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Operative treatment of two-part surgical neck fracture of the humerus: Intramedullary nail versus locking compression plate with technical consideration

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Abstract

Objective: To compare the outcomes of patients who underwent either open reduction internal fixation with a locking plate and screws or closed reduction internal fixation with an antegrade intramedullary (IM) nail for displaced surgical neck fracture of the humerus.

Design: retrospective comparative study

Setting: single institute, Level-I academic trauma center

Patients and intervention: Sixty-nine patients with two-part surgical neck fracture of the humerus underwent either an IM nail (38 patients Group A) or a locked plate fixation (31 patients Group B).

Outcomes Measurement: Pain on a visual analog scale (VAS), University of California Los Angeles (UCLA) shoulder score, American Shoulder and Elbow Surgeons (ASES) score, and active range of motion (ROM)

Results: At the two-year follow-up, there were no significant differences in the VAS pain score (1.3 in Group A; 0.9 in Group B), ASES score (90.2 in Group A; 91.9 in Group B), and UCLA shoulder score (30.7 in Group A; 31.8 in Group B) between groups. Active ROM did not differ significantly between groups. There were three complications in the IM nail group, one nonunion requiring autogenous iliac crest bone graft and two cases of screw loosening.

Conclusion: For displaced surgical neck fractures of the humerus, both IM nailing and locked plate fixation in patients yielded satisfactory outcomes at the two-year follow-up with no significant differences in pain or ROM between groups.

Key words: humerus neck fracture, intramedullary nail, locked plate

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Introduction

Proximal humerus fractures account for approximately 5% of all fractures, and the incidence has increased with the aging population and increased incidence of osteoporosis[1-3]. Nevertheless, treatment of proximal humerus fractures remains challenging, particularly when associated with osteoporosis in elderly patients.

Fortunately, most proximal humerus fractures are stable and minimally displaced, permitting non-operative treatment. However, if operative treatment is indicated for a displaced surgical neck fracture, open reduction with a locked plate fixation or closed reduction with an intramedullary nail (IMN) are the most widely used treatments among a variety of fixation methods[4-10]. Locked plate fixation has biomechanical benefits and can overcome the pitfalls of the conventional plate and screw construct for osteoporotic fractures[11,12]. As indicated by Miranda, locking plate technology allows for fixed-angle fixation of the screw into the plate so that toggle cannot occur with the application of load[11]. However, IMNrequires only a small skin incision and leads to less soft tissue injury during surgical exposure. Moreover, several studies have reported that the IMN is equivalent biomechanically[4,8].

Despite the merits of IMN, it may lead to pain or functional limitation of the shoulder[13-15], most likely due to cuff-related problems that arise during antegrade IMN insertion through the rotator cuff. Despite locked plate fixation having a high complication rate, rotator cuff-related pain and disability are less likely to occur[16,17].

The purpose of this study was to compare the clinical and radiological outcomes of patients who underwent open reduction internal fixation with a locking plate, to closed reduction internal fixation with an antegrade IMN for a two-part surgical neck fracture of the humerus.

Patients and Methods

This retrospective comparative study reviewed 92 patients who underwent either closed reduction and internal fixation with an IMN (POLARUS, Acumed, Beaverton, OR)(Group A) or open reduction and internal fixation with locking plate fixation (PHILOS, Synthes, Paoli, PA)(Group B) for two-part surgical neck fracture of the humerus between March 2009 and June 2013 at our institute. The indication for surgery was either displacement of more than 1 cm or angulation of more than 45° identified on either x-ray or 3-dimentional computed tomography. All of the operations were performed by a single surgeon. Patient assignment was not randomized and operation method was chosen almost alternately: if one method was used this time, the other method was chosen next time. The inclusion criteria were (1) two-part fracture (surgical neck) on Neer classification[18]; (2) follow-up data available for a minimum of two years after surgery. Exclusion criteria were (1) poly-trauma , (2) severe osteoporotic or comminuted fracture requiring strut fibular allograft; (3) incidentally identified concomitant rotator cuff tear. As a result, 69 patients (38 patients in Group A and 31 patients in Group B) met the above criteria and were included in this study. Our institutional review board approved this study.

