Influence of the Consolidation of the Tuberosities on the Clinical Outcomes of the Reverse Arthroplasty in Proximal Humerus Fractures

Luciano A. Rossi, Camila Juana, Cecilia Fieiras, Rodrigo Brandariz, Ignacio Tanoira, Maximiliano Ranalletta
Shoulder Pathology Sector, Orthopedics and Traumatology Service, Institute of Orthopedics and Traumatology "Prof. Dr. Carlos E. Ottolenghi", Hospital Italiano de Buenos Aires, Autonomous City of Buenos Aires, Argentina

ABSTRACT

Objective: The objective of this study was to compare the clinical outcomes and complications of a consecutive series of patients with proximal humerus fractures (PHF) treated with reverse shoulder arthroplasty (RSA), with and without anatomical healing of the tuberosities. **Materials and Methods:** We evaluated 113 patients >65 years old with PHF treated with RSA. Seventy patients presented anatomical healing of the tuberosities and 43 presented absence of healing. Range of motion (ROM), Constant score, ASES score, visual analog scale (VAS) and the score of the numerical evaluation of single evaluation (SANE) were evaluated. **Results:** The mean follow-up was 56 months (range, 24-96 months) and the mean age was 73 years (range, 65-83 years). Mean postoperative active elevation and internal rotation were 131° (±14) and 27° (±5), respectively. The mean postoperative external rotation in abduction and adduction was 27° (±1) and 15° (±6) respectively. The mean postoperative VAS was 1.7 (±0.8). The mean ASES, Constant and SANE scores were 76 (±6), 62 (±11) and 74% (±7), respectively. Anterior elevation, external rotation, and final mean ASES and Constant functional scores were significantly better in the group with tuberosity healing than in the group without healing. **Conclusions:** In patients >65 years old with PHF treated with RSA, both postoperative ranges of motion and functional scores were significantly better in patients where anatomic tuberosity healing was achieved than in those where it was not achieved.

Key words: Proximal humerus fracture; reverse arthroplasty; tuberosities reconstruction.
Level of Evidence: III

Influencia de la consolidación de las tuberosidades en los resultados clínicos de la prótesis invertida para fracturas de húmero proximal

RESUMEN

Objetivo: Comparar los resultados clínicos y las complicaciones de una serie consecutiva de pacientes con fracturas de húmero proximal tratados con prótesis invertida de hombro y con consolidación anatómica de las tuberosidades o sin ella. **Materiales y Métodos**: Se evaluó a 113 pacientes >65 años con fractura de húmero proximal tratados con prótesis invertida de hombro. Setenta presentaron consolidación anatómica de las tuberosidades y 43, ausencia de consolidación. Se evaluó el rango de movilidad, y se utilizaron los puntajes de Constant-Murley, ASES, SANE y la escala analógica visual. Se documentaron todas las complicaciones y las reoperaciones. **Resultados:** El seguimiento promedio fue de 56 meses (rango 24-96) y la edad media era de 73 años (rango 65-83). La elevación activa y la rotación interna medias posoperatorias fueron 131° (± 14) y 27° (± 5), respectivamente. La rotación externa posoperatoria media en abducción y aducción fue 27° (± 1) y 15° (± 6), respectivamente. La escala analógica visual promedio posoperatoria fue de 1,7 (± 0,8). Los puntajes ASES, de Constant-Murley y SANE promedio fueron 76 (± 6), 62 (± 11) y 74% (± 7), respectivamente. La elevación anterior, la rotación externa y los puntajes funcionales promedio finales ASES y de Constant-Murley fueron significativamente mejores en el grupo con consolidación de las tuberosidades. **Conclusiones:** En pacientes >65 años con fractura de húmero proximal tratados con prótesis invertida de hombro tanto la movilidad posoperatoria, como los puntajes funcionales fueron significativamente mejores en los pacientes con consolidación anatómica de las tuberosidades.

