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ORIGINAL STUDY

Anterolateral acromial approach in locking plate fixation of proximal humerus fractures in elderly patients

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We describe our experience with a two-incision anterolateral acromial approach in locking plate fixation of proximal humeral fractures in older adults. Mean time between injury and surgery was 3.08 ± 1.24 days. A proximal anterolateral transverse incision and a more distal longitudinal incision were used. A locking plate was inserted along the lateral side of the humerus from the proximal incision to the distal fragment of the humerus. Mean operation time was 62.37 ± 19.05 minutes. There were no instances of axillary nerve paralysis or infection. Postoperative imaging results were satisfactory in all cases. Three obese patients experienced fat liquefaction at the incision site. Mean total Neer score one year after surgery was 88.16 ± 5.05. We conclude that the two-incision anterolateral acromial approach with use of locking plates appears to be an effective means to treat proximal humeral fractures in older adults.

Keywords : minimally invasive ; proximal humerus fracture ; locked plate ; axillary nerve.

INTRODUCTION

Proximal humerus fractures are common, particularly in the elderly (*9*) ; they account for approximately 5% of all fractures (*7*). The frequency of these fractures appears to be increasing as the proportion of older adults increases (*10*). Their treatment may be challenging and must be considered on a case-by-case basis. Open reduction and internal fixation is the treatment of choice for complex fractures to maximize functional recovery (*7,15*). The optimal surgical approach is yet to be determined. Poor bone quality and an impaired capacity to heal may complicate fracture repair in older adults (*14*).

A deltopectoral approach is typically used for internal fixation with locking plates of complex proximal humerus fractures. Unfortunately, this approach is associated with extensive exposure and may result in soft tissue injury, impaired blood supply to the proximal humerus, and ultimately avascular necrosis of the humeral head (*3,4*). Furthermore there is evidence to suggest that older adults have poorer outcomes than younger adults after treatment of proximal humerus fracture via this approach (*5*). A number of minimally invasive approaches have been described recently (*1,2,4,11-13*). Minimally

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invasive approaches aim to bypass the need for extensive surgical exposure, hasten postoperative functional recovery, and reduce postoperative complications. One such approach used by Gardner *et al* (*1-3*) and Röderer *et al* (*12*) combines an anterolateral acromial approach with localization and protection of the axillary nerve. Over the last 4 years, we have successfully used a similar, but modified approach for the treatment of proximal humerus fractures in older adults. We describe this surgical approach which utilizes a transverse anterolateral subacromial incision and a short longitudinal distal incision. The outcomes are reported of 78 older adults who were followed-up for an average of two years.

PATIENTS AND METHODS

This was a retrospective study of older adults with proximal humerus fractures who underwent reduction and fixation with locking plates via an anterolateral subacromial approach using transverse and longitudinal incisions between January 2007 and February 2010. This study was approved by the Institutional Review Board of Shanghai East Hospital.

A total of 78 patients (43 men, 35 women) with proximal humerus fractures who met the surgical criteria and received locking plate fixation via a two-incision anterolateral acromial approach were included. The mean age of the patients was 61.0 ± 13.5 years. Medical histories included hypertension (18/78 ; 23.1%), osteoporosis (18/78 ; 23.1%), diabetes mellitus (10/78 ; 12.8%), and heart disease (6/78 ; 7.7%). The patients' fracture characteristics are summarized in Table I. Slightly over 50% of patients had right proximal humerus fractures. The most common (≥ 96%) causes of fracture were car accidents and falls. The majority (≥ 84%) of patients had AO type A2, A3, B1, or B2 fractures, none of which were open fractures. Patients with AO type C1 and C2 fractures were treated with shoulder replacement surgery rather than open reduction and internal fixation if computed tomography imaging suggested that the bone mass within the humeral head was insufficient to maintain the articular surface of the humeral head and allow for adequate screw fixation. Patients with glenohumeral fracture-dislocation (AO type B3 and C3) were not eligible for treatment with this approach. Preoperative axillary nerve injury was also considered a contraindication. The average time from injury to surgery was approximately 3 days (range : 1 to 7 days). The mean duration of surgery was slightly over 60 minutes (range : 30 to 110 minutes), and the mean length of follow-up was 2 years (range : 1.5 to 4 years).

