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Reverse total shoulder arthroplasty for failed open reduction and internal fixation of fractures of the proximal humerus

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Background: Open reduction and internal fixation (ORIF) of complex fractures of the proximal humerus may yield unsatisfactory results. This study analyzed the results obtained after revision of failed ORIF of proximal humeral fractures using reverse total shoulder arthroplasty (RTSA).

Methods: Fifty-four shoulders of 53 patients with a subjectively unacceptable outcome after ORIF of a complex fracture of the proximal humerus were revised with RTSA. At a minimum follow-up of 2 years (mean follow-up, 46 months; range, 24-108 months), 44 shoulders were clinically and radiographically reviewed for the purpose of this study. Six patients had been lost to follow-up, and 4 patients (7%) were excluded from functional analysis because of revision surgeries.

Results: The mean absolute Constant score improved from 26 (range, 4-54) to 55 (range, 19-80) points; the mean relative Constant score improved from 32% (range, 4%-85%) to 67% (range, 27%-94%) of an age- and gender-matched, normal shoulder. The mean subjective shoulder value improved from 29% (range, 0%-90%) preoperatively to 67% (range, 5%-95%) at final follow-up. Nineteen patients rated their outcome excellent, 16 good, and 7 fair; 2 patients were dissatisfied.

Conclusion: RTSA is a valuable salvage procedure after failed ORIF of a proximal humeral fracture with relatively low revision rates. Shoulder function, patient satisfaction, and pain levels can be reliably improved.

Level of evidence: Level IV; Case Series; Treatment Study

Keywords: RTSA; failed ORIF; salvage therapy; screw cutout; intracapsular fracture sequelae; extracapsular fracture sequelae

About 80% to 85% of proximal humeral fractures can be treated conservatively.[19] Operative treatment of displaced fractures often involves open reduction and internal fixation (ORIF). This is, however, associated with complication and reoperation rates of up to 35%.[12,18,20,27]

Revision of an unsatisfactory ORIF of proximal humeral fractures is not always satisfactory. Joint-preserving treatment, including reosteosynthesis, shoulder arthroscopy, and partial or total hardware removal, has not consistently been

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successful in addressing pain or restoring shoulder function,[17] especially if glenoid destruction due to screw cutout[20] and avascular necrosis of the humeral head are present.

Therefore, secondary shoulder arthroplasty is often considered. Because of concomitant rotator cuff destruction, malposition, or nonunion of the tuberosities, hemiarthroplasty or anatomic total shoulder arthroplasty is associated with unpredictable outcome and a high complication and revision rate.[11,15,25] Reverse total shoulder arthroplasty (RTSA) can address glenoid bone destruction and at least partially compensate for muscle imbalance. It has therefore been considered for salvage of failed ORIF of proximal humeral fractures and yielded promising results in preliminary studies.[16]

We conducted this study to retrospectively analyze the radiologic and clinical outcome as well as the complication and revision rates of 53 patients in whom an RTSA was implanted at our institution after failed ORIF of a proximal humeral fracture.

Materials and methods

Study population

We retrospectively reviewed all patients identified in our database who had undergone revision RTSA after failed ORIF of a fracture of the proximal humerus between April 2006 and June 2013. There were 53 patients with 54 RTSAs after ORIF identified (Table I).

Table I Patients demographics (RTSA after failed ORIF, April 2006–June 2013, Balgrist University Hospital)

Variable	No. or mean (range)
Patients (total)	53 with 54 RTSAs
Patients included	43 with 44 RTSAs
Follow-up from RTSA (months)	46 (24-108)
Delay from ORIF to RTSA (months)	20 (1-92)
Male	32
Female	12
Age at RTSA (years)	68 (30-86)
Surgical site right	30
Surgical site left	14
Reasons for revision	
Screw cutout	43
Humeral head necrosis	35
Glenoid destruction	37
Patients excluded	10
Lost to personal follow-up	6
RTSA revision surgery with removal of the prosthesis	4
Reason for revision surgery	
Infection	2
Instability	1
Periprosthetic distal humeral fracture	1

RTSA, reverse total shoulder arthroplasty; *ORIF*, open reduction and internal fixation.

