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CASE REPORT

Negative Pressure Wound Therapy and Ultrasound Monitoring for Fracture-Related Infection of the Proximal Femur: A Case Report

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Background: Fracture-related infection (FRI) is one of the main complications of hip fracture. Negative pressure wound therapy (NPWT) seems to be a potential solution for FRI, because of offering exudate management, drainage enhancement, and tissue repair. Additionally, ultrasound cannot be ignored because of its role in evaluating musculoskeletal tissue infections.

Case Presentation: A 55-year-old man mainly suffered from a fracture of the right proximal femur. The fracture was classified as AO/OTA 31-A3. The patient had a history of smoking. After internal fixation of the fracture and other symptomatic treatment, the patient was discharged. However, the surgical incision dehisced one month later. After examination, the patient was diagnosed with FRI with wound disruption and sinus tract formation. The blurred parafemoral shadow in X-ray, positive bacterial culture result, abnormal secretions, and elevated C-reactive protein and erythrocyte sedimentation rate were the bases for diagnosing FRI. In the course of treatment, we made full use of NPWT following limited debridement surgery to effectively treat FRI, and then continuously monitored the changes of lesions in deep infected areas through ultrasound detection. Intravenous infusion of ceftazidime and local rinsing with vancomycin solution were applied during the treatment process. Follow-up results showed that the patient had no recurrence of infection or other adverse events three months after treatment.

Conclusion: This case shows that NPWT combined with ultrasound monitoring can control early fracture-related infection and allow implant retention. This treatment method may be applicable to areas with scarce medical resources. But larger-scale validation is still needed before clinical adoption.

Keywords: fracture-related infection, hip fracture, negative pressure wound therapy, surgical wound infection, ultrasonography, wound healing

Background

Hip fractures, particularly subtrochanteric fractures, are a common type of fracture. The major complications of fracture in this particular area are varied and serious.[1] Intramedullary fixation remains standard treatment, but complications like

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fracture-related infection (FRI) often necessitate reoperation and implant removal. Implant removal in early postoperative cases jeopardizes fracture healing. And Postoperative nutritional status significantly influences the outcomes of hip fracture patient.[2] Now, the infection that occurs after fracture operation has been uniformly defined as FRI.[3] FRI occurs in 1.23% of fracture cases, substantially increasing healthcare costs and treatment failure rates.[4–6] Early FRI management is especially important in proximal femur fractures.[7]

Negative pressure wound therapy (NPWT) seems to be a potential solution for FRI, because of offering exudate management, drainage enhancement, and tissue repair. Modern polyurethane (PU)-based NPWT systems provide sustained negative pressure and better protective effect on soft tissues compared to early designs. NPWT is no longer regarded as an adjuvant treatment method. Unfortunately, one previous study did not perceive advantages of NPWT in the treatment of deep infection after fracture surgery.[8] Therefore, further exploration of NPWT on the infection-inhibiting ability and original implants preservation effect becomes even more important. On the other hand, computed tomography (CT) is often performed to help evaluate FRI via scanning bone status, soft tissue infiltration, and abscesses.[9] However, ultrasound cannot be ignored since it functions in evaluating musculoskeletal soft tissue and joint infections.[10] Even more importantly, it is a convenient and useful imaging method compared to CT and magnetic resonance imaging (MRI).

This case report demonstrated successful management of FRI in a proximal femur fracture through an innovative NPWT protocol with ultrasound monitoring. This method achieved both infection control and implant preservation with constrained medical resources.

Case Report

On December 28, 2021, a 55-year-old man was admitted to Chaoyang County Central Hospital's emergency department following a traffic accident, diagnosed with compound trauma (right proximal femur fracture, bilateral pulmonary contusions/lacerations, right hemopneumothorax, multiple right rib fractures) (Figure 1A). The fracture was classified as AO/OTA 31-A3. After temporary treatment and inferior vena cava filter placement, open reduction and intramedullary fixation of the femur fracture, with titanium cabling and allograft, were performed on January 10, 2022. Post-operative treatment included ultrasound-guided thoracic drainage. The patient was discharged with stable vitals, a healing incision, and satisfactory X-ray findings (Figure 1B). One month later, the surgical incision dehisced.

