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Clinical effect of open reduction and internal fixation with a steel plate through the triceps approach in the treatment of fractures of the middle and lower 1/3 of the humerus

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Abstract. – OBJECTIVE: The stability of fractures of the middle and lower 1/3 of the displaced humeral shaft is poor, and surgery is currently the main treatment. The posterolateral approach to the upper arm has many advantages but it is not widely used in clinical applications. The aim of the study was to investigate the clinical effect of open reduction and internal fixation with a steel plate through the triceps approach in the treatment of fractures of the middle and lower 1/3 of the humerus.

PATIENTS AND METHODS: A retrospective analysis was performed on 26 patients with fractures of the middle and lower 1/3 of the humerus who were admitted to our hospital from January 2018 to December 2021. According to the AO ASIF classification, 12 patients had type A, 8 patients had type B, and 6 patients had type C fractures. The posterior transtriceps approach was used for open reduction and internal fixation with a steel plate to evaluate its clinical efficacy.

RESULTS: All patients were followed completely, and the follow-up time was 6.0-18.0 months. Fracture nonunion occurred in 1 patient after the operation, and the other 25 patients healed well; 2 patients showed symptoms of radial nerve injury and numbness in the tiger's mouth area, which improved after 2 weeks. The average healing time of the fracture was 12.3 weeks. There were no infections or complications such as plate fractures. Elbow joint function according to Mayo scoring standards was as follows: 19 cases were excellent, 3 cases were good, 2 cases were fair, and 2 cases were poor. The excellent and good rate was 84.6%.

CONCLUSIONS: Open reduction through the triceps approach and internal fixation with a steel plate for the treatment of the middle and lower 1/3 of the humerus can directly expose and protect the radial nerve and its branches and reduce radial nerve damage, and plate fixation on the tension side is biomechanical and worthy of clinical application.

Key Words:
Fracture of the middle and lower 1/3 of the humerus, Transtriceps approach, Plate internal fixation.

Introduction

Fractures of the middle and lower 1/3 of the humerus are clinically common fractures. Both direct and indirect trauma can lead to fractures. The fracture area of the middle and lower 1/3 of the humerus is an approximately flattened triangular pyramid in which the shape of the humeral shaft changes from a cylinder to a distal end. This morphological change leads to a relative concentration in the stress transmission process, which makes fracture of this part of the humerus prone to occur[1]. Fractures of the middle and lower 1/3 of the humerus are common in car accidents, falls from heights, and general falls. Fractures of the middle and lower 1/3 of the humerus can occur at all ages. According to statistics, humeral shaft fractures account for 1% of all fractures, and fractures of the middle and lower 1/3 of the humerus account for 16% of all humeral shaft fractures[2,3]. Because this part of the humerus is extremely unstable, the muscles

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tend to move significantly due to traction, and most of these types of fractures require surgical treatment.

Due to the different fracture sites of the humerus, there are also differences in treatment methods. The incidence of proximal humeral fractures and mid-humeral fractures is high. There are many related studies, and many treatment methods, including open reduction and internal fixation with a plate, axial fixation with intramedullary nails and external fixation with brackets, which can often achieve good results[4]. Compared with fractures of other parts of the humeral shaft, for fractures of the middle and lower third of the humeral shaft, there are obvious controversies in the choice of treatment, and the treatment difficulty is significantly higher for proximal humeral fractures and mid-humeral fractures. Fractures of the middle and lower 1/3 of the humerus, due to the particular anatomy, are similar in shape to a triangular pyramid: narrow proximally and wide distally, formed on three sides by the posterior humerus, with anteromedial and anterolateral sides, with final extension of the distal humerus, and with an inner and outer column structure[5]. At the same time, fractures of the middle and lower 1/3 of the humerus are located close to the elbow joint, and the close relationship with the radial nerve makes treatment highly difficult. To date, there is no consensus on the treatment for fractures of the middle and lower 1/3 of the humerus.

