Treatment of nonunions of humeral fractures with interlocking intramedullary nailing

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Objective: To introduce the experience of treating nonunions of humeral fractures with interlocking intramedullary nailing.

Methods: Twelve patients with humeral nonunions were treated with interlocking intramedullary nailing. The time interval between trauma and surgery was 10.5 months on average. Open reduction with anterograde approach was performed. Axial compression was specially applied to the fracture site with humeral nail holder after insertion of distal locked screws. Iliac bone grafting was added.

Results: The average follow-up period was 21 months (ranging 9-51 months). All patients achieved osseous union 5.8 months after treatment on average. Eleven patients had good functions of the shoulder joints and the upper extremities. No patient experienced any permanent neurological deficit. Refracture of the original ununited region occurred in one patient after removal of the internal fixator one year later, but union was achieved after closed re-intramedullary nailing fixation.

Conclusion: Humeral interlocking intramedullary nailing is an effective alternative treatment for humeral nonunion.

Key words: ***Humerus; Fractures, ununited; Fracture fixation, intramedullary***

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Humeral fractures comprise 5%-8% of all fractures.[1] Nonunions are uncommon, and it was reported to be less than 10% [2] or 13% [3] of all humeral fractures. But when they do occur, they present a challenge to orthopedic surgeons and often debilitate patients. Nonunions of fractured humerus often need operative treatment.

Many methods of treating these nonunions, including internal fixation, have been described with various degrees of success.[4-6] Even the method with semiconstrained elbow replacement for distal humeral nonunion has been reported.[7] Conventional compression plates are the most frequently-used internal fixators until now for their high healing rate and good functional recovery.[8] Locking compression plates have been reported recently in treating osteoporotic nonunions of humerus,[9] but reports using interlocking intramedullary nailing to treat nonunions of fractured humerus are scant. The purpose of this study is to report our experience of treating nonunions of fractured humerus with interlocking intramedullary nailing.

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METHODS

Patients

In this study, nonunions were diagnosed according to the following features described by Brashear:[10] (1) bony callus being hardly observed around the fragments; (2) an almost radiolucent band persisting across the mass at the level of the original fractures;and (3) the roentgenograms demonstrating lack of progress in fracture healing.

Twelve patients (8 males and 4 females, aged 25-68 years, mean=34.75 years) with humeral nonunions after fractures underwent interlocking intramedullary nailing from January 1999 to July 2002 in our hospital. Seven patients were injured by road traffic accidents, 3 by falls from a height, 1 by a gun shot with an open wound, and 1 by a machine with a crashed upper limb. The fractures of 3 patients with humeral nonunions were located in the proximal one-third of the humerus, 8 in the middle one-third, and 1 in the distal one-third. There were 9 hypertrophic nonunions and 3 atrophic nonunions. Six patients were combined with complete or partial radial nerve injuries. Twelve patients underwent 14 open reductions: 1 with external fixation and 11 with plate

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fixation. Two patients received a second operation. The time interval from trauma to surgery for nonunions was 10.5 months on average (ranging from 5 to 33 months).

Internal fixation

The humeral interlocking intramedullary nail used in the study was named as Austofix (Austofix Group Co. Ltd, Australia), which was made of stainless steel (ISO 5832 pt.9), with a 5-degree curvature at 5 cm from the threaded end. The nail had a diameter of either 7 or 8 mm. There were three screws with different directions at the threaded end and two parallelled transverse screws at the other end. The specially-designed proximal humeral head screws had an outer diameter of 4.3 mm, with threads passing through them to prevent backout of the nails from the humeral head. The distal locked screws were conventional semi-threaded screws, with an outer diameter of 4 mm. The nail had been used successfully in the treatment of humeral shaft fractures.[11]

Operative procedures

The patients lay on a supine position and brachial plexus anesthesia was employed. Open reduction with middle to proximal lateral incisions on the humerus was performed. During the operation, the radial nerves were exposed and protected. In the 6 patients with radial nerve injuries, the radial nerves were found to adhere to the surrounding scars and neurolysis was performed. The fragments of the nonunions had obvious abnormal movement and were filled with fibrous scar tissues.

