Assessment of the restriction of arm elevation after intramedullary fixation for proximal humeral fractures

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Abstract

Background: Nail protrusion is suspected as a reason for the restriction of arm elevation after antegrade nailing of proximal humeral fractures, although assessment of the restriction of the glenohumeral joint during arm elevation has been insufficient.

Methods: In this retrospective study, 30 shoulders with proximal humeral fractures in 29 cases were treated with Polarus short nails (Acumed, Beaverton, OR, USA). At a mean final follow-up of 14 months, clinical outcomes, bony union, alignment including retroversion of the head and entry points of the nails were evaluated. The ability of a subject to achieve maximum elevation above the zero position was also evaluated.

Results: Constant and Japanese Shoulder Association scores were a mean (SD) of 54 (12) and 71 (8.9) points, respectively. Even though all cases achieved bony union without mal-alignment of the head and greater tuberosity height or protrusion of the nail at its entry point, only six subjects could achieve maximum elevation above the zero position.

Conclusions: Based on these findings, treatment of proximal humeral fractures with an antegrade humeral nail inserted from the top of the humeral head results in restricted arm elevation, even in patients without nail protrusion or fragment malalignment.

Keywords

arm elevation, intramedullary fixation, proximal humeral fractures, short nail

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Introduction

Proximal humeral fractures are common in older persons, their incidence increasing because of increasing life expectancy.^{1,2} Between 15% and 64% of proximal humeral fractures are displaced and many require surgical treatment.³ Various surgical procedures have been proposed, including locking or nonlocking plates and screws, percutaneous pinning, suture or wire fixation, intramedullary nails, and prosthetic arthroplasty; however, there is no consensus on the optimal option for managing these fractures.⁴ Antegrade humeral nailing techniques and implants have undergone significant development, making them a widely used option for proximal humeral fractures.⁵ The Polarus nail (Acumed, Beaverton, OR, USA) is a popular type of antegrade intramedullary short nail.

Many studies have reported satisfactory clinical outcomes after intramedullary nailing;^{6,7} however,

arm elevation is limited in a relatively high percentage of cases.⁸ Nail protrusion or cuff lesions at its entry point reportedly were assumed to be specific reasons for causing its restriction, although assessment of the glenohumeral joint restriction during arm elevation has been insufficient. The objective of the present study was to assess restriction of the glenohumeral joint during arm elevation in cases without nail protrusion after intramedullary fixation for proximal humeral fractures.

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Materials and Methods

This retrospective study included 30 shoulders with proximal humeral fractures in 29 subjects (one with bilateral fractures) of mean (SD) age 70 (10) years (range 50 years to 89 years). They comprised 15 shoulders with two-part fractures and 15 with three-part fracture. No fracture-dislocations were included. At a mean final follow-up of 14 months, the subjects underwent both clinical and radiographic evaluations. No second operations were required in the present study.

Shoulder symptoms and functions were assessed using both Japanese Orthopaedic Association (JOA) and Constant scores.⁹ The JOA score for assessing shoulder disorders is a 100-point scoring system. Patients were assessed postoperatively for pain, strength of forward abduction (by manual muscle testing), activities of daily living, range of motion (ROM) and joint stability and evaluated radiographically.¹⁰ ROM was measured as the combined angles of the glenohumeral and scapular positions in the standing position. The original Constant score has been modified to include sex- and age-matching;¹¹ both the original and modified scales were used in the present study. Either surgeons or physical therapists who were treating the patients determined the scores.

The criteria of Neer¹² were used to assess alignment or displacement of the proximal humerus on anteroposterior radiographs with the arm internally and externally rotated. Superior and posterior displacement of the greater tuberosity and nail head were evaluated. The posterosuperior margin of the greater tuberosity was detected with the arm in the internally rotated position and placed at the patient's side, and the alignment

met Neer's criteria (Fig. 1a). The superior margin was confirmed to be located below the top of the head with the arm in the internally rotated position and placed at the patient's side (Fig. 1b). Also anteroposterior radiographs of both sides with the arm in maximum elevation were assessed. The zero position proposed by Saha¹³ was used to evaluate glenohumeral motion. In the zero position, the humeral shaft was aligned with the scapular axis, which was defined as the junction of the blade and spine of the scapula. The patients were instructed to elevate their arms as high as possible in the standing position; if their muscle power was inadequate to maintain the maximum elevated position during imaging, their upper extremity was supported. The images were examined to determine whether the humerus was more elevated than the scapular axis, and the patients were allocated to one of two groups accordingly (Group I: able to elevate the arm above the scapular axis; Group II: unable to elevate the arm above the scapular axis) (Figs 2 and 3). Computed tomographic (CT) radiographs were used to investigate the angle of retroversion of the head, which was defined as the angle between the humeral head and epicondylar axes, as previously described.¹⁴ Differences in this angle between the injured and healthy sides were computed, except for in the subject with bilateral fractures.