Palabras clave: Fractura de húmero proximal; prótesis invertida; reconstrucción tuberositaria.
Nivel de Evidencia: III

Received on December 26th, 2021. Accepted after evaluation on February 23rd, 2022 • Dr. LUCIANO A. ROSSI • luciano.rossi@hiba.org.ar https://orcid.org/0000-0002-1397-2402

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INTRODUCTION

Although the majority of proximal humerus fractures (PHF) in patients >65 years of age improve with conservative treatment, a subgroup of complex fractures is associated with poor functional outcomes and a high rate of complications, such as nonunions and malunions .[1,2] This subgroup includes four-part fractures with comminution of the tuberosities, dislocation fractures, and fractures that present a split of the humeral head.[1-3]

Osteosynthesis of these fracture subgroups is also associated with suboptimal outcomes, mainly at the expense of a high rate of implant-related complications, such as osteosynthesis failure and secondary osteonecrosis.[4] Another alternative proposed for the management of these complex fractures was the replacement of the humeral head with a hemiarthroplasty.[5] However, a disadvantage of this procedure is that it depends entirely on the anatomical consolidation of the tuberosities for its normal function.[5] This is often a challenge in the context of complex fractures in patients with osteoporotic bone, often with comminution or very poor bone quality for reconstruction around the implant. Boileau et al. evaluated 66 patients treated with hemiarthroplasty for displaced PHF and reported that 50% of patients had tuberosity malposition on the final evaluation radiograph. This was associated with unsatisfactory outcomes, superior migration of the prosthesis, stiffness, and persistent pain.[6]

The unpredictable outcomes of osteosynthesis and hemiarthroplasty in this subgroup of patients have motivated different surgeons to use reverse shoulder arthroplasty (RSA) to manage these complex patterns.[7] By using mainly the deltoid for its normal function, the RSA does not depend on the consolidation of the tuberosities to achieve a good clinical outcome.[8,9] However, the main external and internal rotators of the shoulder insert at the greater tuberosity and lesser tuberosity, respectively. Therefore, some authors argue that, despite the main driver of RSA being the deltoid, every effort should be made to reconstruct the tuberosities and achieve the best possible postoperative function.[10,11]

The objective of this study was to compare the clinical outcomes and complications of patients with PHF treated with RSA, with or without anatomical consolidation of the tuberosities.

MATERIALS AND METHODS

A comparative retrospective cohort study was carried out. All patients who had undergone a RSA for the treatment of a PHF at our institution between January 2013 and February 2019 were screened for inclusion in this study. The information for the development of the study was obtained from the registry of shoulder arthroplasties of our institution. Initially, 160 patients were identified for inclusion in the study.

Selection criteria

Inclusion criteria were patients >65 years of age with acute PHF (<4 weeks from injury), treated with RSA, and a minimum follow-up of two years. Exclusion criteria were patient death or loss to follow-up and RSA due to fracture sequelae (nonunion or malunion). 37 patients were excluded: 20 had been treated for fracture sequelae (14 nonunions, 6 malunions), eight had died, five were <65 years old, and four developed severe dementia and were hospitalized for which evaluation was impossible. Additionally, 10 patients were lost to follow-up. Thus, 113 patients were eligible for inclusion in the study: 70 with anatomical consolidation of the tuberosities and 43 without consolidation. Preoperative radiographs and computed tomography were reviewed to classify fracture patterns according to the Neer classification.[12]

