Clin Orthop Relat Res
DOI 10.1007/s11999-011-2055-z

Clinical Orthopaedics and Related Research®
A Publication of The Association of Bone and Joint Surgeons®

SYMPOSIUM: FRACTURES OF THE SHOULDER GIRDLE

Is Reverse Shoulder Arthroplasty Appropriate for the Treatment of Fractures in the Older Patient?

Early Observations

Christopher Lenarz MD, Yousef Shishani MD, Christopher McCrum, Robert J. Nowinski DO, T. Bradley Edwards MD, Reuben Gobezie MD

Abstract

Background The treatment of comminuted proximal humerus fractures in older patients is challenging. Variable values of functional outcomes scores, ROMs, patient satisfaction, and bony healing have been reported with conventional techniques, including open reduction and internal fixation, percutaneous pinning, and hemiarthroplasty. Another alternative is reverse total shoulder arthroplasty, although it is unclear whether this provides better ROM or function.

Questions/purposes We (1) evaluated ROM, pain level, and American Shoulder and Elbow Surgeons scores of patients who had a reverse total shoulder arthroplasty for displaced three- and four-part proximal humerus fracture and (2) identified clinical and radiographic complications from the procedure.

Patients and Methods We retrospectively reviewed 30 patients in three institutions who had undergone a primary reverse total shoulder arthroplasty for displaced three- or four-part proximal humerus fractures. Mean age was 77 years (range, 65–94 years). Minimum followup was 12 months (mean, 23 months; range, 12–36 months).

Results Mean postoperative American Shoulder and Elbow Surgeons score was 78 (range, 36–98), mean active forward flexion was 139° (range, 90°–180°), and mean active external rotation was 27° (range, 0°–45°). Mean American Shoulder and Elbow Surgeons pain score was 0.7 (range, 0–5) and mean visual analog scale pain score was 1.1 (range, 0–5). Complications were identified in three of 30 patients (10%).

Conclusions At short term, reverse total shoulder arthroplasty relieved pain and improved function. The complication rate compared favorably with those reported for other treatment alternatives.

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

Drs. Nowinski, Edwards, and Gobezie are all paid consultants for Tornier (Edina, MN, USA).

Each author certifies that his or her institution approved the reporting of these cases and that all investigations were conducted in conformity with ethical principles of research.

This work performed at Case Western Reserve University/ University Hospitals of Cleveland, Ortho Neuro, and Fondren Orthopedic Group.

C. Lenarz, Y. Shishani, C. McCrum, R. Gobezie (✉)
The Case Shoulder & Elbow Service, Department of Orthopaedic Surgery, University Hospitals of Cleveland, 11100 Euclid Avenue, HH5043, Cleveland, OH 44106, USA
e-mail: Reuben.gobezie@uhhospitals.org

R. J. Nowinski
Ortho Neuro, New Albany, OH, USA

T. B. Edwards
Fondren Orthopedic Group, Texas Orthopedic Hospital, Houston, TX, USA

Introduction

Displaced three- and four-part proximal humerus fractures in the elderly are complex and challenging to manage. In the older patient population, these fractures occur often in association with substantial osteoporosis, preexisting rotator cuff pathology, and multiple comorbidities. Further, these fractures are associated with a risk of developing osteonecrosis of the humeral head, with reported rates ranging from 21% to 75% in these fractures [25, 28, 33–35, 47]. Revision of a failed open reduction and internal fixation (ORIF) in this patient population is additionally associated

Published online: 31 August 2011

with worse ROM, Constant-Murley scores [11], and UCLA scores [1] versus primary treatment with hemiarthroplasty [5].

Internal fixation of these fractures in this patient population provides inconsistent results with regard to postoperative function, ROM, and pain relief. Failure rates for ORIF in patients older than 60 years range from 13% to 20% [19, 26, 34, 36, 49]. Even with the advent of locking plate technology, complications such as loss of reduction and screw penetration still occur at rates from 21% to 43% [36, 41]. Patient age greater than 60 years also increases the risk for these complications and subsequent worse scores on the Short Musculoskeletal Function Assessment Questionnaire and the Disabilities of the Arm, Shoulder, and Hand questionnaire [36].

The use of hemiarthroplasty for treating displaced three- or four-part fractures was initially reported by Neer [34]. Multiple studies subsequently reported inconsistent results for ROM and function [2–4, 9, 16, 20, 22, 30, 37, 39, 41, 50]. Complications include displacement of the tuberosity fragments, persistent pain, glenohumeral joint space narrowing, and heterotopic ossification (Table 1).

