International Orthopaedics (2020) 44:1331–1340
https://doi.org/10.1007/s00264-020-04612-y

ORIGINAL PAPER

The initial treatment of complex proximal humerus fracture affects the outcome of revision with reverse shoulder arthroplasty

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Received: 8 April 2020 / Accepted: 6 May 2020 / Published online: 25 May 2020

Abstract

Purpose The purpose of the study is to report the results of reverse shoulder arthroplasty (RSA) after three types of initial treatment performed for complex proximal humeral fracture (PHF): conservative, reduction and internal fixation (RIF), or hemiarthroplasty.

Methods This is a retrospective study of 63 patients separated into three groups with a minimum follow-up of two years. Group I included 25 patients with an initial conservative fracture treatment, group II included 25 patients treated by RIF, and group III included 13 patients initially treated by hemiarthroplasty. Patients were assessed using the absolute Constant-Murley score, functional parameters, complications rate, and radiological follow-up.

Results One patient died and five were lost to follow-up. All functional outcomes improved significantly post-operatively for the three groups ($p < 0.005$). The mean Constant-Murley score increased from 13.7 to 54.1 (group I); 16.6 to 48.5 (group II); and 22.6 to 48.2 (group III) ($p < 0.001$). The gain of Constant-Murley and SST scores was better for group I ($p = 0.049$ and 0.028, respectively), while post-operative pain was better in group III ($p = 0.033$). The complication rate was 38% in group III, 30% in group II, and 14.3% in group I.

Conclusions Reverse shoulder arthroplasty represents a good surgical option in complex proximal humeral fracture sequelae. Whatever the initial treatment, function and motion of the shoulder are improved. The final result is better if the initial treatment was conservative. The group initially treated with hemiarthroplasty had the most complications.

Keywords Reverse shoulder arthroplasty · Proximal humeral fracture · Fracture sequelae · Initial treatment failure · Revision

Introduction

Complex proximal humeral fractures are always challenging to treat, especially in elderly patients, regarding significant comminution of the tuberosities, osteoporotic bone, and possible dislocation of the humeral head. Despite the development of new techniques and devices, the failure of initial treatment is frequent, with either non-operative or operative treatment [1–3]. Many surgical options are available to correct soft tissue abnormalities, bone deformities, and a malposition of the previous implant [2, 4–6]. Regardless of the initial treatment, when the rotator cuff is not functional, reverse shoulder arthroplasty (RSA) can be a good option to restore motion and improve pain.

The purposes of this study were to report the results of RSA after failed initial treatment of complex humeral fracture and to compare the clinical outcome depending on the initial fracture treatment: conservative, reduction and internal fixation (RIF), or hemiarthroplasty.

Level of evidence: III, retrospective comparative study

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Material and methods

This retrospective study included 63 shoulders on 63 patients operated from 2003 to 2012 with RSA for failure of initial treatment of complex proximal humeral fracture. The mean age of the patients was 72 years (54–89) and they were

predominantly women (51 females). The dominant shoulder was involved in 33 cases. Inclusion criteria were RSA performed for severe pain and/or significant functional limitation (active anterior elevation < 90°) with a rotator cuff deficiency and difficulty in carrying out daily activities. Exclusion criteria were patients with rheumatoid arthritis, neurological disorders, or other systemic disease. Patients gave their informed consent to participate in this study and ethics committee approval was obtained.

Range of motion (ROM), absolute Constant-Murley score, and simple shoulder test (SST) score were recorded pre-operatively and post-operatively. Subjective pain evaluation was recorded with the pain score as recorded for Constant-Murley score, from zero to 15. In addition, patients were asked about their degree of satisfaction (very satisfied, satisfied, fair) after the RSA. The strength was measured with the arm in abduction of 90° in the plane of the scapula, with a resistance during five seconds against a handheld dynamometer fixed at the level of the wrist.

All the patients had antero-posterior and scapular lateral radiographs before and after surgery at the latest follow-up examination. A CT scan was done pre-operatively to analyze bone deformity, glenoid bone stock, muscle trophicity, and degree of fatty infiltration (according to Goutallier classification). Magnetic resonance imaging was preferred in the group with initial conservative treatment to evaluate the continuity of the cuff and the quality of the muscles [7] (Table 1).

Patients were divided into three groups according to the type of initial treatment for complex proximal humeral fracture. Group I consisted of 25 patients that have been treated conservatively, group II included 25 patients treated with reduction and osteosynthesis, and group III included 13 patients treated with hemiarthroplasty.