Figure 1. (a) In the internally rotated position with the arm at the side, the posterosuperior margin (curved dotted line) was detected and confirmed to be within Neer's criteria. (b) In the externally rotated position with the arm at the side, the superior margin of the greater tuberosity was detected and confirmed to be below the top of the humeral head.

Figure 2. Criteria for inclusion in Group I. The humeral axis (black dotted line) is more elevated than the scapular axis (black line), which is the junction of the blade and spine of the scapula. The humeral axis coincides with the scapular axis in the zero position and the case elevated the humerus above zero position.

Figure 3. Criteria for inclusion in Group II. The humeral axis (black dotted line) is less elevated than the scapular axis (black line). The case elevated the humerus below the zero position.

The same CT images were used to determine whether or not the nail was protruding at its entry site.

Statistical analysis

Values are presented as the mean (SD). Distributed variables were analyzed with Student's or paired *t*-tests. For variables with skewed distribution, the Mann–Whitney test was used.

Results

Mean (SD) JOA and Constant scores were 54 (12) and 71 (8.9) points, respectively. Every item of the JOA shoulder score is presented in Table 1. Mean (SD) shoulder flexion (forward elevation) was 122° (15°); abduction (lateral elevation) was 96° (15°); and external rotation was 37° (15°). The values for the contra-lateral side were 148° (14°), 138° (24°) and 59° (15°), respectively. The values in the shoulder that was operated on were significantly different (paired *t*-test; $p = 0.001$) from those in the contralateral shoulder.

All cases showed good alignment at the surgical neck, with the proximal part of the humerus being within Neer's criteria. In none of the 15 three-part fractures was the greater tuberosity above the top of the head. There were no cases with protrusion of the nail above the articular surface. On CT images of the 28 patients with unilateral fractures, the mean (SD)

Table 1. Mean (SD) Japanese Orthopaedic Association scores.

Criteria	Score
Pain	19 (4.4) [30]
Function	13 (3.0) [20]
Range of motion	19 (3.6) [30]
Radiographic evaluation	4.7 (0.7) [5]
Joint stability	15 (0) [15]
Total	71 (8.9) [100]

Values are expressed as mean (SD) (*n*).

Values in parentheses indicated maximum points.

Table 2. Clinical outcomes of Groups I and II.

	Group I	Group II
JOA score	73 (3.2)	70 (10)
Constant score	59 (6.3)	53 (13)
Adjusted Constant score	84 (8.9)	76 (19)
Flexion (°)	130 (7.1)	114 (21)
Abduction (°)	105 (8.7)	91 (19)
External rotation (°)	38 (14)	34 (20)

Values are expressed as the mean (SD).

JOA, Japanese Orthopaedic Association.

difference in the angle of retroversion of the head between the fractured and healthy sides averaged 4.8° (7.8°) (range –12° to 20°).

There were six patients in Group I and 24 in Group II. All healthy arms other than the subject with bilateral fractures reached above zero position. Group II included five patients who could not hold the arm at maximum elevation and needed support during imaging. The postoperative shoulder scores and ROMs are shown in Table 2. There was no difference in JOA, Constant, or modified Constant scores between the groups (Mann–Whitney test). At the last follow-up, angles of flexion (forward elevation), abduction (lateral elevation) and external rotation with the arm at the side did not differ significantly between the groups (Mann–Whitney test). Mean (SD) differences in retroversion angles were 4.6° (7.9°) (range –12° to 20°) in Group I and 5.5° (7.9°) (range –10° to 15°) in Group II. There were no significant differences between the groups (Mann–Whitney test).

Discussion

Proximal humeral fractures are common in older people. Displaced or unstable fractures often require surgical treatment.³ Antegrade humeral nailing techniques and implants have undergone significant development, making them a widely used option for proximal humeral fractures.⁵ As one downside of using antegrade humeral nails for fractures, arm elevation is limited in a relatively high percentage of cases,⁸ and impingement or rotator cuff lesions at the point of nail entry is assumed to cause its restriction. However, it is currently uncertain to what degree elevation is limited within the glenohumeral joint after intramedullary fixation.