Several authors have suggested the use of reverse total shoulder arthroplasty (RTSA) for these complex proximal humerus fractures [7, 8, 15, 21] (Table 2). However, its use is controversial since complication rates for this procedure have ranged from 10% to 75% [12, 14, 18, 27, 40, 44–46]. The reported complications of RTSA include neurologic injury, glenoid fracture, dislocation, scapular notching, component loosening, and infection. Limitations of these studies have included small populations (ranging from five to 41 patients) and short followup times (mean, 1–6 years).

We therefore (1) evaluated the ROM, pain level, and American Shoulder and Elbow Surgeons (ASES) scores of older patients who had a primary RTSA for acute displaced three- and four-part proximal humerus fracture and (2) analyzed their complications.

Patients and Methods

We retrospectively identified 32 patients from three institutions who underwent a RTSA for acute proximal humerus fracture between January 2005 and December 2008. Inclusion criteria for the study were age 65 years or greater, acute proximal humerus fracture, and minimum clinical followup of 12 months. Exclusion criteria for this study were any patient younger than 65 years and any patient with previous fracture treatment on the affected shoulder. One patient died from causes unrelated to her shoulder surgery 4 months postoperatively and one of the 32 patients did not meet the followup criterion for entry into the study. All injuries were sustained in a fall from standing height. The mean (±SD) age of the group was 76.7 ± 8.1 years (range, 65–94 years). The minimum followup was 12 months (mean, 23 ± 8 months; range, 12–36 months). Twenty-seven patients were women and three were men. Two patients reported actively smoking. Two patients in the group had prior rotator cuff repairs on the affected side. One patient had a rotator cuff repair 6 months before her injury and a second patient had a rotator cuff repair 3 years before his fracture. The humerus fracture was in the left shoulder in 13 patients and in the right shoulder in 17 patients. The dominant arm was involved in 15 patients. One of the fractures was a three-part fracture and the rest were four-part fractures. Four of the four-part fractures were valgus impacted and three were fracture-dislocations. The mean time from injury to surgery was 10 days (SD, 6 days; range, 1–30 days). Medical comorbidities in the patient population included hypertension in 14 patients, hypercholesterolemia/dyslipidemia/coronary artery disease in eight patients, diabetes mellitus in seven patients, hypothyroidism in five patients, chronic pulmonary obstructive disease in two patients, colon cancer in one patient, breast cancer in one patient, and autoimmune hepatitis in one patient. The treating physicians (RG, RJN, TBE) are fellowship-trained shoulder surgeons who exclusively perform shoulder surgery with a tertiary referral practice. During the study period, approximately 15 to 20 proximal humerus fractures were treated collectively by the investigators each month. The majority of these patients were treated nonoperatively, although other surgical techniques were employed as indicated. The authors' selection criteria for patients who would benefit from RTSA as a treatment for complex proximal humerus fractures include patients who are older than 65 years and have multiple comorbidities and/or substantial osteoporosis. The authors also believe a long history of tobacco use is a relative indication for RTSA in this patient population due to its detrimental effects on vascularity and tissue healing. Hemiarthroplasty is also an option for treatment of these injuries. In the authors' experience however, subsequent ROM and function have been unreliable with hemiarthroplasty. Ultimately, the patient selection for RTSA in the treatment of complex proximal humerus fractures, including those in this study, is based on the surgeons' experience and assessment of whether or not each patient would have a successful outcome with ORIF or percutaneous pinning as compared to RTSA.

Preoperative AP, scapular Y, and/or Velpeau radiographic views of the shoulder were used to evaluate the fractures and aid in preoperative planning. The treating physician assessed the fracture type according to the Neer classification [33], evidence of preexisting arthrosis, concomitant injuries, and evidence of osteopenia or osteoporosis.