Surgical technique and post-operative protocol

In all patients, an RSA was performed using Arrow prosthesis (FH orthopedics, Mulhouse, France). The centre of rotation of the prosthesis was outside the glenoid bone and the stem was curved with an onlay polyethylene socket. So compared to the Delta Grammont prosthesis, this prosthesis is a "metallic" lateralized RSA to prevent glenoid notch and potential instability. Patients were placed in a semi-beach chair position under general anaesthesia combined with an interscalenic block. Depending on the first surgery and type of implant which had to be removed before arthroplasty, we used a deltopectoral (59%) or superolateral approach (41%). A deltopectoral approach was preferred when the deltoid was weak or to revise a hemiarthroplasty. Whatever the type of approach, a large release of the soft tissues was done anteriorly and posteriorly to obtain a better passive range of motion before performing arthroplasty. Resection of the supraspinatus was systematically done to facilitate prosthesis implantation, while we aimed to respect the infraspinatus and teres minor tendons posteriorly in order to maintain active external rotation. Osteotomy of the greater tuberosity was done in major malunion of the proximal humerus to prevent a peri-operative fracture of the greater tuberosity and to facilitate the implantation of the RSA. If a deltopectoral approach was chosen, the peeling technique was used to detach the subscapularis from the lesser tuberosity which was reinserted after arthroplasty with transosseous sutures. Previous osteosynthesis material was removed and at least five specimens were systematically sent for biopsy and culture to test for infection; we systematically used preventive intravenous antibiotic treatment for five days and then for three weeks per os with an adaptation to the antibiogram result. The humeral stem was cemented in all cases. The glenoid metal back was positioned with an inferior tilt to decrease shearing forces in the interface bone/metal back and to prevent glenoid loosening. In case of metaphyseal bone loss, a cancellous bone graft was added, taken from the resected humeral head or iliac crest. A tenotomy or a tenodesis of the biceps tendon was done, depending on patient's demands and characteristics.

All the patients are immobilized with a brace in neutral rotation maintained for four weeks. Passive range of motion in forward elevation and external rotation are started immediately until pain limits. Active movements were allowed after six weeks combined with rehabilitation in water. Muscular strengthening of the external rotators and lowering muscles represents the last step of rehabilitation.

Table 1 Pre-operative status of the rotator cuff tears: radiological assessment by MRI (group I) or CT scan (groups II and III)

Tendon	Group I (14 patients)	Group II (19 patients)	Group III (11 patients)
Subscapularis tear	43%	47%	81%
FI stage 3	28%	47%	63%
Supraspinatus tear	50%	52%	81%
FI stage 3	50%	50%	75%
Infraspinatus tear	35%	42%	81%
FI stage 3	26%	42%	73%

FI fatty infiltration assessed according to Goutallier classification in CT for groups II and III, and according to Fuchs classification in MRI for group I

Specific procedure for each group

In group I (n = 25), the patients were operated with superolateral approach in 18 cases and deltopectoral in seven cases. Concerning the long head of the biceps, 15 tenodesis and one tenotomy were performed, while it was left intact in two cases. Six patients needed a metaphyseal bone graft and one patient a glenoid bone graft.

In group II (n = 25) the patients were operated on with a superolateral approach in 15 cases and deltopectoral in ten cases. Six patients needed a metaphyseal bone graft and one patient a glenoid bone graft.

In group III (n = 13), three patients were operated using a superolateral approach and ten with deltopectoral approach. One patient needed a metaphyseal bone graft and another a glenoid bone graft.

Statistical analysis

The analysis was performed with the statistical battery provided by STATA® (version 11.0 for Mac OS; StataCorp, TX, USA). The Shapiro-Wilk test was used to assess the normal distribution of the results, according to the different groups.

The t-Student test was used to compare the pre-operative and post-operative results for all values in the three groups and the Kruskal-Wallis test to compare the results between groups. Statistical significance was determined at a p value < 0.05.

Results

The mean follow-up was 32 months (range 24–50). One patient died and five were lost to follow-up.

Demographics and patients' characteristics per group

In group I, patients were older than in the two other groups with a mean age of 76 years (range 57–89). There were 22 women, while four patients were lost to follow-up. Pre-operative rotator cuff assessment was performed with MRI for 14 patients (Table 1). There were two type 1 sequelae (cephalic collapse or head necrosis), none with type 2 (locked dislocation or fracture dislocation), two type 3 sequelae (surgical neck nonunion), and 21 type 4 sequelae (severe malunion of the tuberosities).

