Shoulder Arthroplasty for Fracture

Does a Fracture-specific Stem Make a Difference?

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Abstract

Background Arthroplasty for shoulder fractures is a technically challenging and unpredictable procedure and its use is controversial.

Questions/purposes We therefore asked (1) to what degree function would be restored, (2) whether tuberosity healing would reliably occur, and (3) whether stem design would influence function in patients treated with hemiarthroplasty for proximal humerus fracture.

Patients and Methods We retrospectively reviewed all patients treated with a hemiarthroplasty for proximal humeral fracture between September 2001 and May 2006. The first 58 patients (September 2001 to March 2004) were treated with a conventional humeral prosthesis. The next 112 patients (April 2004 to May 2006) were treated with a

fracture-specific humeral prosthesis. Clinical measures (American Shoulder and Elbow Surgeons scores, visual analog pain scores, and goniometric measurements of glenohumeral motion) and radiographic evaluation of tuberosity healing were performed at minimum 24-month followup (mean, 32 months; range, 24–96 months).

Results Mean active anterior elevation was 118°, mean active external rotation 37.6°, and mean American Shoulder and Elbow Surgeons score 66. Overall, 127 of 170 (75%) greater tuberosities healed. With respect to stem design, active anterior elevation, active external rotation, and American Shoulder and Elbow Surgeons score were better with fracture-specific stems (129.8°, 39°, and 72, respectively) than with conventional stems (95.4°, 33.0°, and 55, respectively). Fewer tuberosities healed with conventional stems (38 of 58, 66%) than with fracture-specific stems (89 of 112, 79%).

Conclusions The use of fracture-specific stems during proximal humeral hemiarthroplasty for fracture appears to improve functional use of the injured shoulder and tuberosity healing compared to conventional stems.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

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Introduction

In 1951, Dr. Charles Neer first proposed treating displaced and devascularized proximal humerus fractures with a prosthetic arthroplasty (Fig. 1) [11]. Twenty years later, Dr. Neer reported acceptable function in approximately 90% of patients who underwent this surgical option [12, 13]. However, in the decades since Dr. Neer's original report, many other authors have reported reliable pain

relief but unpredictable restoration of function after shoulder arthroplasty for fracture [7, 10, 20].

A number of publications have identified the intraoperative technical challenges associated with these difficult cases, and surgical techniques now more reliably allow for the same restoration of anatomy that Dr. Neer originally described [3, 6, 8, 14, 18, 19]. However, while Dr. Neer reported excellent or satisfactory results in 90% of patients, recent reports suggest unpredictable active glenohumeral motion ranging from below shoulder level to normal active motion and variable tuberosity bone healing rates from less than 50% of cases to more than 90% after these procedures [18]. In an attempt to improve successes, surgeons have begun utilizing humeral prosthetic implants designed to maximize bone-healing potential and hopefully affect functional outcome [2, 6, 8, 18]. These studies have demonstrated predictable tuberosity healing in more than 80% of cases and parallel increases in active overhead elevation. We have also previously reported results for a smaller population of the cohort in the current report, demonstrating improved active elevation and improved tuberosity healing [8]. However, that report was short term and preliminary and the questions of durability and reproducibility served as the basis for continuing the evaluation of this cohort.

We therefore asked (1) to what degree function would be restored, (2) whether tuberosity healing would reliably occur, and (3) whether stem design would influence function in patients treated with hemiarthroplasty for proximal humerus fracture.

Patients and Methods

Between September 2001 and May 2006, we treated 184 patients with a proximal humeral hemiarthroplasty for a displaced three- or four-part proximal humeral fracture. The indications for surgery were dysvascular displaced three- and four-part proximal humeral fractures with concomitant (1) anatomic neck fractures, (2) posteromedial metaphyseal bone extension of less than 8 mm below the articular surface, and (3) medial humeral calcar displacement of more than 2 mm between the humeral shaft and the articular fragment [2]. The contraindications for hemiarthroplasty were (1) vascular humeral head fragments and (2) severe medical comorbidities that prevented general anesthesia. Patients who underwent surgery between September 2001 and March 2004 (67 patients) had a conventional humeral prosthetic stem (“conventional stem”) designed originally for arthritis (Select® Prosthesis; Zimmer, Inc, Warsaw, IN) (Fig. 2). All patients who had surgery between April 2004 and May 2006 (117 patients) were treated with a humeral prosthetic stem designed for fracture implantation (“fracture-specific stem”) (Aequalis® Fracture Stem; Tornier, Minneapolis, MN) (Fig. 3). For the 67 conventional stem patients, nine patients (13%) either died or were lost to followup at minimum 24 months postoperatively. Of the remaining 58 patients, there were 42 women and 16 men. Mean age was 73 years (range, 32–91 years), and mean time from injury to surgery was 16 days (range, 1–35 days). For the 117 fracture-specific stem patients, five patients (4%) either died or were lost to

Fig. 1 An AP radiograph shows a right shoulder with a four-part proximal humeral fracture-dislocation.