Six patients were not available for follow-up. Five of them (aged 77-96 years) refused further follow-up appointments because of poor general health status and no complaints of the surgical shoulder. One 62-year-old computer scientist had moved to another country. On the phone, all six patients valued the treatment outcome excellent (n = 4) or good (n = 2) with a subjective shoulder value (SSV) between 50% and 90%.

Four patients (aged 49-70 years) needed revision surgery (see Results section, complications) and were excluded from clinical results and satisfaction outcome analysis.

The remaining 43 patients (12 women and 31 men, one bilateral; 30 right and 14 left, 36 dominant and 8 nondominant shoulders) with a mean age of 68 years (range, 30-85) had a minimum follow-up of 24 months (mean, 46 months; range, 24-108 months). All 43 patients with the involved 44 shoulders were reviewed for the purpose of this study. In addition to a structured interview assessing disability, physical examination including scoring according to Constant and Murley[5] and imaging using conventional radiographs were performed.

The mean duration from ORIF to RTSA was 20 months (range, 1-92). Fifty patients had ORIF using plates (Philos Plate [Synthes Inc, West Chester, PA, USA], n = 45; 1/3 tube plates, n = 4; blade plate, n = 1); 3 patients were primarily treated with a nail and 1 patient with transcutaneous K-wire fixation.

The most common cause for revision was painful subjective impairment of shoulder function. The painful dysfunction was associated with screw cutout (n = 43, 79%), humeral head necrosis (n = 35, 65%), or glenoid destruction (n = 37, 69%; Fig. 1).

A thorough preoperative workup, including radiographs and computed tomography (CT) scans, laboratory (C-reactive protein and erythrocyte sedimentation rate) studies, and joint aspiration for microbiology and cell count and cell differentiation, was performed in every patient to exclude a pre-existing (low-grade) infection of the shoulder joint.

Surgical technique

All 54 procedures were revised using the Zimmer Reverse Anatomical Shoulder System (Zimmer, Warsaw, IN, USA). A deltopectoral approach was used, leaving the cephalic vein laterally. The humerus was exposed; the subscapularis muscle was mobilized, detached, and grasped with No. 2 FiberWire (Arthrex, Naples, FL, USA) sutures. If present, the tendon of the long head of the biceps was tenotomized at the level of the groove. After removal of the hardware, the humeral head was resected. In 6 patients, hardware had been removed in a previous operation without relieving pain and dysfunction. The glenoid was then evaluated for glenoid destruction, especially in cases with screws penetrating the humeral head surface. The glenoid was then minimally reamed to conserve as much subchondral bone as possible. Care was taken to have a low position, slight inferior tilt, and neutral version of the baseplate.

The height of the prosthetic stem was determined using the contralateral humerus as a template as it was the goal to obtain an overall lengthening of the humerus of 2 to 2.5 cm compared with the healthy side. The decision for cementation of the stem was made intraoperatively, depending on bone quality and quality of press-fit with the largest possible stem; 31 stems were cemented and 13 were press-fitted. A fracture or a standard stem was used, depending on the rotatory stability of the implant and the need for osteotomy and repair of the tuberosities. The stem was implanted in between 0°

Figure 1 A 55-year-old woman with a 4-part fracture of the proximal humerus (*first row*) treated with a Philos plate (*second row*). At 2 months after open reduction and internal fixation (*third row*), the patient showed humeral head necrosis with screw cutout and glenoid destruction and was therefore treated with reverse total shoulder arthroplasty (*fourth row*).

and 20° of retroversion not exceeding 20° to avoid tension on the greater tuberosity during internal rotation. The definitive humeral cup was inserted with the stem after a trial reduction. In severe malunions or nonunions (n = 9), the greater tuberosity was osteotomized, mobilized, and reattached if possible in the anatomic position to the prosthesis and transosseously to the humeral metadiaphysis with No. 2 and No. 5 FiberWire sutures.

The postoperative care included 2 suction drains for 48 hours and a sling for a maximum of 6 weeks. All patients were treated with passive external and internal rotation and active assisted elevation exercises for 6 weeks, beginning on day 1.

Assessment

Patient satisfaction and functional scoring according to Constant and Murley (Constant score), SSV,[8,13] and pain levels (assessed in Constant score) were assessed as primary end points. Range of motion, complications, and radiographic outcome were assessed as secondary end points.