In group II, 25 patients treated by osteosynthesis were included with mean age 69 years (range 45–84). There were 21 women while one patient died and one was lost to follow-up. Two patients had osteosynthesis with K-wires, 12 with closed reduction and internal fixation with intramedullary nail, and 11 with open reduction and internal fixation (ORIF) with proximal humerus anatomical plate. Radiological rotator cuff assessment was done with pre-operative CT in 19 patients (Table 1).

Group III included 13 patients treated with hemiarthroplasty with mean age 65.7 years (range 57–80), and there were eight women. Radiological cuff assessment was done pre-operatively with CT in 11 patients. There was a higher rate of cuff tears than in the other groups (Table 1).

Clinical outcome and complications

In group I, there was a significant increase of mean absolute Constant-Murley score from 13.7 to 54.1 points post-operatively: a gain of 41.4 points that was bigger than the gain in groups II and III (mean rank of 34.4 for group I; 26 for group II; and 20.3 for group III, p = 0.049). Functional parameters and subjective results were significantly improved post-operatively (Table 2). The group 1 had better values regarding post-operative SST score (mean rank of 27.6 for group I; 19.3 for group II; and 13.8 for group III) (p = 0.028). In group I, we had three complications (14.3%) (Table 3) for which we did two open revision operations: one transient palsy of the axillary nerve; one mechanical failure of the polyethylene (PE) socket which was changed; one anterior dislocation for which the humeral insert was changed to a new one of 10 mm height that secured stability. The two patients that underwent revision surgery were satisfied at last follow-up (Figs. 1 and 2).

In group II, all functional and subjective outcomes significantly improved post-operatively (Table 2) while there were seven post-operative complications (30%) (Table 3). Four patients required an open revision surgery. Two of them had a mechanical failure of the glenosphere (dissociation) and they were revised with a new glenosphere screwed into the baseplate but the RSA was retained. In the third case of revisions, we removed cerclage of the humerus that had been used due to metaphyseal fracture. The fourth revision that we did for this group was due to post-operative complete palsy of the brachial plexus on a female patient. We performed a neurolysis of the supraclavicular and infraclavicular trunks at three weeks follow-up. The patient had a partial recovery, a weak deltoid, and a stiff shoulder (Fig. 3).

In group III, all outcomes significantly improved post-operatively but the gain of mean absolute Constant-Murley score was smaller than in groups I and II (Table 2). Group III has better values regarding post-operative pain score (mean rank of 36.8 for group III; 32.8 for group II; and 23.6 for group I) (p = 0.033). There were five complications (38%), which represents the highest rate of the three groups while four open revision operations were necessary (Table 3). One revision was made due to mechanical failure of the glenosphere (dissociation) after a fall and we revised with a glenosphere and a screw. The rest three patients that required revision had dislocation of the prosthesis. In one case, we used a humeral insert of 10 mm and a glenosphere 39 mm. In the second case, we put higher the humeral stem and we fixed it with cement, while in the third case, we changed into a humeral insert of

Table 2 Clinical results, subjective outcome, and patient satisfaction (mean group values, SD in parenthesis)

	Group I			Group II			Group III		
	Pre-op	Post-op	Gain	Pre-op	Post-op	Gain	Pre-op	Post-op	Gain
Flexion	43° (33.9)	114°[1] (32)	76° (42)	56° (26)	105°[1] (31)	48° (32)	47° (23)	100°[1] (42)	53° (42)
External rotation 1a	5° (13.7)	19.7°[1] (10.7)	13° (15)	− 1.8° (13)	16°[1] (12)	17.5° (15)	2.7° (9)	20°[1] (14)	17.3° (12)
Internal rotation	6.7° (8.1)	22.5° (15.8)	10° (8)	3.8° (5.2)	21°[1] (9.4)	16.2° (10.6)	3° (4)	10° (8)	7° (5)
Strength (pts)b	0.8 (2)	5.7[1] (3.2)	5.9 (2.5)	0.9 (1.5)	5.6[1] (5)	5.1 (5.6)	1.2 (2.1)	5.2[1] (3.3)	4.3 (3.5)
Absolute Constant-Murley score	13.7 (12.7)	54.1[2] (12)	41.4[3] (13.5)	16.6 (10.8)	48.5[2] (16.3)	31.8[3] (14.1)	22.6 (10.3)	48.2[2] (13.9)	25.5[3] (14.6)
SST	2.5 (2.2)	8.5[1] (1.5)	6[4] (2.7)	1.7 (2.6)	6.6[1] (2.6)	5[4] (4.5)	1.5 (1.2)	5.3[1] (3)	2[4] (2)
Pain[c]	2.6 (3.5)	10.1[1,5] (5.3)	6.7 (5.4)	3.2 (3.2)	13[1,5] (3)	9.8 (3.6)	4.5 (4.1)	13.5[1,5] (3.1)	8.6 (5.5)
Patient satisfaction VS		37.5%			25%			30%	
S		62.5%			65%			40%	
F		0%			10%			30%	