Table I. — Summary of fracture characteristics (n° 78)

Side	
Left	35 (45%)
Right	43 (55%)
Cause of fracture	
Traffic accident	35 (45%)
Fall	43 (55%)
AO classification	
A2	10 (13%)
A3	19 (24.5%)
B1	15 (19%)
B2	22 (28%)
C1	7 (9%)
C2	5 (6.5%)
Open fractures	0
Time between injury and surgery (days)	3.08 ± 1.24 SD
Operation time (min)	62.37 ± 19.05 SD
Length of hospitalization (days)	8.76 ± 3.16 SD
Complications (number)	3 (4%)

SD = standard deviation.

The following surgery-related variables were recorded for all patients : time interval between injury and surgery, operation time, length of hospitalization, complications, and Neer score (*8*) one year after surgery. The Neer score assesses pain, function, range of motion, and anatomy on a 100 unit scale. A score > 89 indicates excellent recovery, 88 to 80 indicates satisfactory recovery, 79 to 70 indicates unsatisfactory recovery, and < 70 indicates failure.

All operations were performed by one of four general orthopaedic surgeons with 9, 14, 20, and 22 years of surgical experience, respectively.

Surgical Technique

General or interscalene block (for patients with pulmonary insufficiency) anaesthesia was used. The patient was positioned supine on a radiolucent operating table. The acromion, coracoid, and proximal humerus were marked, and the level of the transverse incision was marked on the skin under fluoroscopy guided by a K-wire on the skin perpendicular to the proximal humerus

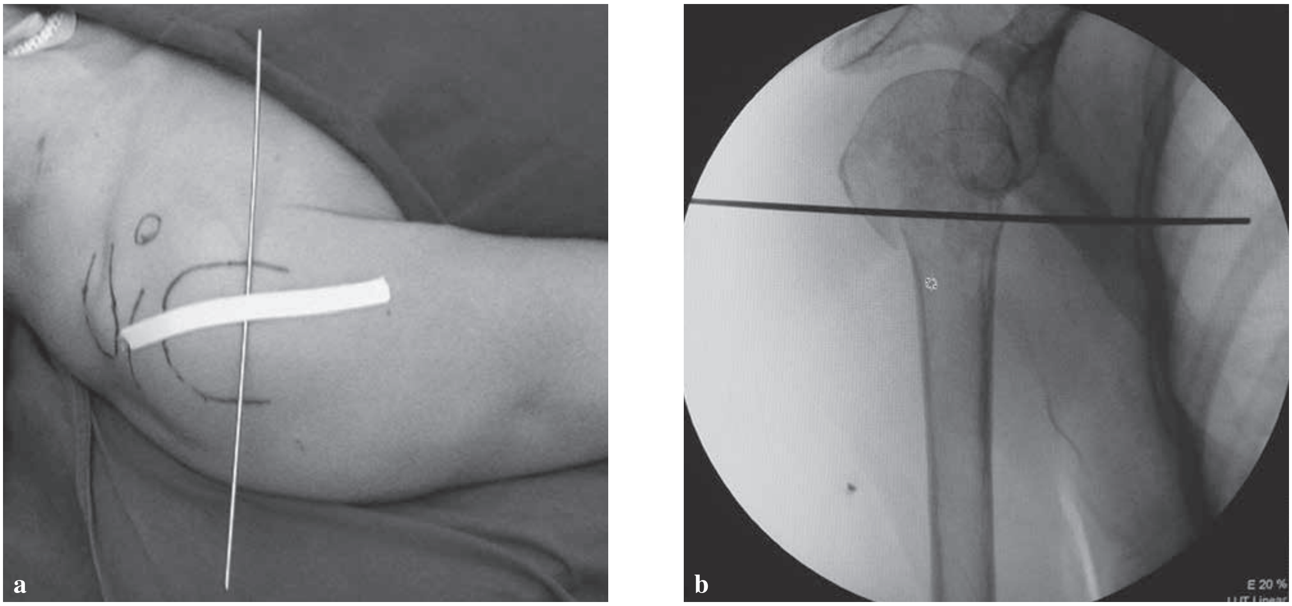

Fig. 1. — (a) The acromion, coracoid, and proximal humerus are marked before surgery and a K-wire is placed on the skin over the fracture line, perpendicular to the axis of the humerus.
(b) The height of the incision is determined under fluoroscopic guidance by moving the K-wire on the skin and the incision is typically made approximately 1.5 cm distal to the greater tuberosity of the humerus.