Humeral interlocking nails were inserted through the anterograde approach. The supraspinatus tendon was incised for approximately 1 cm in length and carefully protected during operation. The endosteum was reamed sequentially for approximately 1 cm larger than that the nails could be inserted. The nails were manually inserted deeper than the humeral head. The threaded end should be 1.5-2 cm beneath the greater tuberosity, otherwise it would affect the abduction function of the shoulder. The other ends of the nails should be 1-2 cm above the olecranon fossa. After nail insertion, the distal screws were locked first, then axial compression of the fragments was accomplished through extracting the nails to the proximal direction using a nail holder. Then the proximal screws were locked. Iliac bone grafting was performed between and surrounding the fragments.

Postoperative management and follow-up

The wounded arm was supported in a neck sling for about 1 week after surgery. Tolerable motion exercise was encouraged as early as possible. The degree of exercise and the activity of the operated arm were increased gradually. The patients were permitted to use the arm for daily life and light work in the short term after operation. They were permitted to do heavy work until the callus between the fragments was solid. After removal of the suture, clinical and radiological evaluations were made on the patients every 1 month during the first 2 months, every 2 months thereafter. The status of fracture healing and progress of recovery were recorded.

RESULTS

The average operation time was 2.2 hours (ranging 1.9-4 hours). All the patients were followed up for 9-51 months (21 months on average). They achieved eventual union with a mean time of 5.8 months (ranging 3.5-8 months).

There were no cases of wound infection or ectopic ossification. No patient experienced any permanent neurological deficit of axillary nerve or radial nerve injuries. The functions of the radial nerve in the 6 injured patients were all recovered.

The patient with refracture was a young and active gentleman. The refracture occurred at the original ununited site when he was playing table tennis one year after removal of the interlocking intramedullary nails. Closed humeral interlocking intramedullary nailing was performed and osseous union achieved 6 months after operation.

The shoulder and elbow functions were good in 11 cases. The abduction function of the shoulder was limited with pain in the remaining patient because of excessive length of the end of the nails left above the entrance. The abduction range of the motion was 90°. The shoulder function recovered after removal of the nails (Figs. 1 and 2).

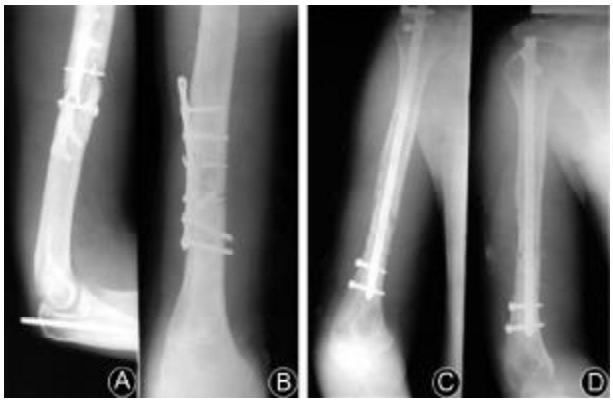

Fig. 1. A, B: Nonunion of right humeral fracture after plating fixation. **C, D:** X-ray examination after iliac bone grafting and humeral interlocking intramedullary nailing.

Fig. 2. A, B: Osseous union in 6 months after operation. **C, D:** X-ray examination after removal of intramedullary nails.

DISCUSSION

Analysis of etiology of humeral nonunions

Contributing factors Various contributing factors of humeral nonunions have been reported. Some of the predisposing factors include mid-shaft fractures, transverse or short oblique fractures, primary open reduction, unstable surgical fixation, osteoporosis, infections, open fractures, obesity, and alcoholism. [3, 12, 13]

In this series, there were 9 hypertrophic types but just 3 atrophic types of nonunions. The reasons for nonunions may be invalid internal fixation of the fragments or invalid stabilization after operation of the humerus. Thus micromovement persisted in the fragments and the bony callus was absorbed and nonunions occurred. Baba and Razak[12] reported that 23 nonunions (10.5%) occurred in 218 fractures of the humeral shaft. Factors such as comminuted opened fractures in the middle one-third of the humerus, soft tissue interposition, improper immobilization and poor patient compliance were found to be directly associated with the nonunions.