Preop pre-operatively, *Post-op* post-operatively, *Gain* the difference between pre-op and post-op score, *SST* simple shoulder test, *VS* very satisfied, *S* satisfied, *F* fair, *SD* standard deviation

[a] External rotation with arm at side (0° abduction)

[b] Strength was measured with the arm in abduction of 90° in the plane of the scapula, with a resistance during 5 s against a handheld dynamometer. The results for strength (points) are calculated according to the Constant-Murley score as 1 point per 0.5 kg, maximum 25 points

[c] Pain score from Constant-Murley score, ranging from 0 to 15, with 0 representing maximal pain and 15 no pain

[1] Statistically significant difference $p < 0.005$ between pre- and postoperative state

[2] Statistically significant difference $p < 0.001$ between pre- and postoperative state

[3] There is significant difference regarding gain of absolute Constant-Murley score between groups, with group I showing the greater gain (Kruskal-Wallis test, mean rank of 34.4 for group I; 26 for group II; and 20.3 for group III, $p = 0.049$)

[4] Statistically significant difference ($p = 0.028$) among three groups for the gain of SST (Kruskal-Wallis test, mean rank of 27.6 for group I; 19.3 for group II; and 13.8 for group III)

[5] Statistically significant difference ($p = 0.033$) among three groups for the postoperative pain score (Kruskal-Wallis test, mean rank of 36.8 for group III; 32.8 for group II; and 23.6 for group I)

pts : points for the Constant score for the strength the maximum score for strength is 25 points and 1kg equal 2 points

5 mm and a glenosphere 39 mm. At last follow-up, all patients who underwent revision surgery were satisfied (Fig. 4).

Discussion

Our study shows that RSA after failure of any kind of treatment for complex proximal humeral fracture improves the functional outcome of the patients irrespectively of the initial treatment method (Table 2). The improvement of functional result was better when initial treatment was conservative management, while the post-operative pain was better when initial treatment was hemiarthroplasty (group III). Increased rates of complications (38%) were found in group III. Relatively few studies have reported the functional outcomes of RSA for the treatment of failed complex proximal humeral fracture [8–10].

Table 3 Rate of complications

Complications	Group I ($n = 25$)	Group II ($n = 25$)	Group III ($n = 13$)
Component dissociation	1	2	1
Dislocation	1	0	3
Thrombophlebitis	0	1	0
Axillary nerve/brachial plexus palsy	1	1	
Infection	0	1	0
Haematoma	0	1	0
Regional pain syndrome	0	0	1
Hardware removal	0	1	0
Total (%)	3 (14.3)	7 (30)	5 (38)