Fig. 2 An AP radiograph shows a right shoulder after proximal humeral hemiarthroplasty with a conventional stem.

followup at mandatory minimum 24-month review and were not included in this study. Of the remaining 112 patients, there were 92 women and 20 men. Mean age was 72 years (range, 37–98 years), and mean time from injury to surgery was 14 days (range, 1–22 days). Complete demographics for the two groups reveal the fracture-specific group included a higher ($p = 0.04$) incidence of dominant-extremity involvement; no other parameters differed between the two groups (Table 1). Pre hoc and post hoc power analyses were not performed. The minimum followup was 24 months (mean, 32 months; range, 24–96 months). No patients were recalled specifically for this study; all data were obtained from medical records

Fig. 3 An AP radiograph shows a left shoulder after proximal humeral hemiarthroplasty with a fracture-specific stem.

and radiographs. This retrospective study was approved by the research board of the W.B. Carrell Memorial Clinic Shoulder and Elbow Research Foundation.

All patients were operated on by one surgeon (SGK) using the same surgical technique for proximal humeral hemiarthroplasty and tuberosity osteosynthesis that has been previously described, regardless of prosthetic design [8]. All humeral stems were cemented. For the patients with the conventional stem, structural cancellous bone graft from the humeral head harvested with a saw was placed in the following locations: (1) under the greater tuberosity; (2) under the neck of the prosthesis; and (3) under the lesser tuberosity (morselized cancellous graft). For the fracture-specific stem patients, three structural cancellous grafts were harvested from the humeral head using a specifically designed osteotome and placed in the following locations: (1) within the humeral stem itself in a designed “window”; (2) under the greater tuberosity; and (3) under the humeral neck. Any remaining cancellous graft was morselized and packed between the tuberosities [8].

All patients were immobilized after surgery in a Velpeau arm sling for 6 weeks. All patients were seen by a physical therapist postoperatively, even if admitted to a rehabilitation or skilled nursing facility. Passive supine forward flexion to 90° and external rotation to 30° were begun during the first postoperative week until Week 4. From Weeks 4 to 6 after surgery, passive supine full forward flexion and external rotation to 30° were initiated. No pendulum or pulley exercises were allowed until active motion was begun at Week 7. Resistance exercises (closed-chain) began at Week 10. Isometric scapular stabilization exercises were initiated while patients were in their slings as soon as pain allowed such participation.

All patients were seen in followup at 2 weeks, 6 weeks, 3 months, 6 months, 12 months, and 24 months postoperatively. After 24 months, patients were followed on an annual basis. From the 6-week mark on, each evaluation included both clinical measures and four-view radiographs (AP views in neutral and external rotation, axillary lateral

Table 1. Demographic data for conventional stem and fracture-specific stem patients

Parameter	Conventional stem	Fracture-specific stem	p Value
Number	58	112	NA
Mean age (years)	73 (range, 32–91)	72 (range, 37–98)	0.8
Sex (female/male)	42 (72%)/16 (28%)	92 (82%)/20 (18%)	0.26
Time to surgery (days)	16	14	0.9
Isolated fracture	57/58 (98%)	110/112 (98%)	0.9
Handedness (right/left)	55 (95%)/3 (5%)	104 (93%)/8 (7%)	0.75
Hand dominance (dominant/nondominant)	22 (38%)/36 (62%)	60 (54%)/52 (46%)	0.04
Fracture pattern (4-part/3-part)	53 (91%)/5 (9%)	107 (95%)/5 (5%)	0.31

NA = not applicable.

view, and transthoracic scapular “Y” view). We obtained from all patients scores on the 100-point scoring system of the American Shoulder and Elbow Surgeons (ASES) [16] and a visual analog score (VAS) for pain from 0 to 10 (0 = no pain; 10 = worst pain). One of us (SGK, the treating surgeon) documented the ROM of the shoulder in active anterior elevation (AAE) and active external rotation (AER) using a goniometer in an attempt to remove intra-observer variability from this measure. Internal rotation (reaching behind the back) was not reported for this series due to the subjective nature of this measure. We defined “functional elevation” as AAE of 120° as this ROM is necessary to reach the top of the head [15].

