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Case Report

Upper limb reconstruction by humerus lengthening after forearm mangled injury: a case report

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Abstract: Objective: The current study was aimed at introducing a novel method to manage the mangled extremity by upper limb reconstruction using distraction osteogenesis. Methods: A 25-year-old man was admitted to our hospital after a severe mangled injury, his right forearm bones and the surrounding soft tissues were compromised. After initial debridement, the infection of his right forearm recurred. Unavoidably, the forearm bones of the patient were eradicated in the further debridement. His right humerus was lengthened by distraction osteogenesis to compensate for the loss of ulna and radius. The distraction period was about 340 days and 220 mm of humerus regenerate were formed. Moreover, at the ex-elbow site the humerus was bent 40° in flexion to allow for better function of forearm and hand. Results: Bone regeneration was achieved at the end of treatment. Two-year postoperative follow-up revealed no recurrent infection. The Surgery-Hand/Arm Grading System was used for evaluating the function of "newly formed" forearm after the whole treatment, and the score was significantly improved to 79. Conclusion: This case report indicates that severe mangled extremity could be salvaged, and bone distraction osteogenesis can play a very important role in managing this massive bone defect.

Keywords: Massive bone defect, distraction osteogenesis, mangled injury, lengthened humerus, osteomyelitis, functional reconstruction

Introduction

A mangled extremity, which usually results from high-energy injury, involves highly comminuted bone fracture, massive bone defect, and severe injury to soft tissue like artery, tendon and nerve [1]. It is usually associated with considerable early and long-term morbidity [2]. Management of mangled injury is very complex because it requires surgeons to make a quick decision of amputation or salvage based on thorough evaluation. However, salvage can usually lead to refractory infections and poor soft tissue coverage, indicating a secondary amputation in the later treatment period.

With rapid advancements in evacuation, resuscitation, wound care, soft tissue reconstruction, and internal and external fixation technique, the limbs which would have been amputated in the past can be salvaged at present. The decline in amputation rate for mangled extremity from 72% at World War II to less than 10% during recent Middle East War [3] approves the notion. In an attempt to salvage the extremity, management of massive bone defect such as free vascularized and autologous cancellous bone graft, and fibular grafting, is of great importance and lays the foundation for further functional reconstruction. The management of the massive bone defect by these methods, however, has not been reported previously. In the current case report, a patient suffering from mangled injury and refractory infection of ulna and radius was managed by distraction osteogenesis and his forearm was reconstructed. To the best of our knowledge the current case is the first report on reconstruction of forearm bones by this method.

Case report

A 25-year-old man was admitted to our institute because of severe mangled injury. His right upper extremity was wrapped with gauze bandage and fixed with a splint. General physical

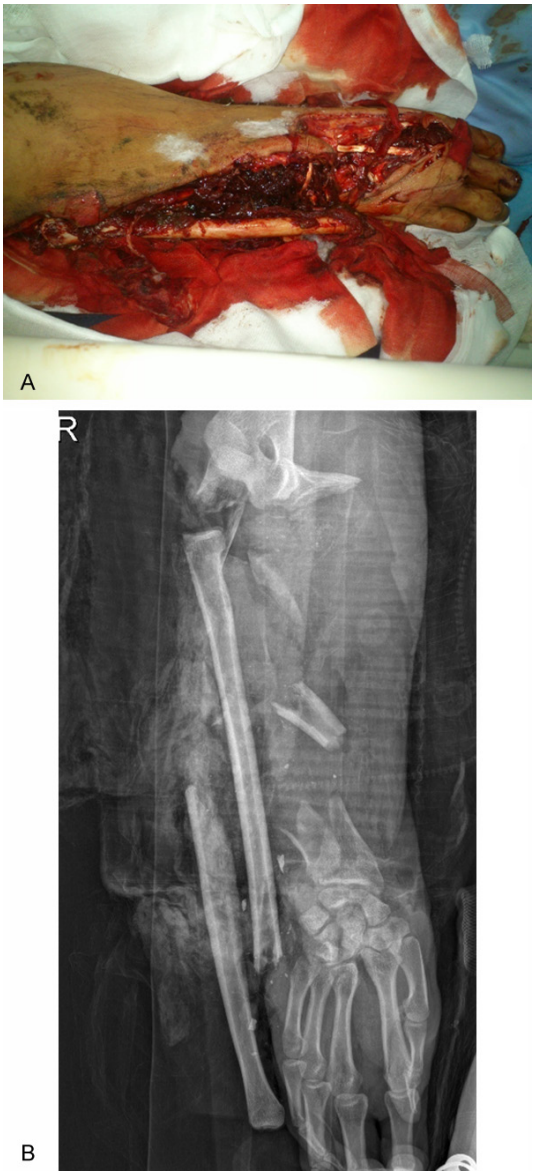

Figure 1. A: The severely injured forearm after the patient was admitted to our hospital. The detached bones and badly contaminated soft tissue could be observed. B: The radiograph of the patient's right forearm before the gauze and bandage were removed. Highly comminuted fracture and displacement of both radius and ulna could be observed.

examination showed stable vitals such as blood pressure 115/67 mmHg, pulse rate 86 beats/min, and body temperature 38.1°C.