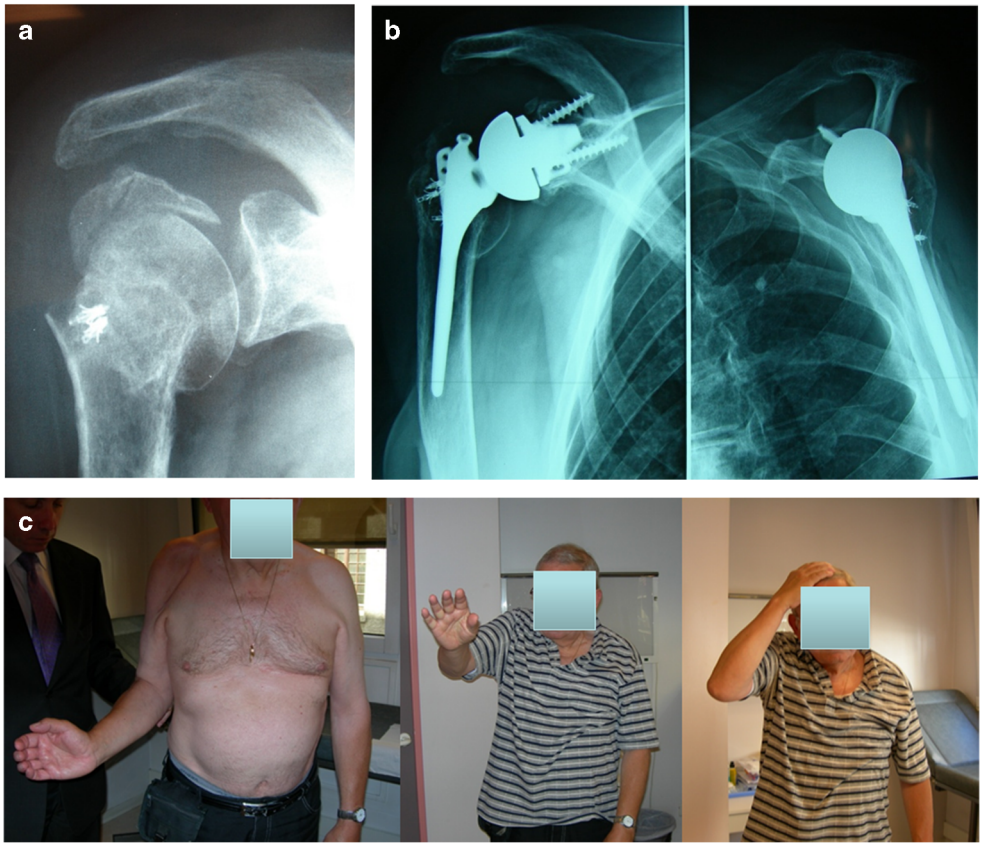

Fig. 1 Three years after reverse total shoulder arthroplasty for fracture sequelae type 4. **a** Anteroposterior radiograph of the right shoulder shows type 4 fracture sequelae in a 65-year-old male patient after conservative treatment of a three-part proximal humerus fracture (group I). **b** Anteroposterior and scapular lateral radiograph of the reverse total shoulder arthroplasty that was performed. RSA was combined with L'Episcopo procedure. **c** Range of motion for external rotation 1, anterior elevation, and external rotation 2 at 3 years after the index surgery

No studies have compared the benefits of the RSA after failure of three different initial fracture treatments: conservative, osteosynthesis, or arthroplasty.

When analyzing the pre-operative status of the rotator cuff, there is great difference between the groups. The worst results are in the hemiarthroplasty group with 81% of cuff tears and more than 63% of fatty infiltration grade 3. The status of the cuff pre-operatively influences the final outcome of the RSA. These results could be explained by a higher severity of the initial fracture, which lead the surgeon to choose hemiarthroplasty instead of conservative or osteosynthesis treatment.

Complications after RSA for fracture sequelae have been noticed by several studies especially when the fracture was initially treated with either internal fixation or hemiarthroplasty [11, 12]. In our study, the complication rate was 23% and was highest in group III (38%). Previous studies showed complication rate up to 60% in patients younger than 60 years and revision rate 36% [11]. Revision rate up to 8% for the RSA was also noted in a large study from the Danish Shoulder Arthroplasty Registry even in cases with initial conservative treatment for proximal humerus fracture [13]. The authors noted that dislocation was the indication for revision in two-thirds of patients with revised RSA. In accordance to previous studies, the greatest challenge in our series was to reproduce the humeral length especially in group III (initially treated with hemiarthroplasty) and to restore a good deltoid tension which is frequently weakened [13, 14]. Another reason for complications is the use of older models of RTSA [11]. For our series for the first generation of the Arrow prosthesis, we used a glenosphere impacted without any screw to fix it into the base plate (period 2003–2006), while the PE socket was impacted into the stem without any metal tray support (period 2003–2006). In the second generation of this prosthesis, we used a screw to fix the PE socket into the humeral stem (period 2006–2008). These initial designs may explain the high rate of mechanical failure of the glenosphere and the PE socket. Since 2009, these mechanical complications disappeared since we used the metal tray and PE socket as onlay system and a glenosphere impacted and screwed into the baseplate. The high rate of dislocations in our group III could be explained by the malposition of the initial component and the difficulties to restore a good length for the humerus. This may be attributed partially to the fact that we did not use to measure the contralateral length of the humerus at that period. The testing of the stability intra-operatively is a good way but still an approximate one. Our recommendation when we revise a failure of arthroplasty to an RSA is that we should analyze the aetiologies of the functional failure and the pain with an imaging study. Proper radiographs are required to measure the length of the contralateral side in order to evaluate the need of spacer