Functional and radiological assessments

For the functional assessment, a visual analog scale (VAS) for pain, the American Shoulder and Elbow Surgeons (ASES) score, the University of California Los Angeles (UCLA) shoulder score, and active range of motion (ROM) were determined. For active range of motion (ROM) measurement, three movements were included: forward flexion in the scapular plane, external rotation with the arm at the side, and internal rotation. Internal rotation was estimated by determining how far the patients could reach their thumb along the spinal segments. For ease of statistical analysis, the spinal segment was converted into numbers: segments at T1 through T12 were designated as 1 through 12, segments at L1 through L5 were designated as 13 through 17, and the sacrum was designated as 18. An independent examiner who was blinded to group assignment assessed shoulder scores and active ROM. For the radiological assessment, the anteroposterior (AP) view of the shoulder and 3-dimensional computed tomography of the shoulder were performed before surgery to identify the two-part surgical neck fracture according to the Neer classification[18]. After surgery, the shoulder true AP, AP in 20° external rotation, and axillary view were taken at two weeks, six weeks, three months, six months, one year, and two years postoperatively. The neck-shaft angle was measured on the AP view in 20° of external rotation, and varus collapse was defined as a neck-shaft angle that was reduced by more than 10° during the follow-up period[7].

Postoperative rehabilitation

Regardless of the fixation method, the affected arm was kept in a sling for six weeks after surgery. On the first day after surgery, pendulum exercise, self-assisted circumduction exercise, and gradual passive ROM were begun as tolerated. After six weeks postoperatively, active ROM exercise was begun. After three months postoperatively, isotonic strengthening exercises with an elastic band were begun.

Statistical analysis

SPSS software (IBM SPSS statistics version 20.0) was used for the statistical analyses. Student *t*-test was used for between-group comparisons of continuous or continuous ranked data, including the VAS pain score,

ROM, and shoulder functional scores (ASES and UCLA). The Fisher exact test was used to compare the categorical data. Statistical significance was set at $p < 0.05$.

Results

Patient demographics

Group A (IMN) included 12 men and 26 women, and Group B (locked plate fixation) included 11 men and 20 women. The mean age at the time of surgery was 59.7 years (range, 30 to 74 years) in Group A, and 58.6 years old (range 29 to 75 years) in Group B. The dominant arm was involved in 16 patients in Group A and 16 patients in Group B. The interval between injury and surgery was 0.6 days in Group A and 0.5 days in Group B. None of these characteristics differed significantly between groups. However, there were significant differences in operation time (72 minutes, Group A; 103 minutes, Group B; $p < 0.001$) and blood loss (52 ml, Group A; 177 ml, Group B; $p < 0.001$) (Table 1).

Functional and radiological outcomes

There were no significant differences in functional and radiographic outcomes. At the two-year follow-up, the mean VAS score for pain was 1.3 in Group A and 0.9 in Group B (p = 0.349) . The mean ASES score was 90.2 in Group A and 91.9 in Group B (p = 0.712), while the mean UCLA shoulder score was 30.7 in Group A and 31.8 in Group B (p = 0.558). (Table 2, Figure 1). Active ROM in forward flexion, external rotation, and internal rotation was measured at the two-year follow-up, with no significant differences between groups (Table 3). The neck-shaft angle was 138° ± 7° in Group A and 135° ± 5° in Group B (p = 0.124). With the exception of one patient in Group A, all fractures went on to union between three and six months postoperatively. During the follow-up period, no avascular necrosis or varus collapse was observed.

Complications

With the exception of postoperative stiffness, most complications occurred in the Group A (IMN). One patient went on to nonunion within the first year after surgery. Bony union was obtained after an additional operation requiring autogenous iliac crest bone graft. Postoperative stiffness was found in eight patients (8/38, 21%) in the IMN group and seven patients (7/31, 23%) in the locked plate fixation group. In this study, we defined postoperative shoulder stiffness as 120° or less in forward flexion and abduction. The occurrence of postoperative shoulder stiffness did not differ significantly between groups. If this stiffness was refractory to self-assisted ROM exercises and physical therapy after 3 months postoperatively, intra-articular steroid injection was administered. There were two cases of screw loosening in the IM nail group during the first 6 weeks, and we recommended revision surgery to convert to locked plate fixation. However, neither patient wanted to undergo further surgery. For this reason, we recommended delaying the onset of active motion in rehabilitation. Union occurred at the expense of ROM. Four patients (4/38, 11%) in the IMN group showed supraspinatus weakness (on a scale of 0 to 5, 4 = good) in forward flexion (scapular plane) and had

computed tomographic arthrography (CTA) to evaluate rotator cuff integrity, however, no cuff tear was identified. Overall complication rate did not differ significantly between groups (Table 4)

Discussion

Our study compared clinical and radiological outcomes between IM nailing and locked plate fixation for displaced 2 part surgical neck fractures of the humerus. Both fixation methods produced satisfactory outcomes and final pain scores and ROM did not differ significantly between groups.