Preoperative CT scans and standard anteroposterior, axillary lateral, and scapular radiographs served to classify fracture sequelae according to Boileau.[3] Category I (intracapsular) fracture sequelae, which are characterized by humeral head impaction with cephalic collapse and moderate displacement of the humeral head and greater tuberosity, were differentiated from category II (extracapsular) fracture sequelae, which are characterized by displacement with major extracapsular humeral head displacement and substantial greater tuberosity displacement (Fig. 2).

During follow-up including the last visit, implant position, inferior scapular notching, signs of loosening, and position of the greater tuberosity were analyzed radiographically on standardized, anteroposterior, axillary lateral, and scapular lateral radiographs.

Scapular notching was assessed according to Sirveaux et al.[24] Humeral loosening was assessed with the methodology described by Sperling et al.[26]

Figure 2 Category I (intracapsular) fracture sequelae are characterized by humeral head impaction with cephalic collapse and moderate tuberosity displacement. Category II (extracapsular) fracture sequelae are characterized by displacement with major extracapsular humeral head displacement and substantial greater tuberosity displacement.

Table II Clinical results

	Preoperative	Postoperative	Improvement	*P* value
CS (points)	26 (4-54)	55 (19-80)	29 (−20 to 69)	<.01
RCS (%)	32 (4-85)	67 (27-94)	35 (−20 to 83)	<.01
SSV (%)	29 (0-90)	67 (5-95)	39 (−20 to 80)	<.01
VAS pain (points)	7 (0–15)	12 (4-15)	5 (−5 to 13)	<.01
ROM (°)				
AAE	59 (0-120)	104 (10-160)	45 (−35 to 130)	<.01
AAB	54 (0-110)	103 (40-160)	49 (−30 to 140)	<.01
AER	13 (−20 to 60)	17 (−30 to 45)	3.6 (−55 to 40)	.32
AIR (CS level)	3 (0-10)	3.5 (1-6)	0.4 (−4 to 4)	.26

CS, Constant score; *RCS*, relative Constant score; *SSV*, subjective shoulder value; *VAS*, visual analog scale; *ROM*, range of motion; *AAE*, active anterior elevation; *AAB*, active abduction; *AER*, active external rotation; *AIR*, active internal rotation.
Values are presented as means (range).

Statistical analysis

The paired Wilcoxon test was used to test for a difference of the primary and secondary outcomes before and after the RTSA operation. A paired Student *t*-test was used to evaluate the values of the 2 fracture sequelae groups. Differences were considered significant at a P value < .05.

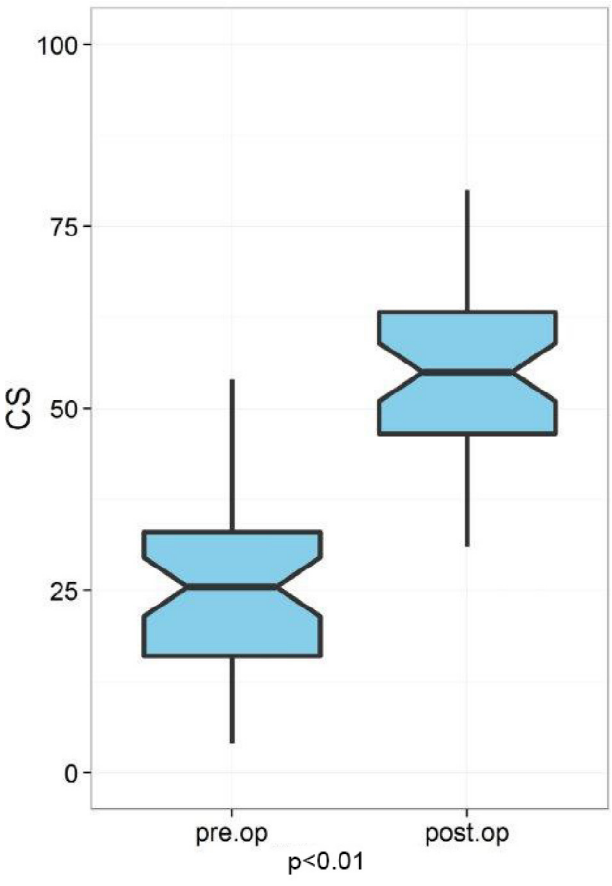

Figure 3 Constant scores (*CS*) of patients with failed open reduction and internal fixation before (preoperative mean, 26 points) and after (postoperative mean, 55 points) reverse total shoulder arthroplasty.