Table 1. Summary of literature reporting proximal humerus fractures treated with hemiarthroplasty

Study	Number of patients	Mean age (years)	Mean followup (months)	Mean AFF	Mean AER	Pain	Complications	Mean outcome scores
Zyto et al. [50]	27	71	39	70° each (3-/4-part)	45°/35° (3-/4-part)	9 patients (33%) with moderate to severe	2 infections, 1 plexus injury, 1 HO, 3 greater tuberosity displacement > 1.5 cm	Constant-Murley 51/46 (3-/4-part)
Mighell et al. [30]	72	66	36	128°	43°	5 patients (7%) report moderate pain	16 tuberosity complications, 18 HO, 1 infection, 1 aseptic loosening, 1 RSD, 1 ankylosis	ASES 76.6, SST 7.5
Christoforakis et al. [9]	26	65	50	150°	30°	25 patients (96.2%) had mild or no pain; 1 patient (3.8%) had moderate pain	2 infections, 1 lesion of the axillary nerve (occurred at time of injury)	Constant-Murley 70.4
Kralinger et al. [22]	167	70	29	41.9% with ≥ 90°	NA	35 patients (21%) with moderate to severe pain	77 (46%) tuberosity complications	Constant-Murley 55.4
Prakash et al. [37]	22	69	33	93° (77° if > 65 years)	24°	3 patients (14%) with moderate to severe pain	3 with tuberosity complications, 1 anterior dislocation, 1 HO, 1 loosening	20/22 were satisfied
Becker et al. [3]	27	67	45	52°	16°	7 patients with mild to moderate pain	HO in 15	Constant-Murley 45
Boileau et al. [4]	66	66	27	101°	18°	8 patients (12.5%) with moderate to severe pain	50% tuberosity complication	Constant-Murley 56; 42% dissatisfied
Robinson et al. [39]	138	69	6.3 years	NA	NA	Mean Constant-Murley pain score of 15 (interquartile range, 10–15)	10 infections, 53 tuberosity displacements, 1 hematoma	Constant-Murley 64
Hawkins and Switlyk [20]	20	64	4	72°	16°	18 patients had mild or no pain; 2 patients had moderate pain	1 axillary nerve injury, 1 posterior dislocation, 1 loose prosthesis, 1 hardware failure	75% good or fair results
Goldman et al. [16]	22	68	30	107°, 93° if ≥ 70 years	31°, 25° if ≥ 70 years	16 patients had no or slight pain	7 with evidence of loosening, 3 superior subluxations of the prosthesis, 3 HO, 1 superficial wound dehiscence	73% had difficulty with 3 or more activities of daily living

Table 1. continued

Study	Number of patients	Mean age (years)	Mean followup (months)	Mean AFF	Mean AER	Pain	Complications	Mean outcome scores
Solberg et al. [41]	48	67	35	NA	NA	Mean Constant-Murley pain score of 12.3	3 Infections, 7 greater tuberosity nonunion	Constant-Murley 60.4
Antuña et al. [2]	57	66	10.3 years	100°	30°	9 patients (16%) with moderate to severe pain	1 posterior dislocation, 1 severe limitation in ROM, 1 component loosening,	30 unsatisfactory results (Neer grading)
Grönhagen et al. [17]	55	72	4.4 years	NA	NA	Mean Constant-Murley pain score of 10	1 wound infection, 52% superior migration, one dislocation	Constant-Murley 42
Demirhan et al. [13]	32	58	35	113°	NA	1 patient (3%) with moderate or severe pain	1 RSD, 1 axillary nerve injury, 6 greater tuberosity problems, 1 superior placement of humeral head, 2 superior migrations	25% unsatisfactory results by Neer criteria; Constant-Murley 68

AFF = active forward flexion; AER = active external rotation; NA = not available; HO = heterotopic ossification; RSD = reflex sympathetic dystrophy; ASES = American Shoulder and Elbow Surgeons; SST = Simple Shoulder Test.