Although IM nailing for proximal humerus fracture is associated with satisfactory results[4,7], several studies have reported that antegrade IM nailing is more likely to lead to postoperative shoulder pain and limitation of motion (LOM)[13-15]. Cheng et al. reported that the use of an antegrade IM nail for humeral shaft fracture yielded inferior shoulder scores and required a longer time for functional recovery[15]. Recently, however, several investigators have reached different conclusions regarding outcomes of an antegrade IM nail and locking plate for proximal humerus fracture[4,7]. Zhu et al. found that patients treated with an IM nail had comparable shoulder functional scores and radiological outcome to patients treated with a locked plate fixation group at the three-year follow-up, even though some functional outcomes were inferior with the IMN at the one-year follow-up[7]. Gradl et al. found no significant difference between use of an IM nail and locked plate fixation at the one-year follow-up[4].

There are strengths and weaknesses to both IM nailing and locked plate fixation for the humeral neck fracture. In IM nailing, the strengths include:preservation of the fracture site, a small incision, and reduced blood loss[7], and in the current study, the IM nail group exhibited significantly shorter operation time and less blood loss than the locked plate fixation group. However, iatrogenic injury to the rotator cuff is a concern. In order to minimize iatrogenic injury to the cuff, the longitudinal split should be made in line with fibers of the supraspinatus and onto the side of the musculotendinous junction, not onto the cuff insertion site. Despite retraction of the split cuff bilaterally with small retractors, the affected arm must also be adducted as much as possible and slightly extended so as to place the entry site out of the acromion. Finally, under fluoroscopic guidance, the tip of the awl should be placed sufficiently away from the greater tuberosity so that the entry hole does not violate the cuff insertion site. Nevertheless, four patients (4/38, 11%) in the current study developed weakness of the supraspinatus, even though CTA revealed an intact cuff. The strengths of locked plate fixation via the deltopectoral approach are direct reduction, insertion of the locking screw into the inferomedial calcar for medial calcar support, and no violation of the rotator cuff[19]. However, these strengths are counterbalanced by several weaknesses, including a longer incision, longer operation time, greater blood loss, and higher rate of complication in some studies [7,16,17]. In the current study, although postoperative stiffness did not differ significantly between groups, there were no nonunion or implant loosening cases in the locking plate group.

Because IM nailing generally violates the cuff, we hypothesized that it would lead to inferior pain scores even though locked plate fixation requires longer incision. We also hypothesized locked plate fixation would yield inferior ROM after surgery because it requires a longer incision and more aggressive approach. However, at final follow-up, there were no significant differences between groups in pain scores or ROM. Although previous investigators have found inferior shoulder functional scores and ROM after IM nailing, we suggested that meticulous care regarding the cuff split and repair can minimize the drawbacks of IM nailing for surgical neck fracture of the humerus[7,13-15].

If postoperative stiffness is refractory to conservative treatment, we suggest that lysis of adhesions, either by an open or arthroscopic approach, concomitant with implant removal. However, with IM nailing, the rotator cuff may be re-injured during implant removal, no matter how meticulously it is performed, although no studies have tested this hypothesis. In the IM nail group, stiffness was improved by steroid injection during the early postoperative period, except in the patients with screw loosening. In contrast, steroid injection was not effective for stiffness in the locked plate fixation group. However, in the current study, this postoperative

stiffness was not studied and we therefore cannot make any conclusions regarding the effect of corticosteroid on postoperative stiffness. Our study has several limitations. First, this study is a non-randomized, retrospective comparative study and as such, has inherent limitations. Thus, there might have been a potential selection bias. Second, we did not evaluate bone mineral density before surgery. Thus, we could not confirm that both groups had similar bone mineral density. Also, our results could be applicable to the patients with relatively good bone quality to support IM nail or locked plate fixation. Third, even though functional scores and ROM did not differ significantly between groups, we cannot exclude the possibility that these findings may result from type II error. Thus, the above limitations should be considered when interpreting our findings. Fourth, another criticism of our study could be the lack of an objective evaluation of bone quality, which could have influenced fixation. However, considering the mean age (~59yrs) of the patients in each group, both study groups likely had relatively comparable bone quality.

Conclusion

For two-part surgical neck fracture of the humerus, the pain score and ROM at the two-year follow-up did not differ significantly between groups. This implies that either method if correctly performed will lead good long term results when treating displaced 2 part proximal humerus fractures surgically.