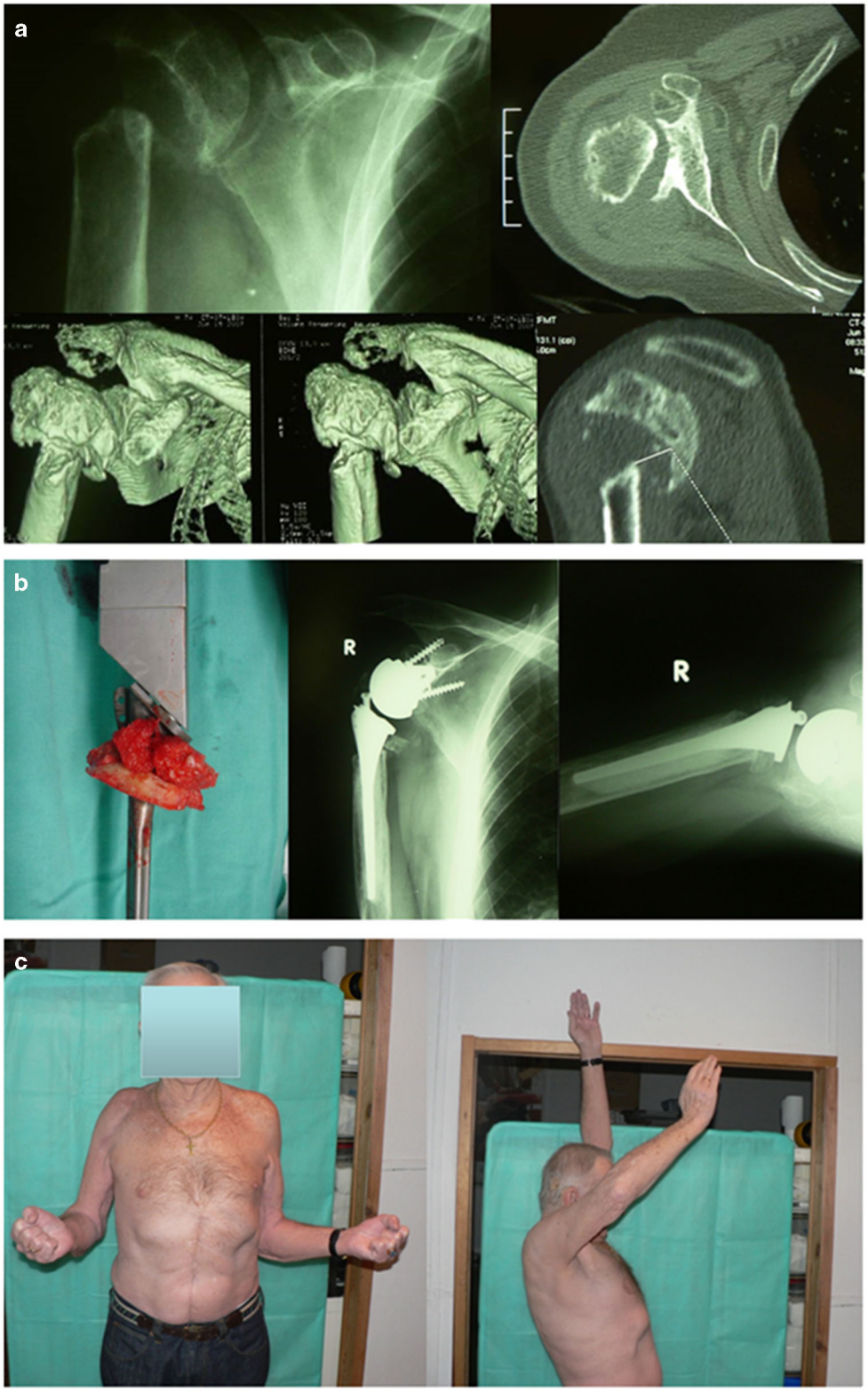

Fig. 2 Fracture sequelae type 3 in a 70-year-old male patient that presented with severe pain and shoulder stiffness. **a** Type 3 fracture sequelae 2 years after conservative treatment of two-part proximal humerus fracture (group I). **b** Reverse shoulder arthroplasty with use of autograft (humeral head) for metaphyseal bone loss was performed (right). Anteroposterior (middle) and axillary lateral radiographs (left). **c** External rotation and anterior elevation 2 years after RSA on the left side