All patients in this study received a RTSA prosthesis produced by Tornier (Edina, MN, USA). The patient was placed into the beach chair position. We implanted all prostheses through a standard deltopectoral approach. The greater and lesser tuberosity fragments were identified with the attached rotator cuff and mobilized. We then secured these fragments using numerous heavy nonabsorbable sutures through the tendinous insertion using a modified Mason-Allen suture configuration. The remainder of the humeral head and its fragments were removed. The humeral medullary canal was reamed and broached to the appropriate size. The glenoid was exposed and the central drill hole was then drilled slightly inferior to the center of the glenoid such that it was equidistant from the anterior, posterior, and inferior rims. Next, we reamed the glenoid in preparation for the baseplate. The reamers were angled inferiorly between 0° and 10°. The baseplate was impacted into the glenoid and the screws were placed appropriately before insertion of the glenosphere. We placed a cement restrictor into the humeral canal at an appropriate depth for the selected stem. The depth of placement for the humeral stem was estimated during surgery by approximating the normal anatomic height of the humerus in two ways: (1) utilizing the superior border of the pectoralis major tendon insertion, which is approximately 5.6 cm caudad to the superior aspect of the humeral head [32], as a reference for the proper height of the humeral stem and/or (2) anatomically reconstructing the tuberosity fracture fragments to the humeral shaft so that the normal position of the greater tuberosity relative to the humeral shaft could be ascertained. The stem size for these implants was determined by using distal reamers until cortical contact was made at the proper intramedullary diameter for each patient. From this approximation of the native anatomy, the prosthesis was placed in the position normally recommended for a standard RTSA. We placed the humeral prostheses in approximately 20° of retroversion based on the epicondylar axis of the elbow. The humeral stem was cemented into the humeral shaft after two drill holes were made in the lateral cortex of the humerus and two nonabsorbable sutures were passed through these holes to later form tension band sutures as described by Boileau et al. [6]. Additionally, the sutures securing the greater tuberosity and attached rotator cuff were then passed around the medial and inferior portion of the prosthesis stem as described by Boileau et al. [6]. The shoulder was then taken through a trial ROM and stability was assessed by looking for humeral decoaptation from the glenosphere throughout the passive ROM. Specifically, the shoulder was tested in (1) shoulder adduction, extension, and external rotation and (2) 90° of abduction and external rotation. If decoaptation was detected on examination, the thickness of the polyethylene insert was increased to increase the tension on the

Table 2. Summary of literature reporting proximal humerus fractures treated with reverse total shoulder arthroplasty

Study	Number of patients	Mean age (years)	Mean followup (months)	Mean AFF	Mean AER	Mean pain score	Complications	Mean outcome scores
Boileau et al. (fracture sequelae) [5]	5	72	40	122°	9°	VAS 1.7	1 intraoperative glenoid fracture, scapular notching and HO noted for entire group but not specifically for fracture sequelae group	Constant-Murley 61
Cazeneuve and Cristofari [8]	36	75	6.6 years	NA	NA	Constant-Murley 12	11% dislocation rate, 3% infections with acinetobacter, 19 scapular notching, one aseptic loosening of base plate	Constant-Murley 55
Bufquin et al. [7]	41	78	22	97°	8° (neutral) 30° (abducted)	Constant-Murley 12.5	1 glenoid fracture, 5 neurologic complications, 1 acromial stress fracture, 3 RSD, 1 dislocation, deltoid dehiscence, 14 tuberosity nonunions, 5 tuberosity malunions, scapular notching in 5, HO in 36 shoulders	Constant-Murley 44, DASH 44
Gallinet et al. [15]	16	74	12	98°	9°	Constant-Murley 13	1 deep infection, 1 superficial infection, 1 RSD	Constant-Murley 53
Klein et al. [21]	20	75	33	122°	25°	NA	Recurrent dislocation in 1 patient and 2 infections	Constant-Murley 68 ASES 68
Lenarz et al.	30	76	23	138°	27°	VAS 1.0 ASES 0.6	1 patient with CRPS, DVT, and tuberosity resorption, 1 patient with tuberosity malunion, 1 patient with Grade 1 scapular notching	ASES 78

AFF = active forward flexion; AER = active external rotation; NA = not available; VAS = visual analog scale; ASES = American Shoulder and Elbow Surgeons; HO = heterotopic ossification; RSD = reflex sympathetic dystrophy; CRPS = complex regional pain syndrome; DVT = deep venous thrombus; DASH = Disabilities of the Arm, Shoulder, and Hand.

prosthesis and subsequent stability. The wound was then closed in the standard fashion. Two of the three surgeons routinely use subcutaneous drains (21 of 30 patients). Appropriate intravenous and perioperative antibiotics were administered to each patient.

All patients were placed in a shoulder sling postoperatively for a period of 3 weeks and were encouraged to perform active elbow, wrist, and hand ROM exercises. Physical therapy for the shoulder commenced on Postoperative Day 10 with gentle pendulum exercises, using 10 to 20 repetitions, two to three times a day. Passive shoulder ROM was started on Postoperative Day 14 with forward flexion limited to 90° for 1 week. Active ROM was begun at 3 weeks postoperatively.

Patients were followed postoperatively at intervals of 2 weeks, 6 weeks, 3 months, 6 months, 12 months, and annually thereafter. Each postoperative evaluation included a clinical examination and radiographic images including AP and axillary views of the shoulder. Outcomes assessed at each visit included the ASES score and visual analog scale (VAS) pain score [29, 38]. There were no missing data.