Results

Constant score

The mean absolute Constant score (ACS) improved from 26 (range, 4-54) to 55 (range, 19-80) points (Fig. 3). The age- and gender-matched relative Constant score (RCS) improved from 32% (range, 4%-85%) before to 67% (range, 27%-94%) at final follow-up. The improvements of the ACS and RCS were highly significant (P value < .01; Table II); 93% (41 patients) had an improved Constant score.

In 2 patients, the Constant score had decreased after RTSA. A 71-year-old man had had partial axillary nerve palsy before RTSA. His Constant score decreased postoperatively, but he still considered the overall result excellent because his pain had been treated successfully. Another patient with partial axillary nerve palsy at RTSA had a loss in Constant score and a subjectively fair result.

Subjective shoulder value

The mean SSV improved from 29% (range, 0%-90%) preoperatively to 67% (range, 5%-95%) after RTSA (P < .01; Fig. 4). It is interesting that the SSV, which as the Constant score had improved in 91% of the patients, was rated as high as the RCS.

Pain

The pain level as measured with the Constant score, which assigns 0 points for the most severe pain to 15 points for freedom from pain, averaged 7 (range, 0-15) points before and 12 (range, 4-15) points after RTSA (Fig. 5). The improvement of the pain status also was highly statistically significant (P < .01). Of 44 patients, 39 (89%) reported an improvement of the pain status.

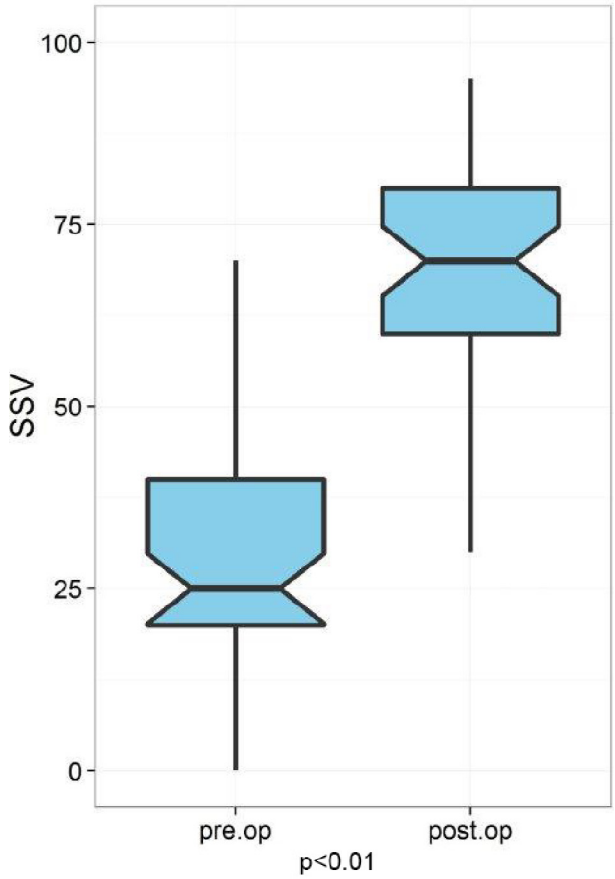

Figure 4 Subjective shoulder value (*SSV*) of patients with failed open reduction and internal fixation before (preoperative mean, 29%) and after (postoperative mean, 67%) reverse total shoulder arthroplasty.