At present, conservative treatment, external fixation, and open reduction and internal fixation are commonly used for the treatment of fractures of the middle and lower 1/3 of the humerus. Conservative treatment often leads to the appearance of malunion of the fracture, stiffness in the elbow joint, and limited joint mobility. Because external fixation cannot obtain satisfactory fracture reduction, there will be complications with conservative treatment. Open reduction and internal fixation are the currently accepted methods for the treatment of fractures of the lower 1/3 of the humeral shaft. At present, mostly anterolateral approaches are used. After the radial nerve is dissected, internal fixation is performed. Regional anatomical specificity, irregular shape, mismatch of the plate and bone, and internal fixation affect the healing of fractures, and there is a risk of damage to the radial nerve[6,7]. The stability of the fracture during intramedullary nailing is poor, which limits early functional exercise in the affected limb. Minimally invasive internal fixation with an anterior approach and a plate has achieved satisfactory clinical results in the treatment of mid-humeral shaft fractures[8]. However, this treatment is not suitable for fractures of the middle and lower 1/3 of the humerus. It is difficult to ensure the reduction effect with indirect reduction of fractures of the distal 1/3 of the humerus. Minimally invasive incisions cannot determine the position of the radial nerve. The radial nerve is injured in the process.

The posterior side of the distal 1/3 of the humerus is covered by the triceps muscle, without important blood vessels and nerves, and thus is relatively safe. More importantly, the posterior area of the distal 1/3 of the humerus is relatively flat, which is conducive to the placement of internal fixation materials such as steel plates[9]. At the same time, these plates are placed on the posterior side of the humerus, which conforms to the principle of tension band fixation and is conducive to fracture healing. In view of this, in recent years, our department has tried to use a posterior transtriceps approach for open reduction and internal fixation with a steel plate for the treatment of fractures of the middle and lower 1/3 of the humerus, and we have achieved satisfactory clinical results. Through our summary of the treatment of fractures of the middle and lower 1/3 of the humerus via the triceps approach, we hope to provide a theoretical basis for a wide range of clinical applications.

Patients and Methods

General Information

From January 2018 to December 2021, 26 patients with fractures of the middle and distal 1/3 of the humeral shaft presented to our hospital. There were 16 males and 10 females, aged 18-62 years old, with an average age of 39.38±12.15 years old. The causes of injury were as follows: 13 cases of falls, 9 cases of traffic accidents, and 4 cases due to other reasons; there were also 6 patients with fractures in other parts of the humerus. The fractures were classified according to the AO/ASIF classification: 12 patients had type A fractures, 8 had type B, and 6 had type C; 3 patients had radial nerve injury before the operation. All patients underwent open reduction and internal fixation with a posterior transtriceps approach. The inclusion criteria included the following: (1) age ≥18 years, (2) closed fractures or grade I or II open fractures, and (3) requiring early activities.

The exclusion criteria included the following: pathological fractures, grade III open fractures, and patients with secondary operations.

Surgical Methods

All patients underwent brachial plexus anesthesia; while lying on the contralateral side, a support frame was placed under the elbow of the affected limb. The forearm was in a naturally drooping position, and the deep fascia was cut at the line connecting the posterior edge of the acromion and the olecranon to reveal the three heads. At the proximal end, the long head and lateral head of the triceps brachii were separated, and at the distal end, the triceps muscle belly and tendon transition were used as the base point to incise the aponeurosis. The radial nerve is generally located at the proximal part of the base point at a length of approximately 2 transverse fingers from the bone surface. Whether to expose the radial nerve was decided according to the location of the fracture. If the location of the fracture was distal, the radial nerve was not exposed, and the end of the fracture was directly reset; if the location of the fracture was proximal, the radial nerve needed to be exposed. After the radial nerve was separated, it was retracted slightly to increase the space for fixing the steel plate and screws. For type A or type B fractures, a titanium alloy dynamic compression plate was placed on the posterior side of the humerus for fixation. For type C fractures and osteoporotic fractures, a locking plate was used for fixation. The front and side fluoroscopy views confirmed that the fracture was well aligned and internally fixed. The object position was normal. For patients with bone defects, bone grafts were routinely performed, and drainage sheets were routinely placed.