Microstructure of humeral nonunions A commonly-accepted view regards that the fragments of most nonunions are fibrous and/or fibrocartilagious calluses.[14] In this series, all the fragments of nonunions had obvious abnormal movement and were filled with fibrous scaring tissues under naked eyes. However, it may be different tissues in microstructure. The microstructure of human shaft nonunions was investigated by Wen et al.[15] by using scanning electron microscopy, transmission electron microscopy and X-ray microdiffraction. It was noted that the microstructure of human humeral nonunions was not so simple. They found that nonunion had a trabecular structural framework similar to woven bones. Cavities in the trabeculae were subdivided into small chambers by thin plates of collagen fibrils. Noncrystalline calcium phosphate deposition and insufficient mineralization of the collagen fibrils may be two important microstructural features of the nonunions of human humeral shaft fractures. These may be caused by complex pathological agents due to invalid fixation and micromovement of the fragments.

Fixation methods for humeral nonunions

Compression plating fixation Compression plating fixation has the advantages of high union rate and good functional recovery. But for humeral fractures or nonunions, it is recommended that long and broad steel plates of 4.5 mm in thickness should be used by Arbeitsge-meinscheft for Osteosyntheses Fragen/Association for the Study of International Fixation (AO/ASIF) group. For nonunions with osteoporosis, 10- or 11-hole plates with five or more screws proximal or distal to the nonunions are recommended.[16] Even though locking compression plates and screws may fix the bone with osteoporosis and have been reported in treating humeral nonunions with osteoporosis,[9] this still requires a very long skin incision and extensive soft-tissue stripping that may interfere with fracture healing[16, 17] and it also has the risk of radial nerve injury. The incidence of radial nerve palsy after compression plating is approximately 10%.[18] When removing the internal fixators after bone union, the risk of radial nerve injury with severely-scarred soft tissues around the nerve is even higher.[19]

Interlocking intramedullary nailing Interlocking intramedullary nails have the advantages over steel plates of fewer tissue traumas, fewer circulatory impair-

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ments and lower risk of radial nerve injury when removing the nails. They have been widely used in acute humeral fractures, pathologic fractures and nonunions.[8, 11, 20, 22] Austofix humeral nails had been successfully used by Ingman and Waters[11] in treating humeral shaft fractures and its use will not be limited by the type of nonunions or the part of nonunions. Distal one-third nonunions can be treated with retrograde approach.[8] Also the thickness of medullary canal does not affect the use of intramedullary nails. Bajaj et al.[18] successfully used intramedullary supracondylar femoral nails (Smith & Nephew Richards, Memphis, TN) to treat 7 cases of nonunions of humeral shaft with a wide medullary canal. All the nailings were performed with anterograde approach with static locking. Osseous union was achieved in all the 7 cases 5.6 months after operation on average. Limbers et al.[23] treated 8 patients with Huckstep nail fixation for humeral shaft nonunion. Union was achieved in 7 out of the 8 patients (87.5%). Four patients had occasional mild pain after union. All the patients achieved good arm function. No patient experienced any permanent neurological deficit. Lin et al.[8] treated 41 patients with 13 delayed unions and 28 nonunions with humeral locked nails. All but two patients achieved osseous union (94.1%). During the follow-up period for the patients with anterograde nailing, all but four patients had less than 20° of limitation of shoulder abduction.