(humeral insert 0, 5, or 10 mm) or cement or allograft to restore the length of the humerus since this may be the cause of instability and dislocation of the RSA. Also, CT scan provides information regarding malposition of the humeral stem (anteversion), a superior tilt of the baseplate, the trophicity of the residual cuff (subscapularis and teres minor) as possible

Fig. 3 A 55-year-old male patient from group II 8-year follow-up after RSA. **a** Three-part proximal humerus fracture of right shoulder (top), treated with intramedullary nail (group II). At 18 months after closed reduction and intramedullary fixation, the anteroposterior radiograph shows fracture malunion (bottom left). He was treated with reverse shoulder arthroplasty Arrow FH (bottom right). **b** Anterior elevation, external rotation 1, and internal rotation at 8 years follow-up after the RSA

reasons for failure, and as a way to predict the need for a combined tendon transfer.

Previous studies have shown improved results of RSA in proximal humerus fracture sequelae especially after type IV that is the most frequent [15, 16]. In type I, results of RSA were similar to non-constrained prosthesis [17]. In type II, when the tuberosities were healed in anatomic position, hemiarthroplasty was preferred to RSA. Except in chronic anterior dislocation, with a subscapularis deficiency, RSA was indicated [18]. In type III, the rate of complications after RSA was too high and a peg bone graft with a plate fixation was recommended [19]. Raiss et al. suggested that RSA is the preferable option especially in fracture sequelae type IV, where hemiarthroplasty provides poor result [20].

Willis et al. recommended to implant the humeral stem more retroverted to accommodate to the bony deformity and the soft tissue imbalance, in association with a large size glenosphere to prevent dislocation [21]. The gain in external and internal rotation was partially attributed to a larger glenosphere which further increases the lateral offset. This lateral offset re-tigthen the remaining cuff and the deltoid, and enhances the stability and rotation without the risk of impingement to the scapula posteriorly or anteriorly. In our study, the improvement of the external and internal rotation could be explained by an increasing of the lateral offset caused by the thickness of the metallic base plate. In cases of posterior impingement of the greater tuberosity, this requires osteotomy and refixation in anatomical position or tuberoplasty. Martinez et al. [22] recommend the use of a bone graft from the humeral head or an allograft to restore the metaphyseal part of the humerus and a long stem with a large glenosphere size 44 mm to avoid dislocation that occurs due to the net effect of soft tissue deficiency and bone loss on both humeral and glenoid side.

The RSA after failure of complex proximal humeral fractures treated by hemiarthroplasty improves function and motion more than any other technique. A metaphyseal humeral bone allograft may be needed to correct the proximal humeral bone loss [23, 24]. A comparative study regarding the results of RSA after ORIF or hemiarthroplasty showed that there is a tendency for patients with previous hemiarthroplasty to have a worse outcome [25].