Arm elevation is one of the most important functions of the shoulder. To evaluate arm elevation after treatment, we used the zero position proposed by Saha¹³ and supported by many investigators.^{15–17} The range of rotation is restricted when the arm is elevated because the insertions of the short rotators are close to the glenoid surface and the capsule surrounding the head tightens. By a primarily ligamentous mechanism, the shoulder joint is easily placed in the zero position regardless of whether elevation of the upper limb is initiated by a movement of flexion or abduction. This position is unique in that the humeral shaft aligns with the scapular axis and is essentially considered the final elevated position, above which the glenohumeral joint only translates without axial rotation.¹⁶ Both axes of the humeral and scapular bones were determined on plain radiographs in the present study, and the study subjects were allocated to one of two groups according to whether they were able to achieve the zero position in elevation. To our knowledge, the present study is the first to quantify the degree of restriction in the glenohumeral joint after intramedullary fixation for proximal humeral fractures. Clinical outcomes were assessed with JOA and Constant scores; these scores did not differ between the groups, and both the original Constant scores and their age-matched scores were compatible with those of previous studies.^{8,18} Additionally, the angles of flexion, abduction and external rotation did not differ between the groups. This might be explained by the fact that the share of the scapular movement in elevation or rotation increases in restricted glenohumeral joints and compensates the total arc of motion. Whether this decrease in glenohumeral contribution affects shoulder function needs to be examined.

Several factors are considered to affect arm elevation. A restricted elevation is the result first of the trauma with a fracture regardless of the treatment. Mal-positioning of the fracture fragments, such as a cranial displaced greater tubercle and varus deformity at the surgical neck, could also cause this restriction.

Impingement or rotator cuff lesions may restrict arm elevation by preventing smooth gliding of the greater tuberosity under the coracoacromial arch. Nail protrusion or cuff lesions at its entry point might be specific reasons for causing its restriction. In the present study, no nail protrusion was observed postoperatively on plain radiographs or CT images. Split cuffs were routinely tightly repaired using several non-absorbable stitches with their knots buried within the articular side after insertion of the nails, likely reducing the incidence of impingement by the proximal end of the nail or rotator cuff lesions and thus minimizing such impairment on arm elevation.

Displacement of the greater tuberosity above the top of the head reportedly restricts elevation, causing subacromial impingement. Angulation of the neck is also a prognostic factor. Curvilinear nails with their lateral entry points carry a risk of splitting the greater tuberosity and may also have the disadvantage of preventing varus moment. A high percentage of cases treated with these nails reportedly progress to varus collapse, whereas, in our series of patients with Polaris nails, no increase in tuberosity height or progressive varus collapse occurred. It has been suggested that making the nail entry point at the medial articular surface is a key to preventing varus collapse.⁵ A possible explanation for our lack of cases with greater tuberosity split or varus collapse is that we inserted the nails on the more medial side of the head, which would have damaged the articular cartilage of the head. Studies of contact analysis have shown that the contact area of the humeral surface in the zero position is around the top of the head.¹⁷ Inserting nails around the top of the head thus carries an inherent risk of restricting arm elevation because of the associated destruction of the proximal articular surface. The rotator cuff might adhere to the hole of the entry point in the top of the articular surface of the humerus. Some studies recommend a straight rather than curvilinear nail because the former enables avoidance of cuff violation and varus collapse.¹⁸ However, straight nails should be inserted more medially and may have a tendency to restrict elevation by destructing the superior articular surface.

There were some limitations to the present study. We did not include shoulders treated with conservative treatment or other methods. It was not possible to show any causality from different treatments, resulting in a decreased ROM, because this only involved patients treated with a short nail. Second, there were no second operations in the present study and we only confirmed alignment of the fragments and the nail head in the images. However, the study showed that 80% of the patients (24 of 30) were restricted in their glenohumeral elevation even if mal-alignment of the fragments or protrusion of the nail head were carefully

prevented. We consider that using the antegrade nail had this inherent disadvantage. In addition to this, other factors causing a restriction in ROM should be considered to conclude which method would be better for treating fractures of the proximal humerus.

In conclusion, elevation of the arm can be restricted after treatment of proximal humeral fractures with a nail inserted at the top of the humeral head, even in cases without protrusion of the greater tuberosity or impingement by the proximal end of the nail.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: A part of this study was presented in the 43rd annual meeting of the Japanese Shoulder Society.

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Ethical Review and Patient Consent

The subjects gave informed consent to participate in the study. The study was approved by our institutional review board (No E-12) and was carried out in accordance with the World Medical Association Declaration of Helsinki.

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