Reverse Shoulder Arthroplasty is Similar to Hemiarthroplasty to Manage Proximal Humeral Fractures in Elderly Patients: A Mid-Term Survival Retrospective Study

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Abstract

Background: The aim of the study was, firstly, to compare the 1) functional and 2) radiological outcomes of RSA with HA in elderly patients with acute proximal humeral fractures, secondly to compare the 3) mid-term survival of these two types of arthroplasty.

Methods: All patients treated by RSA or HA for acute proximal humeral fracture, in primary hospital center were retrospectively identified. The primary endpoint was absolute and weighted Constant-Murley score. We also performed a statistical survival analysis of Kaplan-Meier.

Results: Forty-nine patients were included in the clinical and radiological analysis and 141 patients were included in the survival analysis. At the final follow-up, the absolute Constant Score was higher in the RSA group, but there was no significant difference between HA and RSA groups, respectively 57.4 ± 21.8 *vs.* 65 ± 17.1 (p=0.184). However, the weighted Constant score was clinically and statistically significantly better in the RSA group (HA: 81.16 ± 28.9 *vs.* RSA: 108.04 ± 27.6; p=0.001). The estimated mean survival time was 50 ± 6 months in the RSA group and 64 ± 8 months in the HA group. The analysis of the survival curve of Kaplan-Meier did not show any significant difference between the HA and RSA groups (p=0.11).

Conclusion: By using an optimized surgical technique, with implants designed for trauma, RSA can be the first option in the management of complex proximal humeral fractures in patients older than 65.

Level of evidence: IV, retrospective study.

Keywords: Hemiarthroplasty; Reverse shoulder arthroplasty; Survival rate; Functional outcome; Humeral fracture

Introduction

The prevalence of proximal humeral fractures is increasing and constitutes a major public health problem. It currently is the third most common fracture in people over 65 [1]. Undisplaced or minimally displaced fractures can usually be traited non-surgically with good outcomes [2-4]. Displaced fractures may require surgical treatment [5]; however, the management of this trauma is currently not very consensual. Osteosynthesis by humeral locking plate or nail can permit stable fixation [6]. Nevertheless, in elderly patients due to osteoporosis and high risk of osteonecrosis or nonunion, complex proximal humeral fractures are managed with shoulder Hemiarthroplasty (HA) [7]. Yet, it's a surgical challenge to achieve a good HA following a fracture. Indeed, anatomic tuberosities reconstruction, humeral length and retroversion are often difficult to perform. Long follow-up studies highlight some limitations with this procedure [8], especially because functional outcomes of HA depend on the healing of tuberosities [9]. Thereafter, due to the success of Reverse Shoulder Arthroplasty (RSA) in the treatment of cuff tear arthropathy, it was proved to be a viable solution for elderly patients with 3- and 4-part fractures [10,11]. Functional outcomes seem to depend on the deltoid rather than on tuberosities healing and the rotator cuffs integrity. Furthermore, the recovery of patients is faster and they need less rehabilitation [12].

Although, Bonnevialle et al. [13] showed RSA after fracture offers good results in short-term and though their number is recently increasing with newly trained orthopedic surgeons [14,15] and with implants designed for trauma, HA remains the gold standard because survival after RSA is controversial [16,17].

The aim of this retrospective study was, firstly, to compare the 1) functional and 2) radiological outcomes of RSA with HA in elderly patients with acute proximal humeral fractures, secondly to compare the 3) mid-term survival of these two types of arthroplasty. Our hypothesis is that complex proximal humeral fracture in elderly patients should be managed with RSA.

Methods

Patient inclusion

From June 2007 to June 2017, all patients treated by RSA or HA for acute proximal humeral fracture, in primary hospital center were retrospectively identified by searching through our database for proximal humeral acute trauma.

Inclusion criteria were based on the Near classification [2] (a four-part fracture, or a three-part fracture with severe Comminution of the greater tuberosity, or a fracture-dislocation or a fracture that involved an articular split of the humeral head), in elderly patients over 60 years old, and who were all treated with a trauma shoulder arthroplasty. Exclusion criteria were a less than 12 months follow-up, a residence further than 150 km from the hospital, dementia or mental inability.

Indication to use RSA rather than HA was based on the patient's prior history of rotator cuff disease, severe tuberosity comminution preventing reconstruction, radiographic evidence of glen-humeral arthropathy or rotator cuff tear shown on preoperative CT-scan.