Surgical technique

The surgery was performed by three shoulder surgeons from our institution who used the Biomet reverse shoulder prosthesis (Biomet Comprehensive® Shoulder System). The patients were operated in the beach chair position. All prostheses were implanted using a standard deltopectoral approach. Once the tuberosities were located, they were secured using nonabsorbable sutures through the tendinous insertion. For the glenoid preparation, the metaglene guide was aligned with the inferior glenoid rim with a 10° inferior tilt. The metaglene was impacted into the glenoid and fixed with a central cortical screw and four peripheral locking screws. After inserting the metaglene, the chosen glenosphere was inserted. The size of the glenosphere (36mm or 40mm) was chosen based on the size of the patient. The humeral medullary canal was reamed to the appropriate size. All placed stems were cemented and a cement restrictor was placed in the humeral canal at an

appropriate depth for the selected stem. Humeral prostheses were placed at 20° retroversion and mini-stems were used in all patients. The humeral stem was cemented into the humeral shaft after creating two holes in the lateral cortex of the humerus and passing non-absorbable sutures through these holes. Once the stem was cemented, the polyethylene trial was inserted. The intraoperative stability of the implant was then confirmed and the patient was found to have full passive range of motion. After verifying that these two conditions were met, the definitive polyethylene was placed. Tuberosity reconstruction was performed in a standardized manner in all patients. To do this, the tuberosities were first tied to the diaphysis with two vertical sutures. Two horizontal cerclage sutures were then tied to compress the anatomically reduced tuberosity onto the humeral stem (Figure 1). The wound was then closed, first the muscle plane, then the subcutaneous cell tissue, and finally the skin. No drains were placed.