Comparison between steel plates and intramedullary nails In comparison of steel plates and intramedullary nails, Wu and Shih[25] reported the results of a nonrandomized study in which 19 patients with humeral shaft nonunion treated with plating and bone grafting and 16 patients with humeral shaft nonunion treated with anterograde nailing (Seidel nail, Howmedica, Kiel, Germany) and bone grafting. They reported that essentially no difference existed between plating and nailing for nonunions (88%-90%) or for union in time (4.4-4.5 months). The complications of iatrogenic nerve injury and a new fracture occurred in 5% of patients with plating, respectively, but neither was reported with Seidel nailing. Their conclusion was that plating and intramedullary nailing were equivalent methods for treatment of nonunions, but they favored the latter.

External fixation External fixation has been used to treat nonunions of the diaphysis. Pullen et al.[24] reported that 4 patients with post-traumatic nonunion and shortening of the humeral diaphysis were treated with a hybrid advanced Ilizarov technique and all the patients obtained union of the humeral fracture with resolution of infection at a mean external fixation time of 8 months. All had improvement in shoulder and elbow motion after treatment. Superficial pin tract infections were obtained in all the patients. Two patients had three refractures after removal of the fixators, two of which were treated by a second application of an Ilizarov frame and one by a plaster cast.

Patel et al.[22] used Ilizarov external fixator to treat 16 patients. Ten of these patients received intramedullary nailing previously and the fixator was placed on the nail to compress the fracture site. One patient failed to achieve healing, who suffered from a severely comminuted open fracture and treated with internal fixation.

In this series, intramedullary nailing was performed with anterograde approach. All the patients achieved osseous union. Shoulder abduction function was limited in one patient because the threaded end of the nail was left too much above the entrance. This should be avoided during operation by using C-arm fluoroscopy. Another patient had refracture when he played table tennis powerfully after removal of the intramedullary nails. This complication had been reported very few in literature. The reason for this complication might be earlier removal of the hardware and vigorous exercise work.

Operative techniques

Basic operative techniques Besides suitable fixation methods, operative techniques are important in the treatment of humeral nonunions. These techniques include the management of the broken ends, soft tissue protection, bone grafting and axial compression of the broken ends. The scar tissues between the broken ends should be debrided, the closed medullary canal should be opened, and unnecessary stripping of the periosteum should be avoided.

Axial compression of the broken ends should be emphasized. This technique was reported by Lin et al.[8] in 2000. Two methods were reported to apply compression to the fractured fragments: the direct application of compression force to both ends of the humerus and the backstrike technique when the smooth end is locked first. In our opinion, the latter is more reliable and effec-

tive and so preferred.

Bone grafting The quality of bone grafting exerts a great influence on the prognosis. The bone grafting quantity should be sufficient. Iliac bone is trimmed to match-like rods and grafted between and around the fractured fragments. The indications for bone grafting have been a controversial issue in treating nonunions.[26] It has been recommended for treating fractures with atrophic nonunions.[16, 27] Healy et al.[27] indicated that concurrent bone grafting is associated with a more reliable healing progress and iliac bone grafting is a safe and easy procedure. We agreed with Healy et al's point and recommended bone grafting as a routine in treating humeral nonunions. All the patients had no complications relating to iliac bone grafting.

Bone stimulators There is little literature supporting the use of bone stimulators when treating humeral nonunions. Volgas et al.[1] described their treatment protocol of treating humeral nonunions with bone stimulators. They thought that bone stimulators certainly should not be used when poor technique has resulted in the nonunion. Dimitriou et al.[4] reported their experiences in using recombinant bone morphogenetic protein 7 (rhBMP-7 or OP-1) as a bone-stimulating agent in the treatment of persistent fracture nonunions. Twenty-five consecutive patients with 26 fracture nonunions (three humeruses) were treated with rhBMP-7. Both clinical and radiological union occurred in 24 cases (92.3%, including the three humeral nonunions). Bone stimulators may contribute to the good outcomes on the basis of good surgical techniques.

In conclusion, humeral interlocking intramedullary nailing is an effective alternative treatment for humeral nonunions, bone grafting is recommended to ensure the union, and certain operative techniques are important for the prognosis.

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