(Fig. 1). A vertical line was marked along the anteroposterior projection of the humerus for dissection of the deltoid muscle (Fig. 2). Skin and subcutaneous tissue were incised along the marked proximal transverse line over 3 to 4 cm (longer for larger patients if necessary), and the fascia of the deltoid muscle was incised vertically, parallel to the external vertical marked line. Blunt dissection was carried out between the anterior and middle portion of the deltoid to expose the greater tuberosity. Further blunt dissection was performed with the index finger along the proximal humerus and the joint capsule anterior and posterior to the humeral head. If subluxation of the humeral head was present, it was reduced by levering with a finger, followed by fracture reduction. The axillary nerve could be palpated at the distal portion of the incision deep within the deltoid muscle (3.5 cm from the apex of the greater tuberosity). The extended anterolateral acromial approach allows minimally invasive access to the proximal humerus (*3*). Soft tissue deep to the axillary nerve was pushed away to elevate (approximately 1 cm) the axillary nerve from the bone to facilitate plate insertion. For fractures located close to the axillary nerve (i.e. AO type A and B), the axillary nerve was typically dissected and isolated to ensure protection. The location of the distal incision was determined according to plate length.

For AO type A fractures, anatomical reduction was achieved by rotation and traction on the arm. In type B1 and B2 fractures, the bone fragment was usually displaced by traction of the rotator cuff. The main bone fragment was palpated and exposed using the index finger. The space remaining after reduction of the humeral head allowed the avulsed large bone fragment to return to the original anatomic position for temporary fixation with percutaneous or direct K-wires. Reduction of the proximal humerus and humeral shaft was achieved by alignment with the sulcus bicipitalis. If the sulcus was crushed, the biceps tendon was used as the anatomic reference during reduction. If the humeral shaft was displaced medially, a fist was placed in the axilla and humeral shaft adduction helped to obtain satisfactory fracture reduction.

A locking plate (PHILOS or LPHP) of appropriate length was inserted from the proximal incision to the distal portion of the fracture along the lateral aspect of the humerus. When inserting the plate, the isolated axillary nerve was lifted with the index finger through the proximal incision to ensure that it was located superficial to the plate. The plate was positioned posterior to the sulcus intertubercularis (or biceps tendon). The anterior edge of the plate was placed as close as possible to the biceps tendon (without compressing the tendon), such that the

Fig. 2. — The horizontal line indicates the place for the transverse incision, whereas the vertical line indicates the place fo the longitudinal incision and longitudinal dissection of the deltoid muscle.

screws were located at the center in the lateral view. The proximal end of the plate was positioned approximately 5 mm inferior to the apex of the greater tuberosity. The distal second hole of the plate was marked on the skin and taken as the center of a 2 cm longitudinal incision. Soft tissue dissection was carried out and the distal portion of the plate was centered on the humeral shaft. The distal second hole was fixed with an interlocking guide device. Two K-wires were inserted through the incision at the distal and proximal ends of the plate for temporary fixation. The height and anteroposterior location of the plate was adjusted under fluoroscopic guidance. Finally, 4 to 6 screws were inserted into the proximal portion of the plate, and 2 to 3 screws were inserted into the distal portion of the plate (Fig. 3). Suction drains were placed before wound closure (Fig. 4).

RESULTS

There were no instances of iatrogenic axillary nerve paralysis or infection. Postoperative imaging (posterior-anterior radiograph) results were satisfactory in all cases (angulation < 10° ; displacement < 0.5 cm). Three very obese patients experienced fat liquefaction at the incision site as indicated by a yellowish discharge, mild swelling, and red skin. This complication resolved in all patients within one week with local wound care. There were no other complications such as impingement, avascular necrosis, nonunion, or screw loosening. The time to radiographic union ranged from 3 to 6 months. The mean Neer score one year after surgery was 88.16 ± 5.05 (Table II). For patients followed-up for at least two years, Neer scores at two years after surgery were similar to those at one year after surgery (data not shown).

Table II. — Neer scores one year after surgery (mean ± SD)

Pain	33.64 ± 2.24
Function	
Strength	16.80 ± 10.86
Reaching	10.00 ± 0.00
Stability	9.95 ± 0.31
Range of motion	
Flexion (sagittal plane)	4.23 ± 0.76
Extension	2.33 ± 0.50
Abduction (coronal plane)	2.59 ± 1.15
External rotation*	4.20 ± 0.99
Internal rotation*	3.71 ± 0.57
Anatomy	8.69 ± 1.12
Total	88.16 ± 5.05

*From an anatomical position with the elbow flexed.