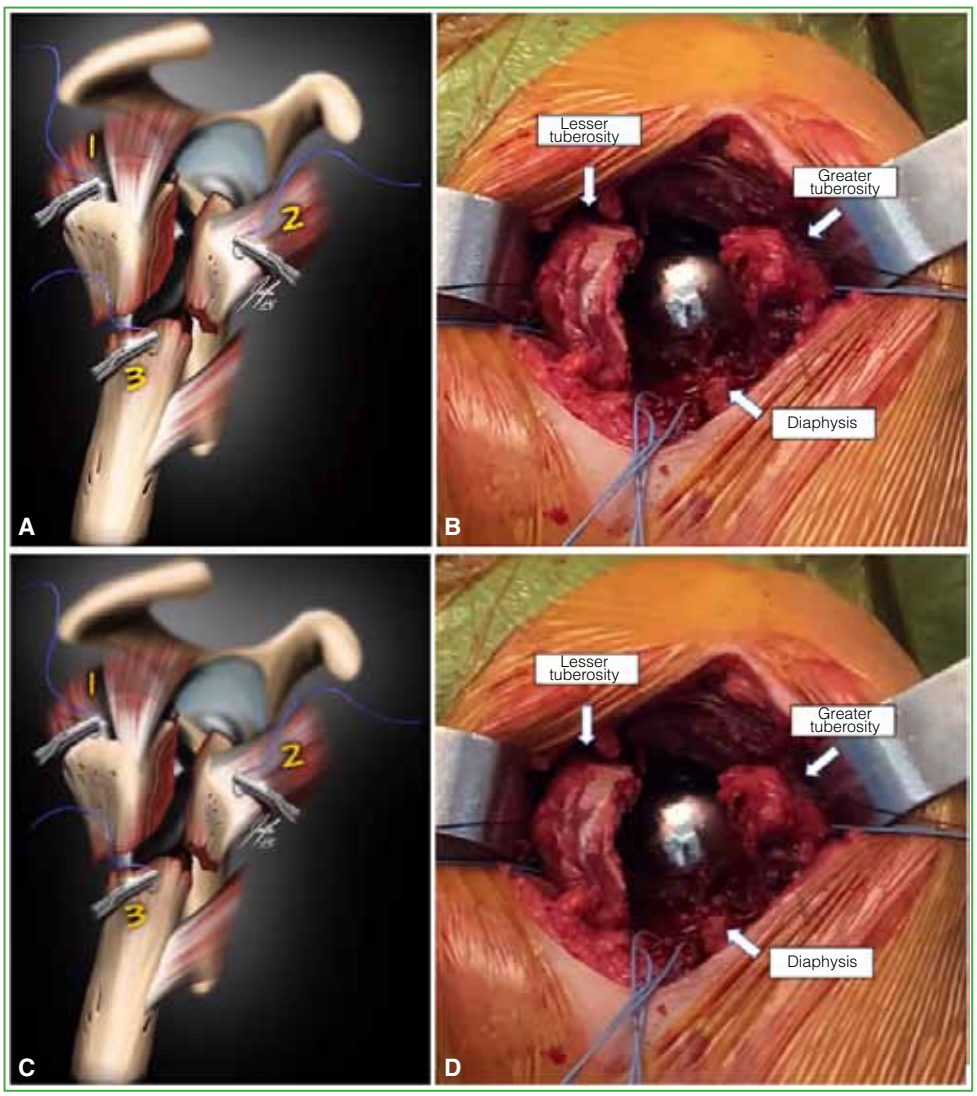

Figure 1. **A.** Illustration. **B.** Intraoperative image of the tuberosities before their reconstruction. **C.** Illustration. **D.** Intraoperative image of the reconstructed tuberosities around the prosthesis.

Rehabilitation protocol

All patients were treated with the same postoperative rehabilitation protocol. They were immobilized with a shoulder sling for a period of four weeks and were encouraged to perform active elbow, wrist and hand movement exercises. In the fifth week, the sling was removed and passive shoulder range of motion exercises with limited forward flexion to 90° were indicated for two weeks. Active range of motion exercises started at 6-8 weeks postoperatively and were followed by strength and coordination training.

Clinical and radiographic evaluation

Postoperative controls were performed at 2-week, 4-week, 3-month, 6-month, and 12-month intervals, and annually thereafter. Each postoperative evaluation included a clinical examination and radiographic images of anteroposterior and lateral incidences of the shoulder. Assessments at each visit from the third month onwards included: range of motion, Constant-Murley, ASES (American Shoulder and Elbow Surgeons) and SANE (Single Assessment Numeric Evaluation) scores, and visual analog scale (VAS). Anatomic consolidation of the tuberosities was defined as bony union of the healed greater tuberosity visible on the anteroposterior radiograph in neutral rotation (Figures 2 and 3).[10]

Radiographic evaluations were performed by two independent physicians (LR and IT). In case of discrepancy, the presence of anatomical consolidation was defined by consensus between the two evaluators.

All intraoperative and postoperative complications and reoperations were documented.

Figure 2. Anteroposterior left shoulder radiographs of a fracture of the left proximal humerus, in the preoperative period (**A**) and one year after surgery with a reverse prosthesis (**B**). The anatomical consolidation of the tuberosities is observed.

Figure 3. Anteroposterior radiograph of the right shoulder, preoperative (A) and one year after surgery for a fracture of the right proximal humerus treated with an reverse arthroplasty. Resorption of the tuberosities is observed.

Statistical methodology

Continuous variables are presented as means and standard deviations, and categorical variables as absolute and relative frequencies. Patient characteristics were compared between the 'with anatomical union' and 'without anatomical union' groups using the χ^2 test and the t-test for categorical and continuous variables. To calculate differences in range of motion and functional scores between groups, Student's independent t-test was used. It was considered statistically significant at a p value <0.05.

Statistical analysis was performed with the STATA MP version 16 program (Stata Corporation, College Station, TX, USA).

RESULTS

The mean follow-up was 56 months (range 24-96) and the mean age was 73 years (range 65-83). 62% were women (70 patients) and 38% were men (43 patients). There were no significant differences between the anatomical union and non-union groups in terms of patient and injury characteristics (Table 1).