Patients were asked to come to our shoulder consultation. Those who could not come at the hospital were seen at home. Patients who did not answer to the meeting notice, after being convened once by postal mail and twice by phone, were considered loss of follow-up.

All patients signed an informed consent form and gave their approval for the use of clinical and radiographic data for scientific purposes.

Surgical technique

All arthroplasties were performed by a single shoulder surgeon, using cemented implants designed for fractures: Total Evaluative Shoulder System (T.E.S.S, BIOMET, Warsaw, US). All patients were operated under general anesthesia associated with an interscalene block, in the beach chair position, by a deltopectoral approach. Careful preservation between tuberosities and humeral shaft, and tenotomy-tenodesis of the long head of the biceps were first performed. In both groups, a suction drain was placed post-operatively for 48 h.

HA group: The Anatomic T.E.S.S Trauma Monobloc was implanted in every shoulder. The height of the implant was based on humeral medial calcar and the implant was placed at 20° of retroversion compared to the forearm with the elbow bent at 90° as described by Kirschnan et al. [18]. The choice of the size of the prosthetic head was always rounded to the smallest if the measurement of the native head was between two sizes. Centered head implants were always used; a cortico-spongy bone graft from the native head was impacted in hydroxyapatite and porous titanium corolla spaces. Tuberosities were sutured in anatomical position as described by Boileau et al. [9]

with:A horizontal non-absorbable suture using Max Braid (through rotator cuff and corolla holes, to fasten tuberosities to each other, to the bone graft and to the corolla) and a vertical non-absorbable suture using Mersuture (to fix tuberosities to humeral shaft). The rotator cuff was closed with non-absorbable suture. After surgery, the shoulder was fixed into internal rotation in an arm sling for 30 days and all patients were sent to a rehabilitation center. The postoperative rehabilitation followed Neer's program as described by Boileau et al. [19], with immediate passive rehabilitation and pendulum exercises. Active helped rehabilitation was started around the 21st day and active rehabilitation around the 45th day, after tuberosities consolidation.

RSA group: The Reverse T.E.S.S Trauma Monobloc was implanted in all shoulders. The same optimize surgical technique was used. The supraspinatus tendon was totally resected. The glenoid preparation included: The resection of labrum, the removal of glenoid osteophytes, the use of a cannulated glenoid reamer, centered beforehand by a Kirschner wire. The glenoid baseplate's size was always rounded to the smallest if the measurement was between two sizes. It was placed slightly next to the inferior glenoid border and with 10° of inferior tilt, and the inferior screw was always fixed first to decrease the risk of scapular notching. As the same, the height of the implant was based on humeral medial calcar and the implant was placed at 0° of retroversion. The polyethylene implant's size was chosen to optimize stability, laxity and deltoid tension. Then, tuberosities were fixed into anatomical position, as described previously, using if necessary cortico-spongy bone graft inserted around the hydroxyapatite reverse corolla. After surgery, shoulder was fixed into internal rotation in a sling for 30 to 45 days, with an abduction cushion during the first 21 days, and all patients were sent to a rehabilitation center. The rehabilitation was shorter than the HA group, with active reeducation beginning earlier, around the 21st day.
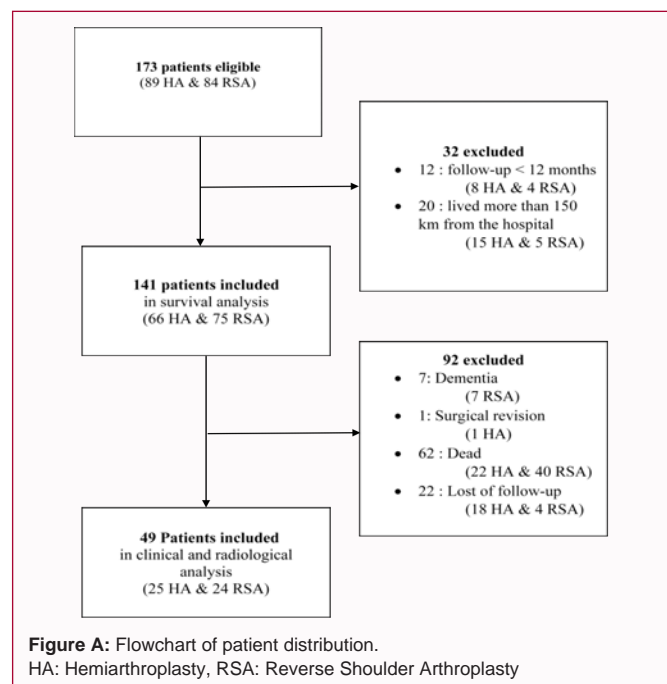
Clinical outcome measures