DISCUSSION

Over a three-year period, we treated 78 older adults with AO type A2, A3, B1, B2, C1, and C2 proximal humerus fractures using an anterolateral acromial approach with two incisions and locking plates. This approach was associated with few complications and excellent total Neer scores one year at least after surgery. Advantages of this technique include small incisions and limited surgical dissection, simple finger and traction reduction and temporary K-wire fixation. Using this approach dissection of the deltoid muscle is the same as with other approaches. The small upper transverse skin incision is more convenient than a vertical incision and improves access to the humeral head and the anterior/posterior parts of the fracture for reduction.

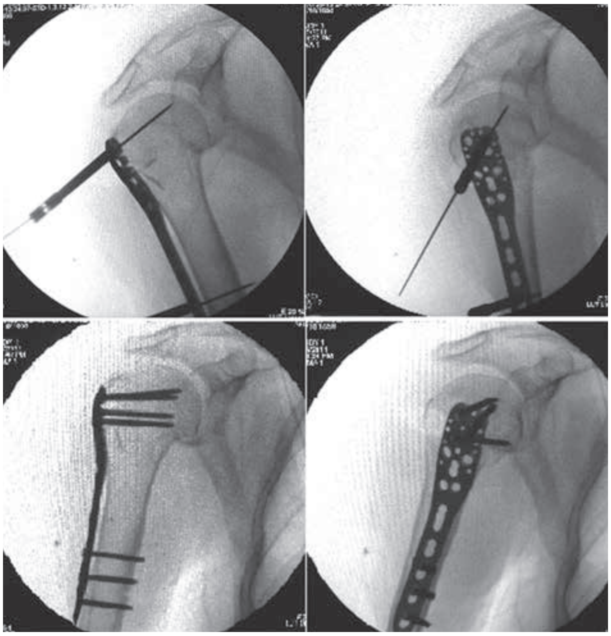

Fig. 3. — Two K-wires are inserted at the distal and proximal ends of the plate for temporary fixation after adjusting the height and anteroposterior position of the plate under fluoroscopic guidance. Finally, screws are inserted into the proximal portion and the distal portion of the plate.

Fig. 4. — Suction drains are placed before wound closure

Complications and functional outcome compare favourably with other studies describing the use of minimally invasive approaches and locking plates for the treatment of proximal humerus fractures (*1,4,12*). The rate of complications (3.85%) in our study is much lower than the rate of 30% including avascular necrosis in 5.5%, reported by Röderer *et al* in patients with a mean age of 70 years (range : 20 to 94), using a minimal anterolateral subacromial approach with non-contact-bridging plates (*12*). Laflamme *et al* (*4*) also reported a relatively high rate of complications (non-anatomic reduction, 32%) with a lateral deltoid-splitting approach using two minimal incisions and locking plates in patients with a mean age of 64 years (range : 38 to 88). We believe that the small transverse incision centered on the fracture and the reduced tissue damage may explain the low rate of complications in our cohort. We did not have axillary nerve damage, contrary to other studies in which minimally invasive approaches were used (*1,4,12*). The functional outcome one year after surgery was excellent, as indicated by a mean Neer score over 85. Other studies have reported acceptable functional outcomes as determined by assessment of Constant and DASH scores (*4,12*).

The surgical approach described requires familiarity with the anatomy of the proximal humerus and experience with more traditional approaches.

Although we typically make the initial incision approximately 2 to 3 cm distal to the acromion, a number of factors such as obesity, joint capsule loosening, and soft tissue swelling can make accurate localization of the acromion difficult and necessitate an extended incision and more extensive soft tissue dissection. Peroperative fluoroscopy is used to locate the fracture site, determine the optimal incision site and reduce excessive soft tissue dissection. The combined small incisions described provide sufficient surgical exposure.

An important concern in the repair of proximal humerus fractures is avoiding axillary nerve injury. Preoperative axillary nerve injury was considered to be a contraindication for this approach. The axillary nerve is located on the deep surface of the deltoid muscle, approximately 5.8 cm from the most proximal portion of the humerus, 6.3 cm (range : 5.3 to 7.0 cm) inferior to the acromion, and 3.5 cm (range : 3.2 cm to 4.3 cm) from the greater tuberosity of the humerus (*2,8*). As the greater tuberosity can be observed directly, its apex is taken as an anatomical landmark and the area approximately 3 to 5 cm inferior to the greater tubercle within a diameter of 2 cm is taken as the danger zone for axillary nerve damage. Although the axillary nerve courses quite close to the deep surface of the deltoid muscle, it can be elevated approximately 1 cm from the cortical bone of the proximal humerus without risking injury (*6*), thus facilitating safe insertion of the locking plate. For AO type A and B fractures, the axillary nerve is relatively close to the fracture site. Thus, if there is a risk of intraoperative axillary nerve injury, the nerve can be easily isolated from the muscle and protected.