The treating physicians (RG, RJN, TBE) evaluated all radiographs of their own patients for radiolucencies under the baseplate, around the central peg of the baseplate, and around the humeral stem. Evidence of a component migration or failure was evaluated by comparing sequential true AP of the scapula and axillary lateral views of the shoulder. The position of the components relative to

constant anatomic markers such as the acromion, coracoid, scapular pillar, and glenoid margins were used to evaluate the glenoid component for changes in position. Periprosthetic fracture, tuberosity nonunion, migration, and resorption were all evaluated on the standard AP and lateral radiographs of the shoulder as well. The presence of notching was evaluated and graded using the methodology described by Sirveaux et al. [40] using a true AP view of the scapula. Scapular notching was graded on a scale of 1 to 4. Grade 1 notching involves the scapular pillar only, Grade 2 notching is in contact with the inferior screw, Grade 3 notching extends to the superior part of the inferior screw, and Grade 4 notching extends under the baseplate beyond the inferior screw.

Results

The mean postoperative ASES score was 78 ± 13 (range, 36–98). The mean postoperative ASES pain score was 0.7 ± 1.4 (range, 0–5). The mean postoperative VAS score was 1.1 ± 1.6 (range, 0–5). The mean postoperative active forward flexion was 139° ± 28° (range, 90°–180°) and the mean postoperative active external rotation was 27° ± 12° (range, 0°–45°).

We noted no radiolucencies or evidence of component subsidence or component migration. One patient had a preoperative brachial plexopathy that had not resolved at last followup. This patient suffered from a fracture dislocation of the shoulder and presumed brachial plexus injury at the time of her fall. She developed a complex regional pain syndrome (CRPS) in the affected extremity postoperatively. In addition, this patient had resorption of the greater tuberosity in followup imaging and a lower extremity deep venous thrombus immediately after her surgery. There was one case of Grade 1 scapular notching. One patient had a malunion of the greater tuberosity but had 150° of active forward flexion and 30° of active external rotation. There were no postoperative infections, hematomas, or dislocations. There were no acromial stress fractures or periprosthetic fractures noted. No complications resulted in reoperation.

Discussion

Comminuted proximal humerus fractures in the elderly represent a difficult clinical problem. Previous reports in the literature demonstrate major complications associated with conventional osteosynthesis and hemiarthroplasty (Table 1). Another alternative is RTSA, although it is unclear whether this provides better ROM or function. We therefore evaluated pain level, ROM, ASES functional scores, and any complications for patients older than 65 years who underwent primary RTSA for complex proximal humerus fractures.

Our study has several limitations. First, we had a selected cohort of patients without a direct comparison group. In the investigators' experience, the use of hemiarthroplasty in the patient population described above has inferior results compared to RTSA for these comminuted fractures. Therefore, we do not use hemiarthroplasty for treatment of these fractures with this patient population and would not attempt a study to directly compare the two techniques. Second, this was a multicenter retrospective study and was not prospective. The criteria for patient selection (described in Patients and Methods) differed minimally among the physicians. Third, we had a relatively small sample size, which decreases the power of the results. Primary RTSA for the treatment of these fractures is relatively controversial and is not performed at a high volume at any center involved in the study. Therefore, combining results from these institutions allows a more meaningful analysis of results. Fourth, we had only short-term followup with these patients. We cannot say whether these implants will be more durable in the long term compared to other alternatives. Lastly, we did not have independent evaluators collecting and reporting our data. Each investigator relied on his individual assessment of the radiographs and ROMs to complete the datasets. These assessments are therefore prone to intraobserver and interobserver variability.

Our patients demonstrated substantial reductions in pain after primary RTSA for displaced three-and four-part proximal humerus fractures. Our results for pain relief are comparable to improvements observed in previously published literature for this procedure (Table 2) [5, 6, 12, 18]. The ROM in our patients for both forward flexion and external rotation are slightly better than those previously reported. In the study by Klein et al. [21], the patients had similar mean forward flexion (122°) and external rotation (25°); however, the remainder of the reported studies have demonstrated mean forward flexion of between 97° and 107° and mean external rotation of 8° to 9°. All of the studies referenced above that evaluated RTSA for the primary treatment of proximal humerus fractures demonstrated forward elevation of the shoulder consistent with all activities of daily living, which typically require up to 90° of shoulder flexion. Our mean ASES score was 78, which is comparable to the study of Klein et al. [21], which reported a mean ASES score of 68 and represents the only other study evaluating RTSA for proximal humerus fractures using the ASES score.