Table 1. Comparison of baseline clinical characteristics between patients with and without consolidation of the tuberosities

	Group 1 Consolidation (n = 70)	Group 2 No consolidation (n = 43)	p
Age, mean (SD), years	73.7 (7)	74.1 (8)	0.6484*
Dominant limb, n (%)	40 (57%)	24 (56%)	0.6132#
Women, n (%)	42 (60%)	28 (65%)	0.8518#
Body mass index, mean (SD)	30.2 (7)	29.9 (9)	0.4273*
Operated side: right, n (%)	36 (51%)	23 (53%)	0.9759#
ASA score, n (%) II III	 31 (44%) 39 (56%)	 20 (47%) 23 (53%)	0.8513#
Follow-up, mean (SD), months	55.1 (8.2)	58.3 (9.5)	0.0827*
Fracture classification			
4 parts, n (%)	25 (36%)	11 (26%)	
3 parts, n (%)	30 (43%)	19 (44%)	
Fracture dislocation, n (%)	10 (14%)	10 (23%)	
Head *split* , n (%)	5 (7%)	(7%)	

ASA = *American Society of Anesthesiologists*.
*t-test for independent samples with similar variances.
#$\chi 2$ test.

Overall, mean postoperative active elevation and internal rotation were 131° (±14) and 27° (±5), respectively. Postoperative mean external rotation in abduction and adduction was 27° (±1) and 15° (±6), respectively. The mean postoperative VAS score was 1.7 (±0.8). The mean postoperative ASES, Constant-Murley, and SANE scores were 76 (±6), 62 (±11), and 74% (±7), respectively. 85% of patients reported being satisfied with the procedure. Anterior elevation, external rotation, and endpoint mean Constant-Murley and ASES functional scores were significantly better in the group with tuberosity union than in the group without union (Table 2). There were 13 complications (11.5%), eight in the group with consolidation (11%) and five in the group without consolidation (12%) (p = 0.579) (Table 3).

Table 2. Comparison of functional outcomes between patients with and without tuberosity consolidation

	Group 1 Consolidation (n = 70)	Group 2 No consolidation (n = 43)	p
Active elevation	137° (19)	120° (11)	<0.001*
External rotation, abduction	36° (9)	23° (8)	<0.001*
External rotation, adduction	22° (7)	13° (7)	0.0187*
Internal rotation, adduction	28° (6)	26° (7)	0.7803*
VAS for pain	1.6 (0.6)	1.8 (0.9)	0.0791*
ASES score	78 (6)	65 (6)	<0.001*
Constant score	64 (9)	53 (8)	<0.001*
SANE score, % Satisfaction, %	79% (9) 87% (8)	73% (9) 84% (7)	0.4052* 0.6752*

VAS = visual analog scale, ASES = *American Shoulder and Elbow Surgeons*, SANE = *Single Assessment Numeric Evaluation.*
Data are presented as mean (standard deviation).
*T test for independent samples with similar variances.

Table 3. Comparison of complications between patients with and without union of the tuberosities.

	Total (n = 13)	Group 1 Consolidation (n = 8)	Group 2 No consolidation (n = 5)	Treatment
Complications				
Dislocation	4	2	2	Liner change
Periprosthetic fracture	3	2	1	ORIF&
Periprosthetic infection Neuropraxias	3 2	2 1	1 1	2-stage revision Control
Loosening of the glenosphere	1	1	0	Glenosphere change
Radiographic findings				
Notching#	4	3	1	Asymptomatic
Humeral radiolucency*	4	2	2	Asymptomatic

ORIF= open reduction and internal fixation.
#According to Sirveaux et al.[13]
*According to Sanchez-Sotelo et al.[14]

DISCUSSION

There were two main findings in our study. First, although RSA in the elderly with PHF was generally associated with favorable clinical outcomes and high satisfaction rates, both postoperative range of motion and functional scores were significantly better in patients with anatomical union of the tuberosities than in those without it. Secondly, regarding complications and reoperations, no significant differences were found between the groups analyzed.