Clinical examination was performed by an independent assessor, not involved with the surgical treatment of these patients. The primary endpoint was absolute Constant-Murley score and weighted Constant-Murley score, adjusted for age and gender [20]. Strength was measured with the arm at 90° anterolateral elevation while maintaining resisted elevation against a conventional spring balance dynamometer. Range of Motion (ROM) was measured using a digital goniometer.

Radiographical analysis

Radiological assessment was performed by an independent radiologist. Standard X-rays included a true Anteroposterior (AP) view in neutral rotation and a Lamy's profile view. Tuberosities' healing was graded as healed or non-union (evidence of a fracture line on the X-ray, evidence of tuberosity resorption or superior/posterior migration). Humeral and glenoid component loosening was measured using the grading system described by Sperling et al. [21]. Heterotopic ossifications were assessed using Sneppen et al. classification [22]. In cases in which tuberosities nonunion or implant loosening were suspected, a CT scan was performed. For the RSA group, inferior scapular notching was classified by Nerot's classification [23].

Survival analysis

We performed a statistical survival analysis of Kaplan-Meier. The starting-point was the date of the initial surgical procedure. Specific events were death or surgical revision. Data were censored if patients

Figure A: Flowchart of patient distribution.
HA: Hemiarthroplasty, RSA: Reverse Shoulder Arthroplasty

Figure B: The statistical survival curve of Kaplan-Meier represents the probability (Y-axis) of surviving a given length of time (X-axis).

reached the end of the study, developed dement or were lots of follow-up.

Statistical analysis

Based on the postoperative Constant score published, we calculated the sample size needed to have 2 comparable groups with a Constant Score difference of 10.4 [24], a power of 80% and a α risk of 5%; 25 patients were required in each group. Statistical analysis was performed by an independent statistician. For the clinical and radiological analysis, we performed per-protocol analysis, so patients who underwent surgical revision were excluded. Qualitative variables were compared using the Khi-deux and Fisher test to detect differences between preoperative and postoperative values. The student's t-test was used for quantitative variables. Regarding the survival analysis, we did an intention to treat analysis. The log-rank test was used to compare survival curves. The hazard ratio with its 95% Confidence Interval (CI) was calculated to compare the survival rate between the two groups. Statistical analysis was performed for all data using a SPSS software (SPSS, Chicago, Illinois). A p value of 0.05 was considered as statistically significant.
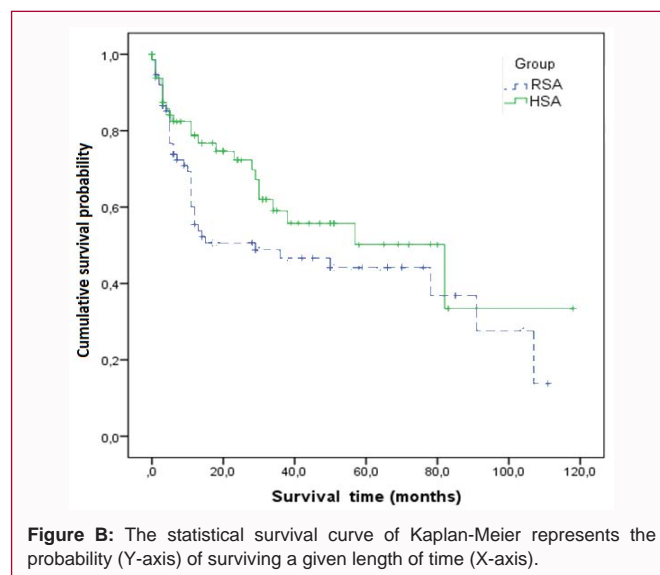
Results

Epidemiological data

Patient distribution is figured on the flowchart (Figure A).

In total, 173 patients (89 HA et 84 RSA) were treated with a trauma shoulder arthroplasty during the studied period.

First, 32 patients were excluded from the survival analysis: 12 because their follow-up lasted less than 12 months and 20 because they lived more than 150 km away from the hospital. In the end, 141 patients were included in the survival analysis.