Readmission examination revealed right thigh swelling, local tenderness, and a 5 cm split incision below the right greater trochanter with white translucent secretions. There was no implant exposure. X-rays showed increased density around the right femur (Figure 1C). Laboratory tests indicated decreased albumin, elevated C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR), and slightly elevated glycosylated hemoglobin. Wound secretion culture identified *Proteus vulgaris* (resistant only to cefazolin/cefuroxime), leading to a diagnosis of FRI with wound disruption and sinus tract formation. This hospital was a secondary hospital and has no MRI or spectral CT equipment. And the patient's

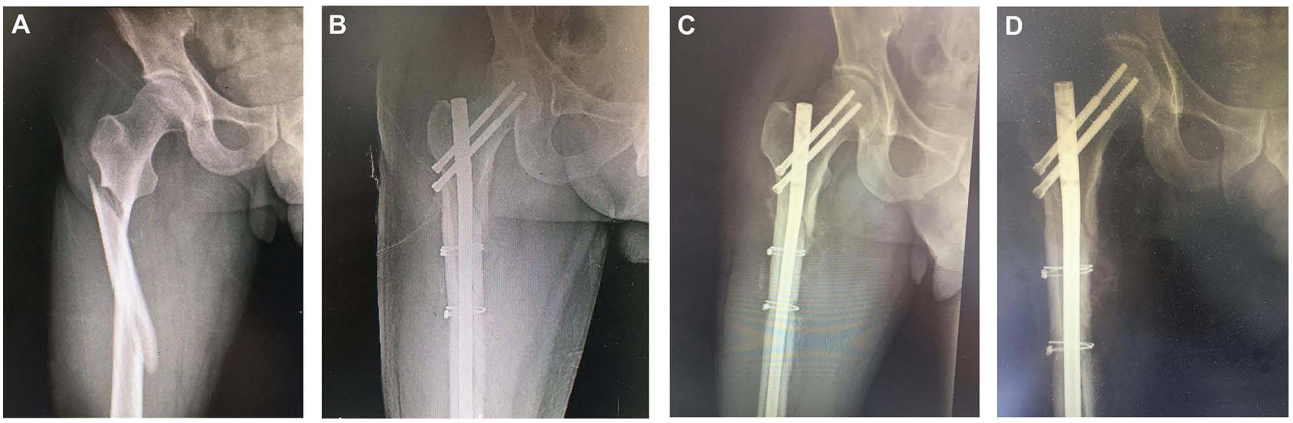

Figure 1 X-ray film taken during treatment of proximal femoral fracture. (**A**) proximal femoral fracture before surgery. (**B**) proximal femoral fracture after surgery. (**C**) Bone necrosis and deep tissue inflammation occurred in the fracture area. (**D**) After NPWT treatment combination with ultrasound detection, the fracture area was clear and the fracture line was blurred.

budget was limited. Making full use of existing resources and achieving implant retention was an urgent need for both doctors and patients. On February 21, 2022, Dr. Mingzhi Song participated in developing a treatment plan preserving the original implants and aiming for in-situ healing.

The same day, under local anesthesia, the first debridement exposed the fracture site, revealing large subcutaneous and deep cavities (Figure 2A). Incising fascia and vastus lateralis released about 200 mL of milky pus containing necrotic tissue. Intraoperative exploration identified a 10 cm-length cavity around femoral extending towards the knee, containing bone fragments and titanium cables. Necrotic tissue and sinus tract walls were debrided and then flushed with 3 L saline. NPWT was modified by adding one washing tube to the head side and one to the tail side, and inserting them into the boundary of both sides of the lacuna. Vancomycin was diluted for a final flush of the diseased area, then a PU sponge was fully inserted into the intraoperative cavity, reserving space in the irrigation tube's path to prevent blockage. NPWT was set at 100 mmHg. Postoperatively, the patient's body temperature, pain sensation, local swelling, color and volume of drainage fluid were observed daily. Intravenous infusion of ceftazidime twice a day was given to the patient. Good nursing and rehabilitation guidance were given. Active and passive functional exercises for the joints below the knee joint are required to be carried out daily. The secretions were cultured at regular intervals. The range of deep lacuna, fluid accumulation and the residual amount were observed by ultrasound. Postoperative CRP and ESR were lower than those before surgery.

One week later, the second debridement found a few purulent secretions, minimal new necrosis, and an unchanged cavity extent (Figure 2B). Extensive rinsing, debridement, tube placement, and NPWT (100 mmHg) were repeated. Postoperative CRP rose transiently. ESR and leukocyte count (LC) decreased, while low albumin persisted. Drainage fluid cleared, and ultrasound showed the range of the liquid shadow significantly reduced. The third exploration revealed fresh granulation tissue and a reduced cavity (Figure 2C). After flushing and minimal debridement were performed. In order to completely surround the femur and implants with soft tissue, the drainage tube on one side was changed to a negative pressure suction tube, leaving the other side to continue flushing. Deep tissues were freshened and then approximated with suturing to close the cavity. The reduced usage of PU sponges were selected, rather than trying to fill the cavity. NPWT was set to 120 mmHg for keeping the prowling areas close to the deep tissue. CRP and ESR decreased markedly. The ultrasonographic results showed that the deep liquid area disappeared. Bacterial culture of secretions collected during the operation was negative. The final operation was completed on March 14, 2022. Because the muscle layer was closed, the drainage tube and flushing tube were pulled out (Figure 2D). The result of the Pinch test showed negative. Based on wound edge debridement, final wound closure was achieved using tension reduction sutures. Additionally, PU sponge assisted in reducing tension in the sutured area for shallow tissue closure with negative pressure (150 mmHg).