Three fellowship-trained shoulder surgeons (SGK, JRR, PDB) each evaluated all four-view radiographs. Radiographs were evaluated for healing of the greater tuberosity to the humeral shaft. Osseous union of the tuberosity to the shaft was considered healing [3, 8]. Any tuberosity non-union or resorption was considered failure to heal. We required consensus agreement among all three observers with regard to healing; if there was no consensus agreement, the tuberosity was considered not healed. Kappa values for interobserver variability were 0.882, 0.774, and 0.603 for each of the three combinations of two of three reviewers. Evaluation of glenohumeral joint space, development of degenerative glenoid arthrosis, and CT evaluation for anatomic tuberosity healing were not performed.

We used paired t test between the two study groups to compare final mean ASES score, final mean AAE, final mean AER, and VAS differences and Fisher’s exact test to compare the incidence of tuberosity healing and incidence

of regaining “functional” elevation above 120°. We used InStat® for Windows (GraphPad Software, Inc, La Jolla, CA) for all analyses.

Results

For the entire series of 170 patients, mean ASES score was 66, mean AAE was 118°, mean AER was 37.6°, and mean VAS score was 2.0. One hundred five of the 170 (62%) patients achieved functional elevation.

One hundred twenty-seven of 170 (75%) greater tuberosities healed (Table 2).

Patients with a fracture-specific stem had greater mean ASES score, AAE, AER, and VAS score (Table 3). A higher ($p = 0.007$) percent of patients treated with a fracture-specific stem could achieve at least 120° than those treated with conventional stems: 77 of 112 or 69% versus 28 of 58 or 48%, respectively (Fig. 4). A higher ($p = 0.03$) percent of patients treated with a fracture-specific stem also were more likely to have healed tuberosities than those treated with a conventional stem: 89 of 112 or 79% versus 38 of 58 or 66%, respectively.

Deep infection occurred in three of the 170 patients (1.8%). One infection after conventional stem implantation was treated with implant removal and resection arthroplasty. Two infections after fracture-specific stems were treated with implant removal, antibiotic spacer placement, and second-stage reverse total shoulder arthroplasty. Periprosthetic humeral shaft fracture distal to the implant after a postoperative fall occurred in two of the 170 patients (1.2%). One occurred after conventional stem

Table 2. Shoulder function and greater tuberosity bone healing for all patients ($n = 170$)

ASES score (points)*	AAE (°)*	AER (°)*	VAS pain score (points)*	Greater tuberosity healed (number of patients)	> 120° AAE (number of patients)
66 (0–92)	118 (0–170)	37.6 (0–70)	2.0 (0–10)	127 (75%)	105 (62%)

* Values are expressed as means, with ranges in parentheses; ASES = American Shoulder and Elbow Surgeons; AAE = active anterior elevation; AER = active external rotation; VAS = visual analog scale (0–10; 0 = no pain; 10 = worst pain).

Table 3. Shoulder function and greater tuberosity bone healing according to prosthetic design

Design	ASES score (points)*	AAE (°)*	AER (°)*	VAS pain score (points)*	Greater tuberosity healed (number of patients)	> 120° AAE (number of patients)
Conventional stem ($n = 58$)	55 (0–91)	95.4 (0–170)	33.0 (0–70)	2.1 (0–10)	38 (66%)	28 (48%)
Fracture-specific stem ($n = 112$)	72 (0–92)	129.8 (0–170)	39.0 (0–70)	1.9 (0–10)	89 (79%)	77 (69%)
Conventional versus fracture-specific stem (p value)	< 0.001	< 0.001	< 0.001	0.2	0.03	0.007

* Values are expressed as means, with ranges in parentheses; ASES = American Shoulder and Elbow Surgeons; AAE = active anterior elevation; AER = active external rotation; VAS = visual analog scale (0–10; 0 = no pain; 10 = worst pain).

Fig. 4A–B Graphs show the distribution of active anterior elevation according to prosthetic design: (A) conventional stem and (B) fracture-specific stem.

implantation and was treated with an open reduction and internal fixation using allograft strut fixation and cerclage wires. One occurred after fracture-specific stem use and was treated with a revision to a long-stem reverse total shoulder arthroplasty combined with allograft strut augmentation at the fracture site. Ten patients (5.9%) who failed their initial hemiarthroplasty due to lack of tuberosity healing were revised to reverse total shoulder arthroplasty. Four had a previous conventional stem, and six had a fracture-specific stem. Two patients (1.2%) who failed their hemiarthroplasty and suffered from anterosuperior escape elected to undergo implant removal and resection arthroplasty for pain relief.

Discussion

Shoulder arthroplasty for fracture has demonstrated reliable pain relief but variable function, despite the excellent

or satisfactory results in more than 90% of patients reported by Dr. Neer [2, 3, 8, 12, 13]. This unpredictability has led to controversy regarding the appropriate management for displaced three- and four-part proximal humerus fractures [10, 19]. Recent surgical technical advances and changes in prosthetic designs have led to more predictable tuberosity healing and restoration of active overhead elevation after arthroplasty for proximal humeral fracture [6, 8, 14, 18]. We therefore asked (1) to what degree function would be restored, (2) whether tuberosity healing would reliably occur, and (3) whether stem design would influence function in patients treated with hemiarthroplasty for proximal humerus fracture.