Then, 92 patients were furthermore excluded from clinical and radiological analysis: 62 died, 7 developed dementia, 1 needed surgical revision and 22 were lots of follow-up.

Thus, 49 patients were evaluated. The RSA group included 24 patients with a mean age of 88.25 years old and a mean follow-up of 54.25 ± 24.8 months (range, 13-111); The HA group included 25 patients with a mean age of 71.68 years old and a mean follow-up of 46.84 ± 25.9 months (13-116).

Patients were significantly older in the RSA group than in the HA group (p=0.0001). There was no significant difference between the two groups for the near classification, sex or surgical shoulder dominant side (Table A).

Question 1: Clinical results

Constant score: In the final follow-up, the absolute Constant Score was higher in the RSA group, but there was no significant difference between the HA and RSA groups, respectively 57.4 ± 21.8 versus 65 ± 17.1 (p=0.184). However, the weighted constant score was clinically and statistically significantly better in the RSA group (HA: 81.16 ± 28.9 *vs.* RSA: 108.04 ± 27.6; p=0.001). Detailed comparison of the four dimensions of the Constant score is shown in Table B. The pain dimension (HA: 10.8 ± 3.3 *vs.* RSA: 13.6 ± 2.6; p=0.001) and the activity dimension (HA: 13 ± 4.4 *vs.* RSA: 16.1 ± 3.6; p=0.010) were significantly better in the RSA group.

Range of motion: There was no significant difference between the 2 groups for anterior elevation, abduction, External Rotation (ER1) or internal rotation.

Question 2: Radiographical outcomes

Among all patients, 24 patients in the HA group and 14 patients in the RSA group had an X-ray acquisition at the final follow-up.

There were 7 (29%) cases of non-union tuberosities in the HA group, and 3 (21%) cases in the RSA group. All were confirmed by CT scans.

Adjusted to tuberosities status, the Constant score was significantly higher when tuberosities were healed in the HA group (healed: 66.5 *vs.* non-union: 39.64; p=0.0035), when it had no significant influence in the RSA group (healed: 67 *vs.* non-union: 46; p=0.07) (Table C).

There were 3 (21%) cases of heterotopic ossification in the RSA group; all were graded 1 by the Sneppen classification. No heterotopic ossification was noted in the HA group.

There were no cases of component loosening in the 2 groups.

In the RSA group, there were 4 (28%) cases of low grade of inferior

Table A: Characteristics of the compared groups.

Criteria	HA group n=25	RSA group n=24	P value
Follow-up (months)	46.84 ± 25.9 (13-116)	54.25 ± 24.8 (13-111)	0.13
Age (years)	71.68 ± 10.59 (61-91)	88.25 ± 4.95 (76-96)	0.0001*
Gender (Male/Female)	8/17 (32%/68%)	3/21 (12%/88%)	0.2
Neer classification (3-part/4-part)	2/23 (8%/92%)	3/21 (12%/88%)	0.5
Arthroplasty on dominant side (yes /no)	13/12 (52%/48%)	14/10 (58%/42%)	0.2

HA: Hemiarthroplasty, RSA: Reverse Shoulder Arthroplasty, Quantitative data are expressed as mean ± standard deviation (range), qualitative data are expressed as effective (percentage). * Significant (<0.05)

Table B: Objective clinical result at the final follow-up.

	HA group n=25	RSA group n=24	P value
Constant Score			
Pain (/15 points)	10.8 ± 3.3	13.6 ± 2.6	0.001*
Activity (/20 points)	13 ± 4.4	16.1 ± 3.6	0.010*
Mobility (/40 points)	23.2 ± 8.7	24.7 ± 7.6	0.534
Strength (/25 points)	10.6 ± 9.1	10.7 ± 6.2	0.947
Absolute (/100 points)	57.4 ± 21.8	65 ± 17.1	0.184
Weighted (%)	81.2 ± 28.9	108 ± 27.6	0.001*
Range of Motion			
Active anterior elevation (°)	111 ± 35.7	110 ± 27.5	0.913
Abduction (°)	102.6 ± 32.3	103.7 ± 24.2	0.889
Active external rotation 1 (°)	43.8 ± 25.2	49.4 ± 25.2	0.443
Active internal rotation (°)	51.2 ± 23.9	58.3 ± 22	0.283

* Significant result (<0.05)

Table C: Influence of tuberosities healing on the Constant score.