There are several risks inherent in treating proximal humerus fractures primarily with RTSA. Overall complication rates of RTSA for the treatment of rotator cuff arthropathy range from as low as 7% [43] to as high as 75% [46]. We encountered no intraoperative surgical

complications. One patient developed CRPS associated with a brachial plexopathy secondary to the injury. This patient also had resorption of the greater tuberosity on followup imaging and poor ROM with pain. The most common complications in previously published reports on the use of RTSA for proximal humerus fracture have included scapular notching (0%–53%), tuberosity nonunion or malunion (0%–46%), and heterotopic ossification (0% and 88%) [5, 6, 12, 18]. We encountered one patient with scapular notching (3%), but the notching was not associated with increased pain or reduced function. No patients had reoperation for a complication associated with their arthroplasty.

Complications reported with hemiarthroplasty for fracture include tuberosity malunion and nonunion, painful glenoid wear, heterotopic ossification, persistent pain, and loosening of the humeral component [2, 4, 9, 13, 16, 17, 20, 22, 24, 30, 31, 39, 42, 48, 50]. The mean active elevation and active external rotation, as well as standard outcomes measures, have been correlated with healing of the greater tuberosity [5, 10, 22, 42]. Often the mean active elevation is reported to be around 100° [10, 31, 42]; however, closer examination of results shows less than 50% of the patients are able to flex past 90° (Table 1) [20, 23, 50]. One study directly compared RTSA with hemiarthroplasty for acute proximal humerus fractures in the elderly [15]. Although limited by its retrospective nature, small study population (21 hemiarthroplasties, 19 RTSAs), and short followup (6–18 months), the authors found a difference between the groups. Patients with RTSA exhibited better anterior elevation (98° versus 54°), abduction (91° versus 60°), and Constant-Murley scores (53 versus 39), but the hemiarthroplasty group exhibited better external rotation (14° versus 9°). The clinical importance of the 5° difference in external rotation between these two groups is unclear. However, the functional difference between 54° and 98° of forward flexion in these two groups is clinically important.

The treatment of displaced proximal humerus fractures in the elderly population represents a difficult problem for the treating physician. Our short-term observations after primary RTSA compare favorably with those reported in the literature for other alternatives and demonstrate reliable pain relief and functional improvements in older patients with these fractures. Long-term followup of the use of RTSA as a primary treatment modality for these fractures is necessary to assess component longevity, duration of pain relief, and ROM, as well as the incidence of late complications.