The main blood supply to the humeral head is the ascending branch of the anterior circumflex humeral artery. This artery is located posterior to the biceps tendon and extends upwards along the tendon, entering the humeral head through the sulcus bicipitalis (*3*). As such, this vessel can be damaged in fractures involving the sulcus intertubercularis. Moreover, the axillary nerve may also be damaged by blind dissection of the soft tissue near the sulcus bicipitalis. For these reasons, we perform blunt dissection with a finger on the surface of the biceps tendon to protect the nerve and vessels.

Reduction is relatively simple for AO type A fractures and can be achieved under direct visualization in most cases. However, reduction is challenging for AO type B and C fractures. Any bone fragments produced by rotator cuff avulsion should be localized and reduction of other bone fragments should be performed in the space remaining after reduction of the rotated humeral head. Experience and familiarity with the anatomy of the proximal humerus is essential. The congruity of the articular surface must be checked. However, for extra-articular fractures, after restoration of the sulcus intertubercularis, acceptable reduction (angulation $< 10°$; displaced length < 0.5 cm on posterior-anterior radiograph) is sufficient, rather than anatomical reduction.

Placement of the plate and insertion of the screws are the most challenging aspects of this procedure. Theoretically, the plate should be located approximately 5 mm posterior to the sulcus intertubercularis (or biceps tendon) (Fig. 5) ; its proximal end should be located approximately 5 mm lower than the apex of the greater tuberosity. The height of the plate can be adjusted under fluoroscopic guidance. However, anteroposterior placement of the plate is difficult in cases with complicated proximal fractures. The anterior margin of the plate should be close to the sulcus intertubercularis or biceps tendon. This allows for insertion of screws close to the center of the humeral head, maximizing the stability of fixation. Low placement of the plate is preferable as four locking screws can be inserted into the humeral head to maintain stability even if the plate is located 1 cm inferior to the greater tubercle. High positioning of the plate may cause acromion impingement and shoulder dysfunction. No cases of impingement syndrome occurred in this study.

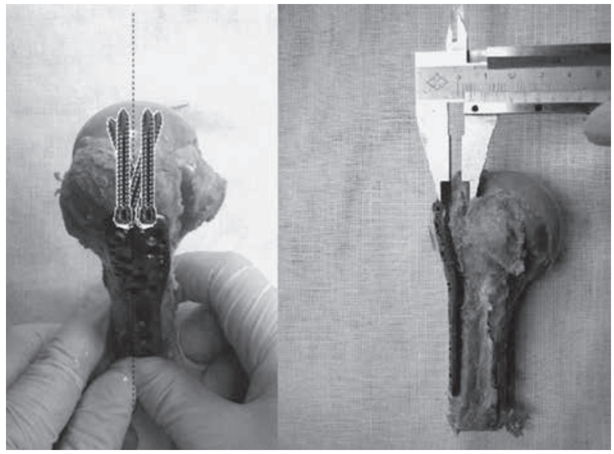

Fig. 5. — If the anterior margin of the plate is located less than 5 mm from the sulcus intertubercularis, screws can be inserted into the humeral head.

If there is an avulsion fracture of the greater tuberosity, bone suturing should be performed or a silk suture crossing the deep surface of the tendon can be fixed to the suture hole in the plate. Single lag screw fixation should be avoided to prevent screw loosening during early mobilisation. The tract of the drill should be explored after drilling to make sure that the drill bit has not entered the joint cavity.

Our study has a number of limitations. It is retrospective. The duration of follow-up was relatively short. However, results were similar at the one- and two-year follow-up for patients followed for ≥ two years. Longer follow-up is necessary to make sure that functional recovery is maintained. Other limitations include the fact that this was a single institution study with a relatively small number of patients. Lastly, examination of the anterior deltoid for isolated atrophy or electromyography for possible axillary nerve injury were not performed. However, none of the patients exhibited postoperative symptoms of axillary nerve injury after functional rehabilitation.

In summary, the two-incision anterolateral acromial approach with the use of locking plates for the treatment of proximal humerus fractures described herein provides good functional outcomes and is associated with less extensive surgical exposure than other approaches and a low rate of complications in older adults.

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