We note several limitations. First, retrospective chart review with all clinical examinations being performed by the treating surgeon creates a potential source of bias. This study would be strengthened by independent clinical evaluation of all patients. Unfortunately, it is difficult to capture and return an elderly cohort for examinations.

We did make measurements of active motion with a goniometer, providing a sort of objectivity not present in other similar reports after hemiarthroplasty for fracture, including the original series by Dr. Neer [10–13]. Second, there would be interobserver variability in any radiographic evaluation of tuberosity healing without advanced imaging (such as CT). We had no independent examiner for radiographic evaluation, but two of three evaluators were not treating surgeons and were not involved in the care of these patients. Third, 14 of 184 patients (8%) were not available for final review, potentially biasing observations. Fourth, our cohort was divided into two sequential case series and was not randomized. While the surgical procedures were performed by the same experienced shoulder surgeon, the lack of randomization could induce potential bias.

We believe our data suggest reproducibility of a fracture-specific hemiarthroplasty for treating three- and four-part humeral fractures. Overall active glenohumeral elevation and incidence of tuberosity healing compare favorably to those reported in the historical and recent peer-reviewed literature over the last 40 years (Table 4) [3, 6, 8, 10, 13, 20]. In elderly patients, the recovery of shoulder girdle muscular function is dependent on not only bone healing after fracture arthroplasty but many other variables (eg, neurologic status, preoperative and postoperative status of the rotator cuff, appropriate restoration of the glenohumeral center of rotation with the prosthetic stem, compliance with postoperative rehabilitation, etc). We attempted to evaluate cuff function by using the ability to achieve functional ROM, defined as AAE of more than 120° [15]. This incidence was increased from less than 50% of patients with a conventional stem to more than 2/3 (69%) with a fracture-specific stem. The ability to reach to the top of the head is important in many activities of daily living and may be especially critical for positioning the ipsilateral hand in space and in helping maintain independence for an elderly patient. While pain relief after

humeral hemiarthroplasty for fracture remains reliable regardless of prosthetic design or implant (there were no VAS differences in our series), the functional gains reported here with a fracture-specific implant are indeed encouraging and approach the original active overhead elevation reported by Dr. Neer (> 80% of his patients achieved elevation > 140°) [6, 12, 13].

The use of such an implant in this series improved AAE, AER, and tuberosity bone healing (79% in this cohort). Kontakis et al. [7] have demonstrated similar bone healing, with tuberosity healing exceeding 80% in their analysis. Similarly, Sperling et al. [18] have also found improved tuberosity healing (75%) and subsequent improved functional parameters with the use of a dedicated fracture stem. These results have been echoed by Boileau et al. [4], with tuberosity healing exceeding 80% using a fracture-specific humeral stem. It has been demonstrated, with proximal humeral fractures, bone healing alone may not completely correlate with return of rotator cuff function [8].

With respect to implant design, the clinical and radiographic data reported here support the use of a dedicated fracture-specific implant during shoulder arthroplasty for fracture. Such implant designs are commercially available from many vendors, and design benefits include smaller implants with less proximal metal to allow for better bony tuberosity contact, proximal bone-friendly coatings/substrates, medial stem offsets that provide more space for tuberosity positioning, and/or implant height markers and adjustments [14]. We conclude the use of a dedicated fracture-specific humeral stem during shoulder arthroplasty for fracture improves functional parameters, improves radiographic bone healing, and appears to standardize the management of these patients. The data reported here parallel the historical reports of Dr. Neer and other recent peer-reviewed publications demonstrating similar tuberosity bone healing and restoration of active overhead elevation [4, 6, 7, 18].

Table 4. Reported series of hemiarthroplasty for proximal humeral fracture over the last four decades

Study	Number of cases	Mean followup (months)	Mean AAE (°)	Mean AER (°)	Greater tuberosity healing
Neer [13] (1970)	43	60	> 80% had elevation > 140°	NA	95%
Moeckel et al. [10] (1992)	22	36	119	40	95%
Compito et al. [5] (1994)	64	33	127	NA	76%
Robinson et al. [17] (2003)	138	75	NA	NA	62%
Mighell et al. [9] (2003)	80	36	128	43	78%
Antuna et al. [1] (2008)	57	123	100	30	63%
Boileau et al. [4] (2011)	30	45	136	34	87%
Krishnan et al. (2011)	170	32	118	37.6	75%

AAE = active anterior elevation; AER = active external rotation; NA = not available.

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