References

1. Amstutz HC, Sew Hoy AL, Clarke IC. UCLA anatomic total shoulder arthroplasty. *Clin Orthop Relat Res.* 1981;155:7–20.
2. Antuña SA, Sperling JW, Cofield RH. Shoulder hemiarthroplasty for acute fractures of the proximal humerus: a minimum five-year follow-up. *J Shoulder Elbow Surg.* 2008;17:202–209.
3. Becker R, Pap G, Machner A, Neumann WH. Strength and motion after hemiarthroplasty in displaced four-fragment fracture of the proximal humerus: 27 patients followed for 1–6 years. *Acta Orthop Scand.* 2002;73:44–49.
4. Boileau P, Krishnan SG, Tinsi L, Walch G, Coste JS, Mole D. Tuberosity malposition and migration: reasons for poor outcomes after hemiarthroplasty for displaced fractures of the proximal humerus. *J Shoulder Elbow Surg.* 2002;11:401–412.
5. Boileau P, Tinsi L, Walch G, Krishnan SG, Romeo A, Sinnerton R. Shoulder arthroplasty for the treatment of the sequelae of fractures of the proximal humerus. *J Shoulder Elbow Surg.* 2001;10:299–308.
6. Boileau P, Walch G, Krishnan SG. Tuberosity osteosynthesis and hemiarthroplasty for four-part fractures of the proximal humerus. *Tech Shoulder Elbow Surg.* 2000;1:96–109.
7. Bufquin T, Hersan A, Hubert L, Massin P. Reverse shoulder arthroplasty for the treatment of three- and four-part fractures of the proximal humerus in the elderly. *J Bone Joint Surg Br.* 2007;89:516–520.
8. Cazeneuve JF, Cristofari D. The reverse shoulder prosthesis in the treatment of fractures of the proximal humerus in the elderly. *J Bone Joint Surg Br.* 2010;92:535–539.
9. Christoforakis JJ, Kontakis GM, Katonis PG, Stergiopoulos K, Hadjipavlou AG. Shoulder hemiarthroplasty in the management of humeral head fractures. *Acta Orthop Belg.* 2004;70:214–218.
10. Compito CA, Self EB, Bigliani LU. Arthroplasty and acute shoulder trauma: reasons for success and failure. *Clin Orthop Relat Res.* 1994;307:27–36.
11. Constant CR, Murley A. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res.* 1987;214:160–164.
12. Cuff D, Pupello D, Virani N, Levy J, Frankle M. Reverse shoulder arthroplasty for the treatment of rotator cuff deficiency. *J Bone Joint Surg Am.* 2008;90:1244–1251.
13. Demirhan M, Kilicoglu O, Altinel L, Eralp L, Akalin Y. Prognostic factors in prosthetic replacement for acute proximal humerus fractures. *J Orthop Trauma.* 2003;17:181–188; discussion 188–189.
14. Frankle M, Siegal S, Pupello D, Saleem A, Mighell M, Vasey M. The reverse shoulder prosthesis for glenohumeral arthritis associated with severe rotator cuff deficiency: a minimum two-year follow-up study of sixty patients. *J Bone Joint Surg Am.* 2005;87:1697–1705.
15. Gallinet D, Clappaz P, Garbuio P, Tropet Y, Obert L. Three or four parts complex proximal humerus fractures: hemiarthroplasty versus reverse prosthesis: a comparative study of 40 cases. *Orthop Traumatol Surg Res.* 2009;95:48–55.
16. Goldman RT, Koval KJ, Cuomo F, Gallagher MA, Zuckerman JD. Functional outcomes after humeral head replacement for acute three- and four-part proximal humeral fractures. *J Shoulder Elbow Surg.* 1995;4:81–86.
17. Grönhagen CM, Abbaszadegan H, Révay SA, Adolphson PY. Medium-term results after primary hemiarthroplasty for comminute proximal humerus fractures: a study of 46 patients followed up for an average of 4.4 years. *J Shoulder Elbow Surg.* 2007;16:766–773.
18. Guery J, Favard L, Sirveaux F, Oudet D, Mole D, Walch G. Reverse shoulder arthroplasty: survivorship analysis of eighty replacements followed for five to ten years. *J Bone Joint Surg Am.* 2006;88:1742–1747.
19. Hawkins RJ, Kiefer GN. Internal fixation techniques for proximal humeral fractures. *Clin Orthop Relat Res.* 1987;223:77–85.

