Diagnosis: Diabetic foot ulcer on the fifth toe of the left foot (Wagner grade 3), bone destruction in the fifth toe of the left foot, and stage V

diabetic nephropathy. The Bates-Jensen Wound Assessment Tool scored 42, indicating a severe condition with a risk of toe amputation. Due to the severe infection and poor microcirculation in the fifth toe of the patient's left foot, and considering the need to prevent exacerbation of infection and reperfusion injury, initial treatment involved wound cleansing followed by the application of Moist Exposed Burn Ointment (MEBO) to the wound bed, adequate drainage to manage exudate, and provision of a moist wound environment.

Figure 1. Preoperative left foot x-ray

Figure 2. Preoperative left foot x-ray

Note: X-ray of the left foot shows that the bones of the distal and middle phalanges of the fifth toe of the left foot were destroyed.

The patient, who was undergoing dialysis treatment for stage V diabetic nephropathy, received local medication. Based on the results of general bacterial culture and drug sensitivity testing, the patient was found to be sensitive to rifampicin. Some scholars have suggested that the topical application of rifampicin can effectively control infections [4,5]. Therefore, the treatment regimen for infection involved the use of regenerative medical technology combined with rifampicin to control the infection. The protocol was as follows: The wound was repeatedly irrigated with hydrogen peroxide and normal saline. Subsequently, 100ml of 0.9% sodium chloride solution was prepared, and the capsules of two rifampicin tablets were removed, with the powder added to the 100ml of saline. The mixture was thoroughly shaken to ensure uniform distribution. This solution was then used to irrigate the wound. After irrigation, a mixture of Moist Exposed Burn Ointment (MEBO, approved by the National Medical Products Administration under the number Z20000004, 60g per tube) and rifampicin powder was prepared by stirring until evenly blended. The medication was applied to a sterile gauze, which was then used to pack the wound. The dressing was changed twice daily. After one week of dressing changes, infection control was observed, with a reduction in wound exudate and a decrease in surrounding erythema and swelling. The foul odor also disappeared. Subsequently, a minimally invasive surgical procedure was performed to remove the necrotic tissue.

3. Minimally Invasive Surgical Plan

The crux of the procedure resides in the meticulous excision of the necrotic joint capsule, bone, and tendons, all the while safeguarding the vascular integrity of the fifth toe on the left foot and averting reperfusion injury. Rather than opting for an extensive incisional debridement, a minimally invasive strategy is employed, leveraging the original 1cm*1cm wound aperture and utilizing micro-instruments to evacuate the bulk of the necrotic tissue, thereby preserving the toe's structural integrity. Should all necrotic tissue be eradicated, it would culminate in compromised stability, a complete loss of function, and an aesthetically displeasing outcome for the fifth toe.

Under the auspices of local anesthesia, the entire necrotic joint capsule was meticulously excised. Subsequently, the articular surface and regions of bone destruction in the middle phalanx of the fifth toe were carefully removed using bone rongeurs (as depicted in Figure 3). In a similar vein, the articular surface and areas of bone deterioration at the distal end of the proximal phalanx were also excised, while preserving a segment of the distal phalanx. The necrotic

extensor digitorum longus and flexor digitorum brevis tendons were then resected and shortened, with a portion of the necrotic flexor digitorum longus tendon retained (as illustrated in Figures 4-5). Through the innovative application of regenerative medical technology, the wound was dressed with gauze impregnated with Moist Exposed Burn Ointment (MEBO), fostering the proliferation of granulation tissue. At this juncture, the retained segment of the necrotic flexor digitorum longus tendon would be supplanted by the gradual encroachment of nascent granulation tissue along the tendon, thereby ensuring the structural stability of the fifth toe. A juxtaposition between the preoperative and postoperative states unveiled the successful eradication of necrotic tissue, with the continued application of regenerative medical technology facilitating the robust growth of granulation tissue within the wound (as portrayed in Figures 6-7).