Postoperative Treatment

Depending on the drainage situation, the drainage tube was removed 1-2 days after surgery to avoid hematoma formation. After the drainage tube was removed, upper-limb exercises were carried out to stimulate the elbow joint, but weight bearing was avoided. Daily activities and light physical labor could be carried out after surgery. The sutures were removed two weeks later, and X-rays were taken in the outpatient clinic every four weeks after the operation until the fracture had healed completely. After the fracture healed, the range of motion of elbow joint flexion and extension was measured, and elbow joint function was scored by Mayo. For patients with preoperative radial nerve injury, the recovery of the radial nerve was evaluated at the follow-up visit.

Clinical Evaluation

The elbow joint function of all patients was evaluated according to the Mayo standard. The Mayo elbow joint function score was used to compare the rehabilitation effect after treatment. The total evaluation score was 100 points: daily function accounted for 25 points, joint stability accounted for 10 points, motor function accounted for 20 points, and pain accounted for 45 points.

Statistical Analysis

Data were processed by SPSS 20.0 statistical software (IBM Corp., Armonk, NY, USA). Measurement data conforming to the normal distribution were expressed as the mean ± standard deviation ($\bar{x} \pm s$) and used two independent-samples t tests. Differences were statistically significant at $p < 0.05$.

Results

Figure 1 shows the 3D printing model before operation, which can clearly see the outline of fractures of the middle and distal 1/3 of the humeral shaft, which is very helpful for our intraoperative fracture reduction.

All patients were followed completely, and the follow-up time was 6.0-18.0 months. The fracture healing time was 8.0-16.0 weeks, with an average

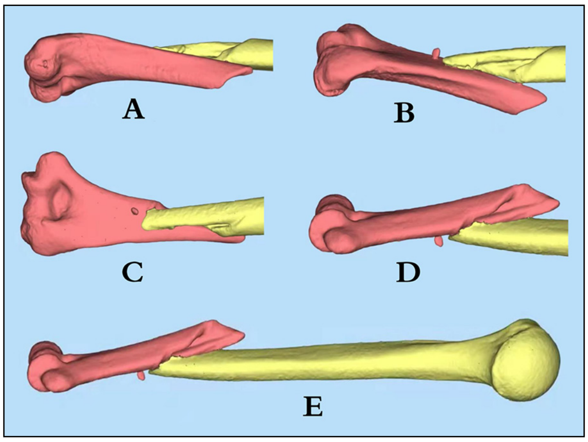

Figure 1. Preoperative 3D printing model of fractures of the middle and distal 1/3 of the humeral shaft. **A-D** and **E** represent fracture characteristics observed in different directions respectively.

of 12.3 weeks. Fracture nonunion occurred in 1 patient after the operation, and the other 25 patients healed well; 2 patients showed symptoms of radial nerve injury and numbness in the tiger's mouth area, which improved after 2 weeks. There were no infections, plate fractures or other complications.

Elbow joint function results according to the Mayo scoring standard were as follows: 19 cases were excellent, 3 cases were good, 2 cases were fair, and 2 cases were poor. The excellent and good rate was 84.6% (typical cases are shown in Figure 2).

Discussion

Fractures of the middle and lower 1/3 of the humerus are a common and characteristic fracture type in clinical practice. The choice of treatment is controversial for these types of fractures, and their injury mechanism lacks biomechanical demonstration and a specialized fracture classification[10]. There are many reports of surgical treatment, but there is a lack of recognized optimal surgical methods. Surgical treatment can restore the patient's function early and can significantly reduce the appearance of limb deformities and joint stiffness, but there are also several limitations, including fixation of the distal bone block, intraoperative treatment of the radial nerve and surgical trauma[11].

The traditional treatment for fractures of the middle and lower 1/3 of the humerus mainly uses an anterior lateral incision. The incision is performed in a supine position and is more comfortable. The disadvantage of this incision is that it requires routine exposure of the radial nerve and maintenance reduction and internal fixation during the operation, which are difficult. At the same time, the radial nerve has a small range of motion at this site. The traction of the radial nerve during the intraoperative reduction of these fractures is likely to cause iatrogenic injury, and when the distal end of the fracture is exposed, the anteromedial subperiosteal artery must be stripped from the middle and inferior 1/3 of the humerus. Thus, the blood supply of the distal humerus is destroye[12,13]. In addition, due to the particular anatomy, the anterolateral bone surface of the middle and lower 1/3 of the humerus is shaped like a twisted rectangle, the bone plate does not easily fit the bone surface, and fracture fixation is not strong, which likely cause fracture nonunion[14].