Clinical examination of his right forearm revealed a 30×5 cm open wound through which bare broken bones were exposed. Abnormal motion of upper limb accompanying contaminated wound and necrosed tissue all around was observed (**Figure 1**). The motion and sensation of ulnar muscle of forearm and hand were intact, but radial pulsation was intact. Moreover, the posterior cubital triangle was completely deformed.

A hemogram revealed a significant increase in his C-reactive protein (CRP) (69.3 mg/L), white blood cell (WBC) (22.4×10^9) and erythrocyte sedimentation rate (ESR) (21 mm/h).

The patient received emergent surgery of debridement, his wound was radically irrigated and the necrotic and contaminated soft tissues were removed. Vibrant vessels, muscles and tendons were repaired; reduction and monolateral span external fixation by Kirschner wire was done on displaced and broken ulna and radius. Due to large soft tissue defect, his wound was covered by vacuum sealing drainage (VSD). Few days later another debridement and implantation of gentamycin-impregnated calcium sulfate (Stimulan®, Biocomposite Ltd., UK) was done and VSD was replaced by a free anterolateral thigh flap. According to his bacterial culture, intravenous cefmetazole sodium was administrated postoperatively for the next 6 weeks.

Despite all the treatments and measures, his infection persisted and could not be controlled. Clinical examination in follow-up revealed a sinus discharging black, viscous and putrid purulence. Radiography revealed nonunion and erosion of broken ulna and radius. Therefore, it was decided to abandon both of the forearm bones and replaced by a lengthened humerus using distraction osteogenesis.

After ceftazidime therapy for more than 2 weeks, almost the entire radius and ulna as well as the surrounding infected soft tissues were resected with another debridement. Subsequently, the dead space was filled with vancomycin-impregnated calcium sulfate, and intravenous ceftazidime was administrated until a new monolateral external fixation was applied 6 weeks after osteotomy.

After a latent period of ten days, distraction was started at a rate of 0.25 mm 4 times a day. It continued until his right forearm was largely reconstructed (**Figure 2**). The total duration for distraction was about 340 days when nearly 220 mm of humerus was lengthened. After distraction, assisted by multiple rotated clamps,

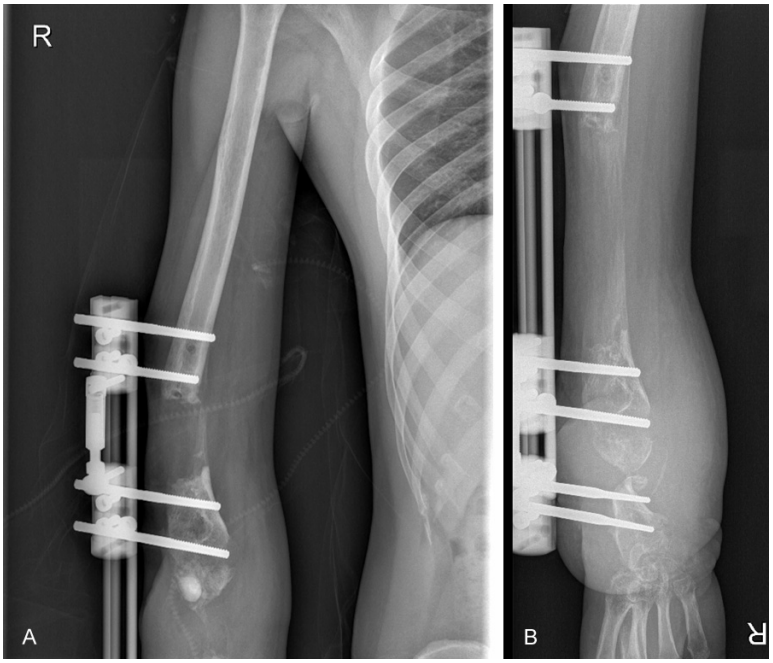

Figure 2. The humerus (A) was lengthened by distraction osteogenesis, from the picture we can see more than 200 mm of new bone (B) was formed.

the distracted humerus was bent 40° in flexion at ex-elbow site to allow for better restoration of forearm function (**Figure 3**). After a consolidation period of approximately 100 days, the radiographs at his outpatient department visit demonstrated bone union (**Figure 4**), and no signs of reinfection was observed. Afterwards, he received another surgery to reconstruct his destructed extensor pollicis longus and extensor pollicis brevis by distracting biceps brachii for grasp function (**Figures 5** and **6**). Finally, the patient underwent physiotherapy for over 2 months and his right hand restored satisfactory mobility to perform delicate movements such as grasping. At 24 months' follow-up, his functional outcome scores [4] were substantially improved (79) (**Figure 7**) according to the Surgery-Hand/Arm Grading System.