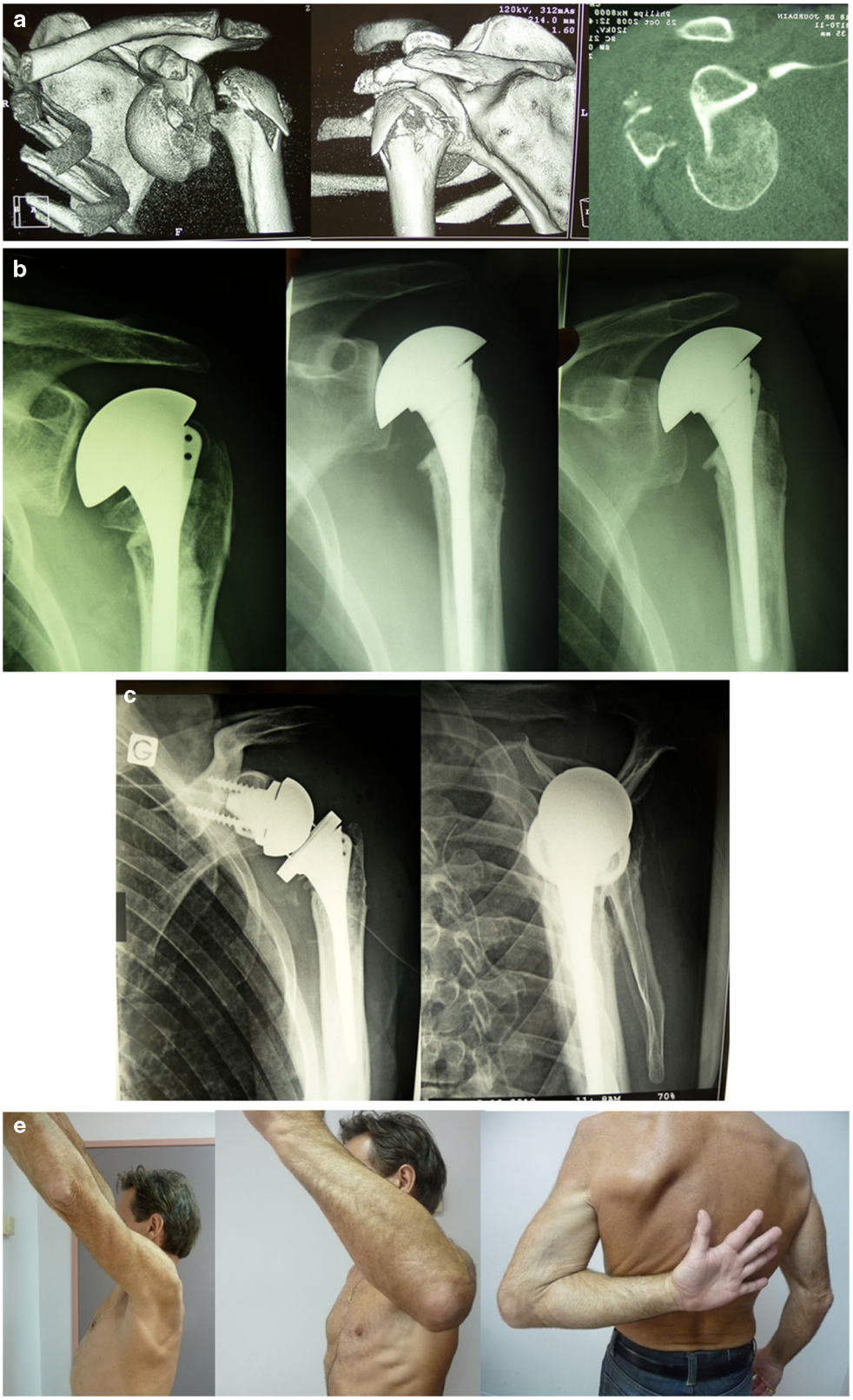

Fig. 4 A 57-year-old patient presented with pain and limited active anterior elevation up to 90° 16 months after hemiarthroplasty for four-part proximal humerus fracture. **a** Three- and two-dimensional CT images showing complex four-part fracture of left shoulder. **b** Anteroposterior radiographs in neutral, internal, and external rotation showing hemiarthroplasty. **c** Anteroposterior (neutral rotation) and scapular lateral radiographs showing reverse total shoulder arthroplasty at 6 months follow-up. **d** Range of motion at 3 years follow-up is excellent

Our study has some limitations. The 3 groups are small and non-homogeneous but it is the first study comparing the clinical outcomes of RSA after three initial treatments of proximal complex humeral fracture. Another weakness is the mean follow-up of 32 months which may be a short term to assess the results of arthroplasty.

Conclusions

Reverse shoulder arthroplasty represents a good surgical option in complex proximal humeral fracture sequelae. Whatever the initial treatment, function and motion of the shoulder are improved. The final result is better if the initial treatment was conservative. The group initially treated with hemiarthroplasty had the most complications. The status of the rotator cuff, which was worst for this group, and the metaphyseal bone loss are factors possibly related to the worst final result. With good preoperative planning to detect these deficiencies and an experienced shoulder surgeon, RSA is a good option in this difficult patient population.

Compliance with ethical standards

This study was classified as observational (non-interventional) by our local ethics committee. Statutory and ethical obligations of observational (non-interventional) studies in France: according to the past Huriet law on biomedical research, and to the current regulation that went into effect in August 2006 (law no. 2004-806), such studies do not require prior submission or approval to/from an IRB, and they do not require written consent. There is a current discrepancy on observational studies between the French legal requirements and the editors' requirements. This observational research on data fulfills current French regulatory and ethical obligations.

Conflict of interest The authors PV, JK, and DK receive royalties from FH orthopedics. The other authors declare that they have no competing interests.

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