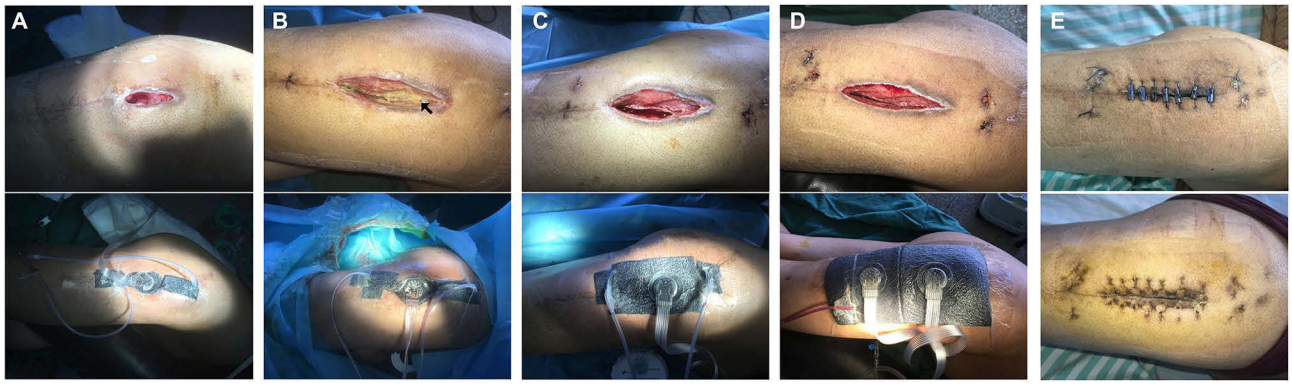

Figure 2 The process of wound healing. (**A**) large subcutaneous and deep cavities during the first debridement (February 21, 2022). (**B**) purulent secretions and minimal new necrosis occurred in the wound (the arrow indicating secretions and necrosis) (February 28, 2022). (**C**) the third debridement revealing fresh granulation tissue and a reduced cavity (March 7, 2022). (**D**) no tissue defect in the muscle layer during the fourth debridement (March 14, 2022). (**E**) suture removal and wound closure (March 28, 2022).

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Sutures were removed after two weeks, confirming complete healing (Figure 2E). Ultrasound showed minimal residual fluid. Re-examination of X-ray revealed resorbed bone necrosis, clear cortical margins, faint fracture lines, and stable implants (Figure 1D). The patient was discharged on March 28, 2022, with instructions for regular follow-up, nutritional support, functional exercise, blood sugar control, and lesion monitoring.

It should be particularly noted that the use of NPWT modification and repeated ultrasound monitoring is part of routine clinical decision-making rather than a research intervention.

Discussion

FRI is a catastrophic complication associated with internal fixation, significantly impacting on patients and healthcare systems through extended stays, reduced quality of life, and increased costs.[11–13] Femur fractures are a confirmed risk factor.[14] While closed fractures have a lower FRI incidence than open ones, comorbidities like diabetes, systemic vascular disease and smoking also elevate risk.[15–18] The treatment plan we developed had to consider the limited medical resources in the area. In this case, treating FRI was a significant challenge.

X-ray, CT, MRI and nuclear imaging techniques are all helpful to observe the lesion and determine the scope of infection.[19] Common laboratory tests, including CRP, ESR and LC, are helpful for the diagnosis of FRI.[20,21] This proximal femur fracture patient had a history of smoking. The increasing density around the right femur of X-ray also had a certain suggestive effect. Hospital tests found low albumin, abnormal blood sugar, and deep vein thrombosis. The positive results of the culture directly confirmed the presence of infection in the fracture. Moreover, the sinus tract combined with wound breakdown and the presence of pus, met the diagnostic criteria for FRI.[22]

Core management of FRI focuses on fracture stabilization, soft tissue recovery, functional restoration, and complete infection eradication.[23] The key challenge lies in deciding whether to retain or remove implants. Fracture healing means that the implant could be removed.[23] Maintaining fracture stability helps control local inflammation.[24] Antimicrobial therapy follows a two-phase approach including empirical medication and targeted therapy.[3] In this case, culture results guided ceftazidime selection against *Proteus vulgaris*. We preserved the original implants while performing thorough debridement and employing specialized NPWT techniques (Figure 2).