20. Hawkins RJ, Switlyk P. Acute prosthetic replacement for severe fractures of the proximal humerus. *Clin Orthop Relat Res.* 1993; 289:156–160.
21. Klein M, Juschka M, Hinkenjann B, Scherger B, Ostermann P. Treatment of comminuted fractures of the proximal humerus in elderly patients with the Delta III reverse shoulder prosthesis. *J Orthop Trauma.* 2008;22:698–704.
22. Kralinger F, Schwaiger R, Wambacher M, Farrell E, Menth-Chiari W, Lajtai G, Hubner C, Resch H. Outcome after primary hemiarthroplasty for fracture of the head of the humerus. *J Bone Joint Surg Br.* 2004;86:217–219.
23. Kraulis J, Hunter G. The results of prosthetic replacement in fracture dislocations of the upper end of the humerus. *Injury.* 1976;8:129–131.
24. Krause FG, Huebschle L, Hertel R. Reattachment of the tuberosities with cable wires and bone graft in hemiarthroplasties done for proximal humeral fractures with cable wire and bone graft: 58 patients with a 22-month minimum follow-up. *J Orthop Trauma.* 2007;21:682–686.
25. Lee CK, Hansen HR. Post-traumatic avascular necrosis of the humeral head in displaced proximal humerus fractures. *J Trauma.* 1981;21:788–791.
26. Lee CW, Shin SJ. Prognostic factors for unstable proximal humeral fractures treated with locking plate fixation. *J Shoulder Elbow Surg.* 2009;18:83–88.
27. Levy J, Frankle M, Mighell M, Pupello D. The use of the reverse shoulder prosthesis for the treatment of failed hemiarthroplasty for proximal humeral fractures. *J Bone Joint Surg Am.* 2007;89: 292–300.
28. Leyshon RL. Closed treatment of fractures of the proximal humerus. *Acta Orthop Scand.* 1984;55:48–51.
29. McCormick HM, Horne DJ, Sheather S. Clinical application of visual analogue scales: a critical review. *Psychol Med.* 1988;18: 1007–1019.
30. Mighell MA, Kolm GP, Collinge CA, Frankle MA. Outcomes of hemiarthroplasty for fractures of the proximal humerus. *J Shoulder Elbow Surg.* 2003;12:569–577.
31. Moeckel BH, Dines DM, Warren RF, Altchek DW. Modular hemiarthroplasty for fractures of the proximal part of the humerus. *J Bone Joint Surg Am.* 1992;74:884–889.
32. Murachovsky J, Ikemoto RY, Nascimento LG, Fujiki EN, Milani C, Warner JJ. Pectoralis major tendon reference (PMT): a new method for accurate restoration of humeral length with hemiarthroplasty for fracture. *J Shoulder Elbow Surg.* 2006;15:675–678.
33. Neer CS 2nd. Displaced proximal humerus fractures. Part I. Classification and evaluation. *J Bone Joint Surg Am.* 1970;52: 1077–1089.
34. Neer CS 2nd. Displaced proximal humeral fractures. Part II. Treatment of three-part and four-part displacement. *J Bone Joint Surg Am.* 1970;52:1090–1103.
35. Neer CS 2nd. Four-segment classification of proximal humerus fractures: purpose and reliable use. *J Shoulder Elbow Surg.* 2002; 11:389–400.
36. Owsley KC, Gorczyca JT. Displacement/screw cutout after open reduction and locked plate fixation of humeral fractures *J Bone Joint Surg Am.* 2008;90:233–240.
37. Prakash U, McGurty DW, Dent JA. Hemiarthroplasty for severe fractures of the proximal humerus. *J Shoulder Elbow Surg.* 2002; 11:428–430.
38. Richards R, An K, Bigliani L, Friedman R, Gartsman G, Gristina A, Iannotti J, Mow V, Sidles J, Zuckerman J. A standardized method for the assessment of shoulder function. *J Shoulder Elbow Surg.* 1994;3:347–352.
39. Robinson CM, Page RS, Hill RM, Sanders DL, Court-Brown CM, Wakefield AE. Primary hemiarthroplasty for treatment of proximal humeral fractures. *J Bone Joint Surg Am.* 2003;85: 1215–1223.
40. Sirveaux F, Favard L, Oudet D, Huquet D, Walch G, Mole D. Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive rupture of the cuff: results of a multicentre study of 80 shoulders. *J Bone Joint Surg Br.* 2004;86:388–395.
41. Solberg BD, Moon CN, Franco DP, Paiement GD. Surgical treatment of three and four-part proximal humeral fractures. *J Bone Joint Surg Am.* 2009;91:1689–1697.
42. Tanner MW, Cofield RH. Prosthetic arthroplasty for fractures and fractures-dislocations of the proximal humerus. *Clin Orthop Relat Res.* 1983;179:116–128.
43. Vanhove B, Beugnies A. Grammont's reverse shoulder prosthesis for rotator cuff arthropathy: a retrospective study of 32 cases. *Acta Orthop Belg.* 2004;70:219–225.
44. Wall B, Nové-Josserand L, O'Connor DP, Edwards TB, Walch G. Reverse total shoulder arthroplasty: a review of results according to etiology. *J Bone Joint Surg Am.* 2007;89:1476–1485.
45. Werner CM, Steinmann PA, Gilbart M, Gerber C. Treatment of painful pseudoparalysis due to irreparable rotator cuff dysfunction with the Delta III reverse-ball-and-socket total shoulder prosthesis. *J Bone Joint Surg Am.* 2005;87:1476–1486.
46. Wierks C, Skolasky RL, Ji JH, McFarland EG. Reverse total shoulder replacement: intraoperative and early postoperative complications. *Clin Orthop Relat Res.* 2009;467:225–234.
47. Wijgman AJ, Roolker W, Patt TW, Raaymakers EL, Marti RK. Open reduction and internal fixation of three and four-part fractures of the proximal humerus. *J Bone Joint Surg Am.* 2002;84: 1919–1925.
48. Wretenberg P, Ekelund A. Acute hemiarthroplasty after proximal humerus fracture in old patients: a retrospective evaluation of 18 patients followed for 2–7 years. *Acta Orthop Scand.* 1997;68: 121–123.
49. Zyto K, Ahrengart L, Sperber A, Tornkvist H. Treatment of displaced proximal humeral fractures in elderly patients. *J Bone Joint Surg Br.* 1997;79:412–417.
50. Zyto K, Wallace WA, Frostick SP, Preston BJ. Outcome after hemiarthroplasty for three- and four-part fractures of the proximal humerus. *J Shoulder Elbow Surg.* 1998;7:85–89.