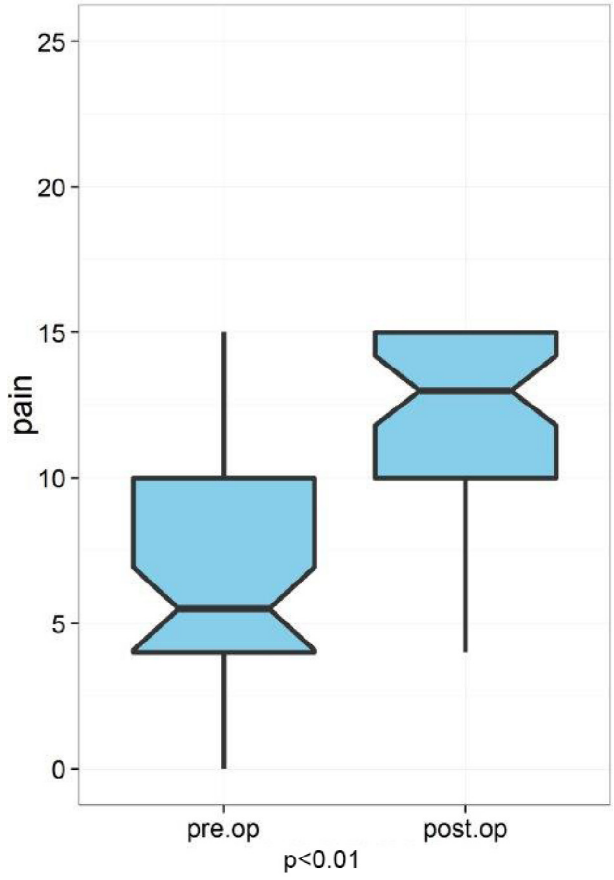

Figure 5 Pain (assessed in Constant score questionnaire, which assigns 0 for the most severe pain to 15 for no pain) of patients with failed open reduction and internal fixation before (preoperative mean, 7 pain points) and after (postoperative mean, 12 pain points) reverse total shoulder arthroplasty.

Satisfaction

At a mean of 45 months after RTSA, 35 patients (80%) judged the treatment outcome of the salvage RTSA excellent (n = 19) or good (n = 16). Seven patients rated the result fair, and 2 patients were dissatisfied ("poor" outcome). Compared with before RTSA, 84% of the patients (37 patients) improved their satisfaction level with operative treatment (Fig. 6). In 2 patients, the level did not change, and in 1 patient, the satisfaction level decreased. Four patients had no prior satisfaction statement because the time between ORIF and RTSA was too short to state a treatment outcome status after ORIF.

The improvement of each primary end point is illustrated in Figure 7.

Of the 2 dissatisfied patients, a 59-year-old female patient who was receiving workers' compensation for chronic low back pain had sustained a partial plexus lesion after the fracture. She reported pain (Constant score, 6) and SSV of 5% with an ACS of 37 points after RTSA (preoperative: Constant pain score, 2; SSV, 10%; ACS, 4). Besides the preexisting partial plexus lesion, no malpositioning, loosening, infection, or other reason could be found for the unsatisfactory result, so that no further treatment was offered. Another 49-year-old male caretaker reported a poor treatment result 24 months after RTSA. His ACS was 21 points, the pain level was 9, and the SSV was 15%. At 6 months before the 2-year follow-up visit, he had been hospitalized in another hospital because of sepsis after an infected athlete's foot. Neither 2 shoulder aspirations nor radiographic follow-up could identify any mechanical problems or signs of periprosthetic infection.

Range of motion

Mean active anterior elevation improved statistically significantly from 60° (range, 0°-120°) preoperatively to 105° (range, 10°-160°) postoperatively, and mean active abduction improved from 54° (range, 0°-110°) to 103° (range, 40°-160°). Mean active external rotation improved from 13° (range, –45° to 70°) to 17° (range, –30° to 45°), and active internal rotation, which was assessed within the Constant score through recording of the highest reached vertebra by the thumb, improved from 3 (0-10) to 4 (1-6) points. The improvement of