In the last decade, RSA has become the first surgical option for the treatment of complex PHF.[7] RSA surgery for PHF increased 406% between 2005 and 2012 and, in 2013, surpassed hemiarthroplasty in patients >65 years of age.[15,16] While hemiarthroplasty and open reduction and internal fixation of fractures are based on the activation of the coupling of force and compression of the concavity through the rotator cuff attachments on the tuberosities, RSA uses the deltoid as the driving force, bypassing the rotator cuff to some extent.[17,18] However, some studies have shown better results in postoperative rotation when anatomic reduction of the tuberosities was achieved, as the compression of the concavity provided by the rotator cuff optimized the function of the larger muscle groups around the shoulder, added to the action of the rotator cuff as an internal and external rotator itself.[19,20]

In our study, the majority of patients obtained favorable postoperative clinical outcomes. The mean postoperative VAS score was 1.7, and the mean postoperative ASES and Constant-Murley scores were 76 and 62, respectively. In addition, 85% reported being satisfied with the procedure. However, anterior elevation, external rotation, and mean endpoint ASES and Constant-Murley functional scores were significantly better in the tuberosity union group than in the group without union. The clinical advantages of tuberosity consolidation in this type of patient have also been published by other authors.[10,11]

In a 2019 meta-analysis, Jain et al. compared the clinical and functional outcomes of RSA in PHF with and without union of the tuberosities.[11] The authors evaluated seven studies including 381 patients and found that patients with consolidated tuberosities had significantly better active anterior elevation (134° vs. 112°), abduction (114° vs. 95°), external rotation (27° vs. at 7°) and Constant-Murley score (63 vs. 56) ($p < 0.05$) than those with unconsolidated tuberosities.[11] In a more recent similar meta-analysis, O'Sullivan et al. evaluated 21 studies with 873 patients and compared the results in patients with and without union of the tuberosities.[10] Patients with healed tuberosities had 18° greater active anterior elevation ($p = 0.008$) and 16° greater external rotation ($p < 0.001$) than those with unhealed tuberosities.

In a recent meta-analysis of the literature, complications associated with the treatment of PHF with RSA were analyzed. The authors reported a complication rate of 5.5% and 9.7% with uncemented and cemented reverse shoulder prostheses, respectively.[21] In our study, the complication rate was 11.5% and did not vary between the two groups (11% and 12%). We believe it is important to highlight that RSA for the management of PHFs has a long learning curve that implies performing at least 20 procedures.[22] Therefore, we believe that this type of surgery should be performed by surgeons with experience in trauma and shoulder joint reconstruction to achieve optimal results.

This study has some limitations that should be mentioned. First, all patients received the same implant. This has the advantage that the series evaluated is more homogeneous, but the results obtained with this implant cannot be generalized to all the reverse prosthesis designs available on the market. Thus, it was not possible to assess the implications of variations between different types of reverse prostheses, such as stem tilt angle, fracture-specific stem designs, and lateralized glenospheres compared to medialized glenospheres. Second, although the aim of the study was to assess short-term outcomes, it is important to note that the number of complications and revisions could increase with a longer follow-up period. Finally, it is important to highlight that the group without anatomical consolidation included patients with reabsorbed tuberosities, consolidated in a non-anatomical position and with pseudarthrosis. It is possible that a subanalysis of all these categories shows differences between the subgroups, which was not possible in our study due to the low number of each of these subtypes.

CONCLUSION

Postoperative range of motion and functional scores were significantly better in patients >65 years of age with PHF treated by RSA and with anatomical union of the tuberosities than in those without union.

Conflict of interest: The authors declare no conflicts of interest.

C. Juana ORCID ID: https://orcid.org/0000-0003-4023-6563
C. Freiras ORCID ID: https://orcid.org/0000-0002-2223-4030
R. Brandariz ORCID ID: https://orcid.org/0000-0003-1030-1475
I. Tanoira ORCID ID: https://orcid.org/0000-0002-2869-2390
M. Ranalletta ORCID ID: https://orcid.org/0000-0002-9145-4010

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