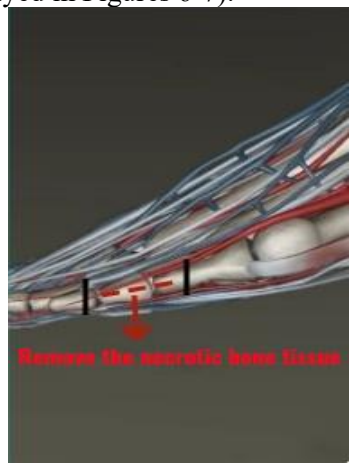

Figure 3. Surgical plan

Figure 3. Removal of necrotic bone. The wound surface was small, no extended debridement was performed, and the debridement process could not be photographed, so simple images were used for analysis.

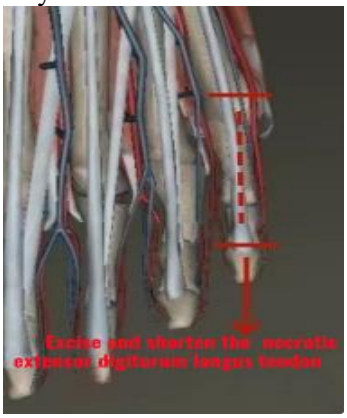

Figure 4. Surgical plan

Note: Figure 4. Excision and shortening of the necrotic extensor digitorum longus tendon.

Figure 5. Surgical plan

Note: In Figure 5. the blue arrows retain part of the necrotic flexor digitorum longus tendon, and the red arrows remove and shorten the necrotic flexor digitorum longus tendon.

Figure 6. Preoperative wound condition

Note: Destruction of joint capsule can be seen on the wound, and the joint surface is gray.

Figure 7. Postoperative wound condition

Note: The wound necrotic tissue is cleared, preserve part of flexor digitorum longus tendon.

4. Regenerative Medical Technology Plan

Following the surgery, regenerative medical technology was employed for treatment. During dialysis, the patient received heparin therapy. The principle of wound dressing changes was to ensure no bleeding, no damage to normal tissues, and no pain, while maintaining the patient's normal dialysis schedule. Initially, the wound was dressed twice daily, every 12 hours (Q12h). A small amount of Moist Exposed Burn Ointment (MEBO) was applied to the wound bed, followed by packing the wound with MEBO-impregnated gauze. It is crucial to note that during the early stages, the gauze should not extend above the skin edge; otherwise, it could lead to slow wound growth and the formation of rolled edges, which would impede healing. On the 10th day post-surgery (as shown in Figure 8), when fresh granulation tissue was observed in the wound, the dressing change frequency was reduced to once daily, with the wound still packed with MEBO-impregnated gauze. However, care must be taken not to pack the gauze too tightly to avoid restricting granulation tissue growth. On the 27th day post-surgery (as shown in Figure 9), further reduction in the wound size was noted. By the 35th day post-surgery (as shown in Figure 10), the wound had healed completely. According to the wound healing criteria, the patient was advised to return for a follow-up examination after 3 weeks. Upon examination, no ulceration was observed in the healed wound of the fifth toe of the left foot (as shown in Figure 11), indicating complete healing. The integrity, functionality, and aesthetic appearance of the toe were preserved.

Figure 8. Postoperative dressing change day 10

Note: Granulation tissue fresh.

Figure 9. Postoperative dressing change day 27

Note: The wound is reduced.

Figure 10. Postoperative dressing change day 35

Note: All wounds healed.

Figure 11. Wound healing criteria

Note: After 3 weeks, there was no ulceration and the toe was completely healed, preserving the integrity,

functionality, aesthetics and stability of the toe.

5. Results

Upon presentation, the patient was subjected to a meticulously standardized treatment regimen. In light of the underlying diabetic nephropathy, preoperative strategies were meticulously devised to proactively manage infection and ensure optimal drainage. A synergistic therapy comprising topical application of rifampicin and Moist Exposed Burn Ointment (MEBO) was administered over the course of one week, effectively quelling the infection. During the surgical intervention, a minimally invasive technique was judiciously employed to minimize vascular insult and obviate the risk of reperfusion injury. Postoperatively, the wound was treated with regenerative medical technology, specifically MEBO therapy, to foster the proliferation of granulation tissue and epithelialization, thereby expediting the wound healing process.