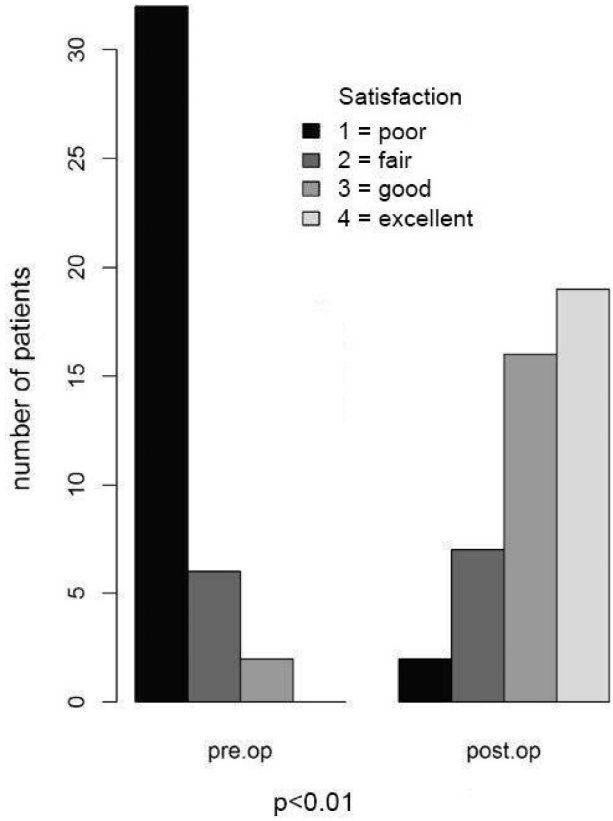

Figure 6 Treatment satisfaction of patients with failed open reduction and internal fixation before (preoperative) and after (postoperative) reverse total shoulder arthroplasty.

active external rotation and internal rotation did not improve with statistical significance (Table II).

Radiographic results

There were no implant loosenings in the radiographic controls. No greater tuberosity migration was found. In total, 41 patients (93%) had glenoid notching; 6 patients (14%) had glenoid notching grade III and 4 patients (9%) grade IV. Neither scapular notching in general nor the degree of scapular notching influenced the clinical outcome of the patients (Table III). None of these patients has signs of baseplate loosening and none is awaiting revision.

According to the preoperative (pre-RTSA) CT scans and radiographs, 27 patients (61%) had a category I (intracapsular) and 17 patients (39%) a category II (extracapsular) pattern of fracture sequelae.[3] The analysis of the clinical outcome with respect to these categories is presented next.

Patients with preoperative intracapsular (category I) or extracapsular (category II) fracture sequelae of the proximal humerus

Patients with preoperative intracapsular fracture sequelae (n = 27) showed statistically significantly better ACS, RCS, pain scores, active shoulder abduction, and satisfaction levels compared with patients (n = 17) suffering from extracapsular fracture sequelae (Table IV).

Patients with extracapsular fracture sequelae who underwent greater tuberosity osteotomy and refixation during RTSA (n = 9) showed better ACS, RCS ($P = .02$), pain levels, and satisfaction levels compared ($P = .02$) with the 8 patients with extracapsular fracture sequelae in whom the malpositioned greater tuberosity was left alone (Table V).

Complications

There was 1 intraoperative periprosthetic fracture in a 73-year-old woman, which was treated with plate fixation.

Of 54 patients, 4 needed 5 revision surgeries after RTSA, resulting in a revision rate of 9%. A 70-year-old retired woman had revision surgery 5 months after RTSA because of a distal humeral periprosthetic fracture after a fall. A 53-year-old female laboratory assistant had a periprosthetic infection with *Staphylococcus aureus*; 9 months after RTSA implantation, the prosthesis was removed, and after a spacer implantation and antibiotic therapy, a hemiprosthesis was implanted 12 months after explantation of the RTSA. A 49-year-old male caterer needed revision (débridement) 11 months after RTSA because of a draining folliculitis of the left axilla. At 14 months after index surgery, the prosthesis was removed, and a cement spacer was implanted because of a periprosthetic *S. aureus* infection. The patient denied further surgery and lives with moderate pain and the cement spacer. Another 70-year-old retired woman needed revision surgery because of a hematoma on the day of surgery. One month after the index surgery, she sustained an anterior dislocation, which was reduced under general anesthesia. One year after the index surgery, a reattachment of the greater tuberosity combined with a latissimus dorsi tendon transfer had to be performed because of a pseudoparalysis of the shoulder.

Discussion

If ORIF of a complex fracture of the proximal humerus fails, RTSA has been suggested to be a reliable surgical option to restore overhead function, even in elderly patients. The current investigation shows that such revision can be performed with an acceptable intraoperative and postoperative complication rate and satisfactory clinical and radiographic midterm results.

Failed ORIF of proximal humeral fractures is often associated with head necrosis, severe glenoid erosion due to screw cutout after locking plate fixation, or rotator cuff dysfunction due to malunion or nonunion of the tuberosities or tendon tear. Such situations with 1 or several of these complications leave few options to improve pain and to restore overhead function.