Absolute Constant score (/100 points)	Tuberosity healed	Tuberostity non-union	p
HA group (n=24)	66.5 (n=17)	39.64 (n=7)	0.0035*
RSA group (n=14)	67 (n=11)	46 (n=3)	0.07

n: number of patients in each group
*significant result (<0.05)

Table D: Comparison of survival curves.

	RSA	HA
Sample size (number)	75	66
Event (number, proportion)	40 (53%)	24 (36%)
Censored (number, proportion)	35 (47%)	42 (64%)
Estimated mean survival time (months, mean ± SD)	50 ± 6	64 ± 8

scapular notching (3 grade 1 and 1 grade 2 on Nerot's classification)

Question 3: Survivorship

The survival analysis is represented by Figure B and Table D. In the final follow-up, the estimated mean survival time was 50 ± 6 months in RSA group and 64 ± 8 months in HA group. The analysis of the actuarial survival curve of Kaplan-Meier didn't show a significant difference between the HA and RSA groups (p=0.11). Globally, there was about 20% of death at 6 months after a complex proximal humeral fracture, whatever the arthroplasty (HA or RSA), and despite the fact that patients were significantly younger in the HA group. The hazard ratio was calculated at 0.6691 (95% CI, 0.4096 to 1.0930) favoring HA. However, this hazard ratio was not significant as the confidence interval did include the value 1 (corresponding to equal hazards).

Discussion

Main results

This study compares the functional and radiological outcomes of RSA *vs.* HA in elderly patients with acute complex proximal humeral fractures. After 50 months of follow-up, weighted constant score, pain and activity dimensions of the absolute constant score were significantly better in the RSA group compared to the HA group. Moreover, there were less radiological complications in this former group. The study also compares the mid-term survival rate of these two kinds of arthroplasty, which was not significantly different.

Limitations

Because of its retrospective and monocentric design, this study has several limitations. Due to the acute nature of the shoulder

fractures, the preoperative constant score was unknown. To decrease this bias, we chose to normalize the post-operative data by using the weighted constant score, adjusted to age and gender.

Furthermore, there was small sample size in each group. But before the study, we performed a sample size calculation to have enough statistical power. Moreover, the attrition bias is significant as there were a consequent number of losses of follow-up. This is due to the age of the patients and the low survival rate of the victims of this kind of lesion. We tried to limit it by doing an intention to treat analysis for survival and a per protocol analysis for clinical and radiological outcome analysis.

Finally, to our knowledge, this comparative cohort of elderly patients is one of the largest studies in the literature with a sufficient follow-up to draw a conclusion about the survival rate.

Question 1: Clinical results

Although previous studies, comparing the outcome of these 2 procedures, remain limited by short follow-up or small numbers, it seems they indicate that the RSA offers better outcomes than the HA. Bonnevialle et al. [13] on his retrospective, multicentric study, comparing 57 HAs and 41 RSAs at a mean follow-up of 39 months, found, like our study, no difference in the constant score but showed significantly higher weighted constant score, adjusted to age and gender. Three other retrospective studies with mean follow-ups between 12 months and 5 years attested that the RSA significantly outperform the HA using different validated scores. These results were confirmed by some meta-analysis [25-30]; except one which found no difference in the ASES score (291 HAs and 110 RSAs) and a significantly higher Constant score for the HA group (420 HAs and 157 RSAs) at an average follow-up of 40 months [31]. Our study also shows better outcomes for the RSA at 54 months of follow-up. This result is all the more significant and surprising because the HA group was younger and in better health. Indeed, patients who benefited from a RSA were necessarily older, in poorer health and with poorer bone quality which predicted a worst result. Prospectively, Sebastia-Forcada et al. [32]. Compared 31 HAs and 31 RSAs with an average follow-up of 29.4 months, and Cuff et al. [33]. Compared 23 HAs and 24 RSAs with an average follow-up of 30 months: They found not only significant better functional results in favor of RSA, but they also found significantly higher ROM in the RSA group for forward elevation and abduction. This difference in abduction and forward elevation is also reported in others publications [13,25,27,29,31]. Results are more controversial concerning the active external rotation. As in our study, most of the authors did not report significant difference in ER1 [13,29,33-35]. Ferrel et al. [31], and Gallinet et al. [25], attested that ER1 was significantly lower in the RSA group than in the HA group. However, they used a surgical technique which consisted in removing rotator cuff and tuberosities for all cases in the RSA group. Sebastia-Forcada et al. [32] was the only one who showed significantly higher ER1 for the RSA group, probably because: Tuberosities were all sutured into anatomical position [23,36], they used implants designed for trauma allowing bone graft between implant and tuberosities, and all patients from the RSA group were sent to a rehabilitation center, allowing quick recovery of ER1 under the control of physiotherapists. Those factors have not been verified in our study, but we think that they are of prime importance. It confirms that ER1, considered as one of the weaknesses of the RSA, is actually similar to the HA.