6. Discussion

Diabetic foot lesions stand as one of the most prevalent complications among diabetic patients, characterized by neuropathy and vasculopathy that predispose individuals to foot infections and ulcerations. Neuropathy renders patients impervious to the timely perception of pain, while vasculopathy undermines the foot's innate healing capacity. Consequently, infections and ulcers can rapidly escalate, even culminating in the dire prospect of amputation. Hence, the early clinical detection, vigilant attention, timely intervention, and expedited healing are of paramount importance in enhancing the patient's quality of life [6].

Rifampicin, an antitubercular agent, boasts a broad-spectrum antibiotic profile with potent antibacterial activity against Mycobacterium tuberculosis, Mycobacterium leprae, Gram-positive cocci, and notably, drug-resistant Staphylococcus aureus [7]. Nevertheless, oral administration of rifampicin may engender adverse reactions, such as gastrointestinal disturbances and hepatic dysfunction [8]. Thorough irrigation of the wound with rifampicin saline can effectively attenuate bacterial load and mitigate the deleterious effects of bacterial toxins on the wound bed. Contemporary pharmacological investigations into MEBO have unveiled that the berberine contained within its constituents, namely Coptis chinensis and Phellodendron amurense, exhibits a broad-spectrum antibacterial effect, demonstrating sensitivity against a plethora of Gram-positive and Gram-negative bacteria, thereby exerting a bactericidal influence [9-11]. In the nascent stages of diabetic foot infection, this combined therapeutic approach can vigorously and effectively control infection, forestalling inflammatory responses and the release of inflammatory cytokines that could impair endothelial cell function and impede wound healing [12].

Diabetic foot grade 3, marked by ulceration that engenders necrosis of tendons, joint capsules, and bone destruction, initiates an inflammatory cascade. Should debridement not be expeditiously undertaken, bacteria and necrotic tissues may proliferate along the tendon's trajectory, exacerbating tissue necrosis and swiftly culminating in partial or complete gangrene of the foot, or even precipitating systemic inflammatory response syndrome. Local vascular impairment stands as one of the contributory factors to diabetic foot ulceration. Minimally invasive surgery endeavors to preserve the toe to the utmost extent feasible. By employing micro-instruments within the boundaries of the original wound dimensions, profound debridement is executed. The merits of this approach encompass minimal trauma, preservation of normal tissues, and circumvention of damage to local blood vessels, thereby forestalling reperfusion injury and further necrosis. Nevertheless, the limitation resides in the restricted field of vision, which may impede the surgical maneuver.

Regenerative medical technology, embracing Moist Exposed Burn Therapy (MEBT) and Moist Exposed Burn Ointment (MEBO), sustains a physiologically moist wound milieu, furnishes indispensable nutrients for wound healing, and fosters tissue regeneration [13]. Presently, regenerative medical technology finds widespread application in the treatment of diabetic foot ulcers. Following debridement, the application of MEBO, whose principal constituents comprise Scutellaria baicalensis, Phellodendron amurense, Coptis chinensis, and vegetable oil, exerts effects such as purging heat and detoxifying, alleviating discomfort, staunching bleeding, and promoting tissue rejuvenation. Furthermore, it is non-irritating to mucous membranes. Owing to its low melting point, elevated surface activity, and robust

adsorption capacity, MEBO can shield cell membranes and fats from oxidative damage, uphold normal tissue metabolism, augment blood microcirculation in the wound bed and surrounding tissues [14], upregulate the expression of vascular endothelial growth factors like VEGF and EGF, suppress wound cell apoptosis, and facilitate the transformation, proliferation of fibroblasts, and wound healing [15].

To sum up, our institution embraces a multi-faceted therapeutic strategy, with regenerative medical technology at its core, for the management of grade 3 diabetic foot. Operating within the contemporary paradigm of Enhanced Recovery After Surgery (ERAS) protocols, this approach endeavors to hasten patient recuperation, abbreviate the disease trajectory, facilitate expedited wound healing, mitigate the economic strain on patients, and elevate their overall quality of life.

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