Hemiarthroplasty or total shoulder arthroplasty might be considered if the rotator cuff is intact, especially in the young, but unpredictable clinical results with high complication and

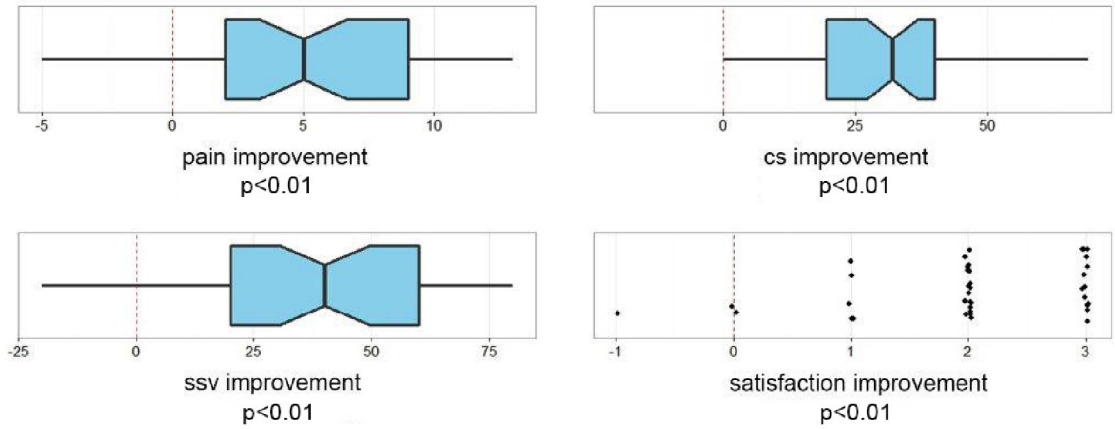

Figure 7 For all 4 scores (primary end points), higher values stood for a better outcome. Values highly significantly improved after reverse total shoulder arthroplasty. *CS*, Constant score; *SSV*, subjective shoulder value.

Table III Scapular notching according to Sirveaux[24] and clinical outcome

	Grade 0 (n = 3)	Grade I (n = 19)	Grade II (n = 12)	Grade III (n = 6)	Grade IV (n = 4)
ACS (points)	48 (61-38)	50 (19-80)	58 (37-73)	64 (47-79)	67 (53-77)
RCS (%)	62 (54-73)	61 (27-94)	70 (47-86)	75 (57-93)	78 (65-89)
SSV (%)	83 (80-90)	62 (15-90)	63 (5-90)	75 (60-90)	75 (60-95)
Pain (VAS-CS)	11 (6-15)	11 (5-15)	13 (6-15)	12 (8-14)	15 (15-15)
Satisfaction average (value)	3.3	3	3.1	3.4	3.7
4 = excellent	1	6	5	3	3
3 = good	2	7	5	1	1
2 = moderate	0	5	1	1	0
1 = poor	0	1	1	0	0

ACS, absolute Constant score; *RCS*, relative Constant score; *SSV*, subjective shoulder value; *VAS-CS*, visual analog scale in Constant score.

Table IV Outcome of intracapsular vs. extracapsular fracture sequelae according to Boileau[3]

	Intracapsular (n = 27)	Extracapsular (n = 17)	*P* value
ACS (points)	61 (43-80)	54 (19-71)	.0001
RCS (%)	73 (55-94)	56 (27-85)	.0003
SSV (%)	75 (50-95)	54 (5-85)	.002
Pain (VAS-CS)	13 (6-15)	10 (4-15)	.009
Satisfaction average (value)	3.5	2.7	.01
4 = excellent	14 patients	5 patients	
3 = good	12 patients	4 patients	
2 = moderate	1 patient	6 patients	
1 = poor	0 patient	2 patients	

ACS, absolute Constant score; *RCS*, relative Constant score; *SSV*, subjective shoulder value; *VAS-CS*, visual analog scale in Constant score.

Table V Patients with extracapsular fracture sequelae with vs. without osteotomy of greater tuberosity during reverse total shoulder arthroplasty (RTSA)

	Tuberosity osteotomy (n = 9)	No tuberosity osteotomy (n = 8)	*P* value
ACS (points)	50 (31-71)	38 (19-54)	.07
RCS (%)	63 (47-75)	49 (27-57)	.02
SSV (%)	62 (5-85)	44 (15-80)	.17
Pain (VAS-CS)	11 (5-15)	9 (4-15)	.44
Satisfaction (value)	3.2	2.1	.02
4 = excellent	5 patients	0 patient	
3 = good	2 patients	2 patients	
2 = moderate	1 patient	5 patients	
1 = poor	1 patient	1 patient	

ACS, absolute Constant score; *RCS*, relative Constant score; *SSV*, subjective shoulder value; *VAS-CS*, visual analog scale in Constant score.

revision rates due to greater tuberosity nonunions and migrations or concomitant rotator cuff lesions have been reported.[1,2,6,10,21] Fusion is performed rarely and only seriously considered in infections that are difficult to treat or major neurologic deficits, specifically complete axillary nerve dysfunction. None of the patients in this study had either of these complications after ORIF of their original fracture.