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Figure legends

Table 1. Patient demographics

Table 2. Visual analog scale (VAS) pain score, American Shoulder and Elbow Surgeon (ASES) score, and University of California at Los Angeles (UCLA) shoulder score for both group at one-year follow-up

Table 3. Active ranges of motion in both groups at final follow-up

Table 4. Complications after surgery between groups

Figure 1. Preoperative, postoperative, 2-year follow-up x-ray and clinical photo of 56 years old female patient. (A) Preoperative AP in 20° external rotation; (B) Preoperative 3-dimensional computed tomography; (C) Postoperative AP in 20° external rotation; (D) Postoperative axillary view; (E) 2-year follow-up AP in 20° external rotation; (F) 2-year follow-up axillary view; (G) clinical photo at 4-year follow-up

Table 1. Patient demographics

	Group A (n=38)	Group B (n=31)	p-value
Sex (male/female)	12/26	11/20	0.732
mean age at the time of surgery	59.7 ± 12.0	58.6 ± 12.3	0.721
Dominant arm involvement	42% (16/38)	52% (16/31)	0.431
Interval between injury and surgery (day)	0.6 ± 1.0	0.5 ± 0.9	0.875
Operation time (minute)	72 ± 14	103 ± 10	< 0.001
Blood loss (mL)	52 ± 39	177 ± 92	< 0.001

Group A, IM nail; Group B, locking plate and screws. The values are given as the mean and standard deviation.

Table 2. Visual analog scale (VAS) pain score, American Shoulder and Elbow Surgeon (ASES) score, and University of California at Los Angeles (UCLA) shoulder score for both group at 3 month, 6 month, one year and two-year follow-up

		Group A	Group B	*p* value
3 month follow-up	VAS pain score	3.8 ± 1.9	4.0 ± 2.1	0.621
	ASES score	59. 6 ± 15.1	60.2 ± 16.0	0.493
	UCLA shoulder score	24.4 ± 5.5	23.9 ± 5.0	0.689
6 month follow-up	VAS pain score	2.6 ± 2.0	2.3 ± 2.1	0.513
	ASES score	79.5 ± 13.4	78.5 ± 12.6	0.477
	UCLA shoulder score	27.0 ± 4.5	27.9 ± 3.9	0.798
One-year follow-up	VAS pain score	1.3 ± 1.4	1.1 ± 1.5	0.568
	ASES score	89.5 ± 9.8	91.2 ± 9.0	0.389
	UCLA shoulder score	30.1 ± 4.2	30.7 ± 4.0	0.465
Two-year follow-up	VAS pain score	1.3 ± 1.3	0.9 ± 1.1	0.349
	ASES score	90.2 ± 7.1	91.9 ± 6.8	0.712
	UCLA shoulder score	30.7 ± 3.1	31.8 ± 2.7	0.558

Group A, IM nail; Group B, locking plate and screw. The values are given as the mean and standard deviation

Table 3. Active ranges of motion in both groups at final follow-up

		Group A	Group B	*p* value
3 month follow-up	Forward flexion	110.5° ± 20.6°	112.5° ± 18.2°	0.546
	External rotation	18.7° ± 15.4°	19.8° ± 14.9°	0.439
	Internal rotation	15.8 ± 2.1	16.1 ± 2.3	0.667
6 month follow-up	Forward flexion	125.6° ± 15.1°	126.8° ± 14.6°	0.719
	External rotation	26.3° ± 13.4°	26.9° ± 12.5°	0.811
	Internal rotation	14.1 ± 2.5	15.1 ± 2.6	0.368
One-year follow-up	Forward flexion	137.0° ± 12.8°	135.6° ± 13.7°	0.793
	External rotation	43.2° ± 11.9°	42.4° ± 11.3°	0.692
	Internal rotation	13.5 ± 2.7	14.2 ± 2.6	0.540
Two-year follow-up	Forward flexion	140.7° ± 10.9°	137.2° ± 12.7°	0.417
	External rotation	46.7° ± 10.3°	44.5° ± 10.9°	0.562
	Internal rotation	12.7 ± 2.6	13.8 ± 3.2	0.689

Group A, IM nail; Group B, locking plate and screw. The values are given as the mean and standard deviation. The internal rotation was measured how far the patient could reach up their thumb at the spinal level. In order to facilitate the statistical analysis, the spinal segment was converted into numbers; T1-T12 indicated 1 through 12, L1-L5 indicated 13 through 17, and sacrum indicated 18.

Table 4. Complications after surgery between groups

	Group A	Group B	*p* value
Non-union	1	0	
Screw loosening	2	0	
Weakness in forward flexion	4	0	
Postoperative stiffness	8/38 (21%)	7/31 (23%)	0.878
Total	**15/38 (39%)**	7/31 (23%)	**0.134**

Group A, IM nail; Group B, locking plate and screw. One patient with non-union and two patients with screw loosening also had postoperative stiffness