In this study, to overcome the shortcomings of anterolateral incision fixation and reduction for fractures, we used open reduction via the posterior transtriceps approach and internal fix-

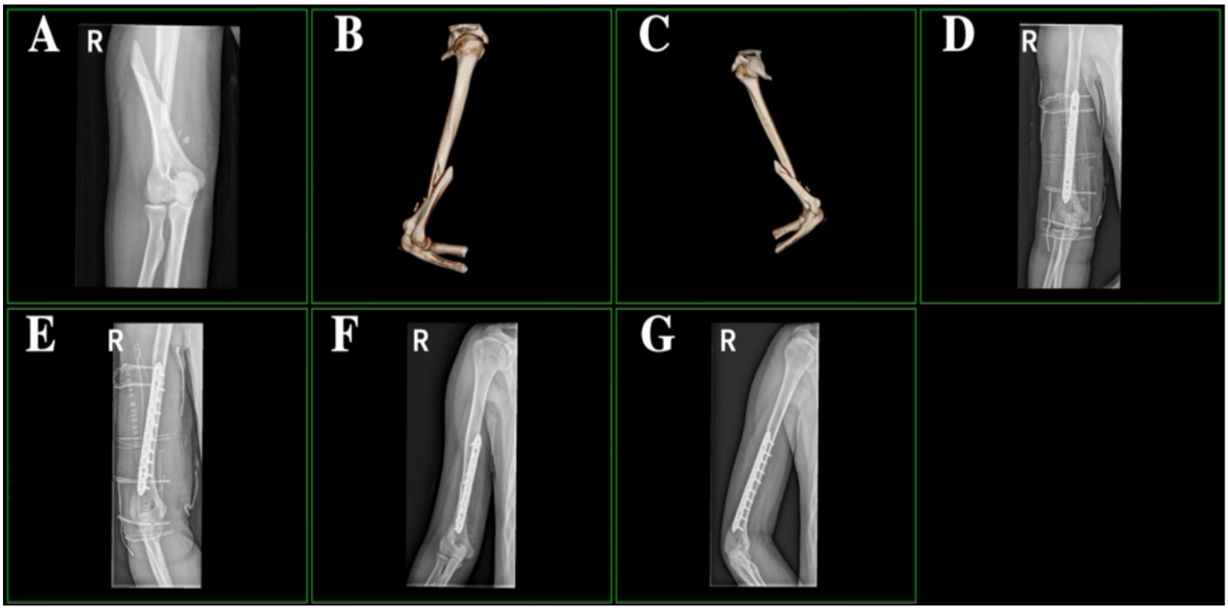

Figure 2. A 28-year-old male patient suffered a fracture of the middle and distal right humerus caused by a traffic injury. **A,** preoperative X-ray; **B,** and **C,** preoperative CT + three-dimensional reconstruction; **D,** and **E,** 1 day postoperatively and lateral view; **F,** and **G,** 8-month postoperative X-ray, indicating good fracture healing. No loosening or breakage due to internal fixation.

ation with a steel plate to treat fractures of the middle and lower 1/3 of the humerus. During the operation, the patients were positioned lying on their side or prone. A stent was placed under the elbow joint, the fractured end was easily exposed due to the natural drooping of the forearm, and the main radial nerve and its branches as well as the accompanying blood vessels were directly exposed through the posterior surgical approach. First, the radial nerve and its branches were protected before proceeding with fracture reduction, and reduction of the fracture was easy to maintain and was not easily moved again. The main nourishing blood vessels of the humeral shaft are distributed in the lower 1/3 of the humerus or anteromedial to the midpoint of the bone. The posterior approach does not require excessive anteromedial peeling of the periosteum. To reduce the possibility of damage to the nourishing blood vessels, only a limited part of the posterior periosteum of the humerus is stripped when the distal end of the fracture is exposed. The distal end is fixed with smaller tipped reduction forceps to reduce damage to the anterior medial periosteum. The posterior humerus is flat and wide, suitable for each of the various types of steel plates that can be placed, and it does not need to be shaped to reduce the shear stress of the steel plate during the fixation process. In the process of plate fixation, the upper and lower radial nerves are far away from the direction of screw fixation, and the radial nerve is retracted to both sides. Thus, the operation can be performed directly. In fact, the posterior approach was first reported by Alonso-Llames in 1972 for the management of pediatric supracondylarfractures[15], and it has gradually been recognized by scholars in recent years. Wilairatana et al[16] treated humeral shaft fractures with plates and screws through the posterior median approach. The results were satisfactory, and there were few radial nerve injury complications. They believed that the posterior median approach was a feasible surgical technique for the treatment of humeral shaft fractures.