Discussion

A mangled injury of extremity usually belongs to Gustilo grade III fracture in most cases [5]. The associated refractory infection and joint injury can pose additional challenge to orthopedic surgeons. In addition to highly comminuted fracture and severe soft injury, the recurrent infection per se in our case caused the eventual abandonment of the bones of right forearm.

Similar to the management of a benign tumor, radical (or expanded) eradication of infected tissues is probably the only solution for refractory infection, especially in cases of comminuted fracture. However, it inevitably leads to massive bone defects and even loss of an entire bone. The refractory infection in our case could be totally eradicated only after repeated radical debridement, which resulted in lossing almost the whole forearm bones.

To manage massive bone defects, several methods have been suggested [6]. Limb amputation is the easiest and can probably avoid systemic sepsis, but it can make the patient destitute, disabled and depressed [7]. Hence, it was strongly rejected by the patient and his family in our case. Other methods of salvage, like vascularized fibula bone transplantation, Masquelet technique and massive cancellous autograft, are mainly to fill a bone defect with bone graft or artificial bony substitute. However, in our opinion they were not applicable in our case because: (a) no recipient vessels were available for anastomosis of nutrient vessels in a vascularized fibula bone transplantation; (b) blood supply was too poor for application of Masquelet technique, and refractory infection produced an unsuitable and unstable environment for formation of new induced-membrane; (c) bone defects were too massive to use cancellous autograft. Overall, all the aforementioned methods can only provide unreliable consolidation. Moreover, the doubtful vascularity in the grafted host bed indicated a high risk of bone nonunion.

Distraction osteogenesis might be a proper option for massive bone defects [8]. It leads to limited dissection and bone loss, promises a more reliable bony stability [9], and allows a desired correction because both the transport rhythm and direction can be adjusted as we want [10]. Although it has been reported in management of a massive forearm bone defect

Figure 3. Before the distracted humerus was consolidated, a multiple rotated clamp was used to bend humerus at ex-elbow site.

Figure 4. Bone union without any infection was achieved after distraction osteogenesis was finished.

[9], its application in treatment of loss of almost entire forearm bones, including the elbow joint, has not been reported. In our case, despite of poor blood supply in the right forearm, distraction osteogenesis was used to lengthen the humerus to replace the whole ulna and radius, and could provide more reliable stability and consolidation. Moreover, our intentional 40° in flexion at ex-elbow site was beneficial for its functional restoration.

Reconstruction of an upper-extremity is much more challenging because it is involved in performing more delicate and complicated functions than the simple weight-bearing function of a lower-extremity. On the contrary, resection of the forearm and hand imposes much inconvenience on patients in their daily life. Therefore, in our view, amputation should be the last option for management of mangled injury of upper-extremity. On the other hand, although some grading systems such as Mangled Extremity Severity Score (MESS) [11] proposed for early assessment of severely injured lower extremities have multiple drawbacks [12], they suggest that systemic and local injury characteristics like irreversible limb ischemia are of more importance for a decision of amputation in clinical practice [13]. Accordingly, in our case, the presence of hand sensation and radial artery indicated a possibility of salvage. More importantly, the patient's strong desire for salvage initially encouraged our attempt for salvage. At last, although significant functional limitation may exist after salvage surgery, deny-

Figure 5. MIR showed the biceps brachii (green arrow) was distracted as well as humerus.

ing amputation may promise possible functional improvements with advance of surgical techniques in the future.

Our treatment has some limitations. First, we regret returning the detached bones in our emergent surgery of debridement, because the bones which had been terribly contaminated, devitalized and lacking in soft tissue coverage were difficult to be thoroughly debrided, and thus could be a potential source of infection. Abandonment of such bones could have been beneficial for prevention of later formidable infection. Secondly, instead of monolateral external fixation it would have been better to choose circular frame for reconstruction, because its hinge rotation center could have helped the "new" forearm to obtain a better functional flexion angle at ex-elbow position. Thirdly, we should have cut the insertion of

Figure 6. The destructed hand extensor tendons were connected with distracting biceps brachii.

Figure 7. The basic forearm and hand function (including grasp function) of the patient was achieved at 2-year follow-up.

biceps brachii when humeral osteotomy was conducted, because it was distracted as well. However, since his hand extensor tendons had been lost in previous debridement, we might as well have compensated for it by the distracted biceps brachii.

Conclusion

A mangled extremity is difficult to treat, and reconstruction of a massive bone defect is of great importance to its overall management. This report highlights the effectiveness of distraction osteogenesis in the management of defects of the entire forearm bones caused by severe mangled injury, and the combination of radical debridement and effective reconstructive therapy could result in good clinical outcomes.

Disclosure of conflict of interest

None.

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