NPWT has been widely applied in the treatment of postoperative incision infections, spinal infections and open fractures of the lower extremities, and has achieved satisfactory therapeutic effects.[25–28] The modality with instillation and dwell time (NPWTi-d) is now developing shows a better antibacterial therapeutic effect.[29] The effect of NPWT on decreasing both *Staphylococcus aureus* and *Pseudomonas aeruginosa* has already been confirmed.[30–32] According to the microbiological characteristics of this case, we selected NPWT to combat *Proteus vulgaris* infection. For deep infected lesions, adequate irrigation and drainage are essential. Therefore, we used catheters as the flushing tubes and inserted them under the PU sponge to reach the infection site. Saline is injected daily through a preset pipe, and then sucked out by the sponges to establish a closed loop. In fact, this improved method was similar with negative pressure wound therapy with instillation and NPWTi-d. As early as 2022, NPWTi-d has been reported for the treatment of deep infection after fracture surgery, especially that with a dead space.[33] Unlike NPWTi-d, we only use normal saline for irrigation, maintaining low flow rate injection and effective negative pressure suction. Currently, NPWT also plays an important role in promoting deep and superficial tissue closure.[34] In this case, the soft tissue of the proximal femur was widely separated from the bone tissue and a cavity was formed. The PU sponge is adequately packed to promote tissue adhesion and eliminate dead space, while the irrigation tube should be timely removed to prevent tissue re-separation. The wound tissue was exposed for a long time, and fibrosis appeared quickly. This is followed by an increase in the tension of wound closure. NPWT again played a powerful role in promoting tissue bonding during this period. The PU sponge is placed above the suture and pressing the flap reduces the closing pressure while pushing the flap towards the femur and further promoting tissue adhesion. During the whole treatment process, the timing of the extraction of the rinsing tube is determined by the local tissue growth and also judged during each operation.

The use of ultrasonography is a preferable method to identify and control soft tissue collections, with advantages over other diagnostic modalities such as CT or MRI. It is known for its low price, convenient operation and good repeatability. Ultrasonography has been used in the diagnosis of skin and soft tissue infections with low cost, easy to reproduce, and real-time data.[35] And it is also helpful for both the detection of implant-related infection and early prediction of impaired

fracture healing.[36] Because the lesions in this case were deep and the surface was blocked by PU sponge, and it was difficult for us to observe the changes of the disease. We used ultrasonography to monitor the changes in the lesion area after each operation for planning the next surgery. Meanwhile, by tracking the changes in laboratory results such as CRP, ESR, blood routine, and serum protein, the focal inflammatory response and overall condition of the patient can be determined.

Although there was no consistent standard for the diagnosis and treatment of FRI, the treatment of this case differed from the conventional therapy. Firstly, limited incision and debridement under local anesthesia were used as the basic surgical method, NPWT was used as the main treatment for irrigation, drainage, antibacterial and healing promotion. Secondly, ultrasonography was used as an auxiliary method for dynamic observation of lesion healing. The above methods achieved the goal of retaining the original implants while reducing tissue damage. It saved medical costs and was not technically demanding.

However, there are still many limitations. Three months is not enough to make sure there is no late recurrence of infection. Therefore, the long follow-up period is needed. Functional results, as an important reference for judging the degree of limb rehabilitation, should be recorded. There is no direct comparison with standard treatment strategies recommended in fracture-related infection guidelines, such as conventional debridement and implant retention protocols. Additionally, ultrasound results may vary depending on the operator and the diagnosing doctor. The above limitations all indicate the treatment method in this single case is not mature. More clinical practice is needed to verify and improve this new treatment in the future.

Conclusions

NPWT combined with simple ultrasound monitoring may be a feasible option to manage early fracture-related infection of the proximal femur and to preserve implants in low-resource settings. This single-case success of NPWT with ultrasound monitoring for FRI management necessitates larger-scale validation before clinical adoption.

Data Sharing Statement

No datasets were generated or analysed during the current study.

Ethics Approval and Consent to Participate

This report was approved by the Ethics Committee of Chaoyang County Central Hospital.

Consent for Publication

A written informed consent from the patient for the publication of this case report and all images was obtained.

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Disclosure

The authors report no conflicts of interest in this work.

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