Intraoperative separation and exposure of the radial nerve is the focus of surgery. The radial nerve is located in the upper arm between the long head and the lateral head of the triceps; it descends posteriorly on the humeral shaft and then obliquely outwards in the radial groove between the medial and lateral heads of the triceps, passing through the lateral muscle compartment and into the osteofascial compartment of the anterior arm. The radial nerve has no other important branches in the radial nerve sulcus except for the lateral cranial branch in the upper part of the radial nerve sulcus. In this study, whether to expose the radial nerve was decided according to the location of the fracture, the distal end of the fracture was entered, the triceps brachii muscle was directly split without exposing the radial nerve, and the fracture end was directly reduced; if the fracture location was proximal, it was necessary to expose the radial nerve. According to our clinical experience, we chose a length 2 transverse fingers proximal to the triceps muscle belly and tendon transition as the radial nerve sign. After separating the radial nerve, it was retracted upward to increase the space for plate and screw fixation. In addition, for patients with radial nerve injury, the radial nerve was explored from the normal position, and patients with nerve contusion were not treated with special treatment. Partial and complete ruptures were performed with epineurium anastomosis.

We used open reduction via a posterior trans-triceps approach and internal fixation with a steel plate to treat fractures of the middle and lower 1/3 of the humerus in the study. The surgical field was fully exposed. The triceps was incised longitudinally on the posterior side. The humeral shaft could be exposed, the anatomical relationship was simple, subperiosteal stripping was easy to perform on both sides, and the upper and lower ends of the fracture were fully exposed. During the operation, the medial head of the triceps was separated sharply or bluntly from the distal end to the proximal end. It was easy to expose the free radial nerve, and the surgical field was clear. The radial nerve was retracted from the fracture end to the anterior side of the humeral shaft, reducing the interference and tension of the nerve during the operation and avoiding the stimulation of foreign body during internal fixation, which effectively reduced the iatrogenicity of the radial nerve. In addition, during this approach, the patient was in a prone or lateral position, using the gravity of the affected limb to easily reduce the fracture. Therefore, we believe that open reduction via the triceps approach and internal fixation with a steel plate for the treatment of middle humeral fractures can directly expose and protect the radial nerve and its branches, reduce radial nerve damage, and fix the plate on the tension side in line with biomechanical and benefits to fracture healing, resulting in few complications and satisfactory results.

In this study, we investigated the clinical effect of open reduction and internal fixation with a steel plate through the triceps approach in the treatment of fractures of the middle and lower 1/3 of the humerus, but there are still some shortcomings. The number of patients in this study is limited, and we have not compared with the conventional surgical approach. Therefore, the follow-up study needs to further increase the number of patients and conduct a comparative study with the conventional surgical approach to make our study more convincing.

Conclusions

In short, for the surgical treatment of fractures of the middle and lower 1/3 of the humerus, internal fixation with steel plates should still be the first choice. If the posterior median approach is adopted, the surgical field is clear, the anatomy of the radial nerve is satisfactory, and pre-transposition of the radial nerve is simple and fast. In contrast, this approach can simplify the operation, reduce the operation time and surgical trauma, and further reduce the complications due to intraoperative radial nerve injury. Internal fixation conforms to the principle of a tension band does not interfere with fracture healing and is conducive to internal fixation of fractures.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Ethics Approval

The study was conducted in accordance with the Declaration of Helsinki and its protocol was approved by the Ethics Committees of Guizhou Provincial People's Hospital.

Informed Consent

All qualified patients and/or their legal guardian signed written informed consent for participation in this study.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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