Question 2: Radiographic results

As described by Boileau et al. [9], functional results of HA are more variable than RSA's and highly dependent on tuberosities status. Indeed, our results show a bimodal distribution of functional results in the HA group: Tuberosities healing improves significantly the constant score in the HA group, whereas there is non-significant difference in the RSA group, whether the tuberosities are healed or not. Furthermore, in our study, tuberosities healing seems better in the RSA group than in the HA group (80% vs. 70% respectively). Wang et al. [35] showed that it can be explain by the biomechanics of RSA: Forward elevation and abduction depend more on the deltoid muscle rather than on the rotator cuff, and so it minimalizes the risk of tuberosities' non-union. Moreover, Robinson et al. [37] described that functional results of HA are deteriorated if surgery occurs after 70 years old, because of higher risk of degenerative rotator cuff tear and poor bone quality, increasing the risk of tuberosities' non-union. So, as it had been proven by several authors, RSA seems to be a reproducible procedure [10,13,23,25], and less dependent on the tuberosities' healing. Moreover, as suggested Nyffeler et al. [38] to avoid scapular notching, we used implants designed for trauma allowing the surgeon to place the glenoid base plate flush with inferior glenoid border, with 10° of inferior tilt, and including lateralization of 3 mm of rotation center to optimize external rotation and abduction strength [39]. We did not find any component loosening, but nevertheless we still had almost 30% of low-grade scapular notching at final follow-up. It would be necessary to perform other studies analyzing the impact of low-grade scapular notching on the long-term functional outcome.

Question 3: Survivorship

Data concerning mid-term survivorship after trauma shoulder arthroplasties is scars in current literature. Sebastia-Forcada et al. was the only one to compare survival rates between 31 HAs and 31 RSAs, with a short follow-up of 29 months on his recent study [32]. They demonstrated a longer survival rate for RSA compared to HA, while taking into account revision only or revision and clinical failure as events. This result is similar to ours. We considered revision or death as events because patients who present complex proximal humeral fracture are frail and with a lot of comorbidities, that leads them to be susceptible to a short-term survival [40,41]. By doing so, we are closer to the real survival rate of elderly patients after arthroplasty than if we only considered revision. Our low revision rate in the HA group, even if the functional outcome was significantly lower than in the RSA group, can be explained by the fact that patients and physicians are ready to accept the poor outcome instead of choosing revision. Moreover, an often-advanced argument to implant HA rather than RSA is that it's easier to revise a HA than an RSA. Nevertheless, Levy et al. [42] found that in the case of a revision of failed HA by RSA, despite an improvement on pain and function, the complication rate was up to 28%. Furthermore, Sebastia-Forcada et al. [32] found an unsuccessful outcome after revision of failed HA by RSA. In total, in our study, as survival of shoulder arthroplasty after a fracture using a trauma design didn't show a significant difference between the HA and RSA groups, while the RSA group is significantly older, it seems to imply the superiority of RSA in the management of complex proximal humeral fracture in elderly patients. This can compensate the fact that the RSA's cost is significantly higher than the HA's as shown Solomon et al. [43].

Conclusion

By using an optimized surgical technique, with implants designed for trauma, mid-term functional and radiological outcome of RSA is

significantly better than HA for complex proximal humeral fractures in elderly patients.

This superiority is maintained over time as the mid-term survival of those two types of arthroplasty appears non-significantly different.

These results suggest that RSA can be the first option in the management of complex proximal humeral fractures in patients older than 65.

A long-term survival prospective study seems adequate to confirm that RSA is the best procedure, and should be the first intention method used to treat this lesion.

Contribution

JV, CM: study design, data acquisition, data analyses, and manuscript preparation. DR, BZ: study conception, data acquisition, and critical revision.

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