The satisfactory outcome with a reasonably low complication and revision rate for RTSA for complex, acute fractures[14] or after failed hemiarthroplasty or total shoulder arthroplasty[28]

justifies the attempt to use RTSA also after failed ORIF, especially in elderly patients.

It was not unexpected that our patients had low functional scores and low satisfaction levels after their failed ORIF. Nevertheless, the dimension of improvement of their shoulder function and their subjective satisfaction was surprising and confirms in a much larger population the observations of Hussey et al.[16] The obtained results are slightly inferior but almost comparable to those obtained in primary fracture arthroplasty studies.[4,7,9,22,23]

Boileau described 2 categories of fracture sequelae of the proximal humerus that influence the outcome in anatomic total shoulder arthroplasty.[3] In our study, the patients with intracapsular fracture sequelae had statistically significantly better outcome than patients with extracapsular fracture sequelae. Within the group with extracapsular fracture sequelae, however, the patients who underwent greater tuberosity osteotomy yielded better outcomes than those without osteotomy and repositioning of a malunited greater tuberosity. Although only patients' satisfaction rates and RCS showed statistically significant differences, we consider these findings in an albeit small subpopulation interesting.

We are aware of the limitations of this study. One is the retrospective review without a matched control group. All patients undergoing shoulder arthroplasty are prospectively included in a database and systematically followed up clinically (Constant score, SSV, and satisfaction rate) and radiographically beginning preoperatively up to a minimum of 10 years. All treated patients have therefore been identified and included, so that a selection bias is excluded. The patients were operated on by 4 different surgeons, and the follow-up examinations were standardized but performed by specifically trained physicians different from the operating surgeon. The loss of follow-up (11%) refers to a clinical onsite visit with radiographic assessment. All 6 patients not reviewed personally could be contacted by phone, had not been revised, did not need revision, and were satisfied with the result but unwilling or unable to report for a follow-up visit. In this respect, a deselection bias is also excluded.

We have previously confirmed[14] that secondary greater tuberosity displacement is associated with an inferior outcome. Therefore, we analyzed the position of the greater tuberosity but could not find any patient with a secondary displacement or migration of the greater tuberosity after RTSA.

Compared with the outcome of patients with greater tuberosity migration after RTSA after acute proximal humeral fractures, the outcome (ACS, SSV, satisfaction rate, and pain) of the patients in this series is substantially better. Therefore, our data support that healing of the greater tuberosity in an anatomic position is a critical and indispensable element of any treatment, be it conservative or with ORIF, hemiarthroplasty, or total shoulder arthroplasty, not only if a secondary conversion to arthroplasty will eventually become necessary.

Notching appeared in almost every patient (93%) but did not correlate with functional or subjective outcome. The mean Constant score and SSV of the 10 patients with glenoid notching grade III or IV was 65 points and 75%, respectively, and averaged higher values than the total cohort, so that notching does not seem to be a factor associated with a worse outcome, at least not in the short-term outcome.

For revision surgery, after a prior emergency procedure, the periprosthetic infection (4%) and revision surgery (9%) rates can be considered acceptable. This might be due to thorough preoperative workup to exclude a pre-existing shoulder joint infection.

Conclusion

RTSA as a salvage procedure for failed ORIF of a proximal fracture of the humerus is a promising treatment option with low complication and revision rates. Patients with intracapsular fracture sequelae have statistically significant better outcomes after RTSA.

In case of extracapsular fracture sequelae, tuberosity osteotomy should be considered. Shoulder function, patient satisfaction, and pain levels can be reliably improved in 90% of the patients.

Disclaimer

Christian Gerber receives royalties from and is a consultant for Zimmer Inc (Warsaw, IN, USA). All the other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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