Short-term results of reverse shoulder prosthesis according to pathology

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Abstract

Aims: To analyze short-term functional results and complications of reverse shoulder prostheses in different shoulder conditions.

Materials and Methods: Between 2009 and 2013 we inserted 85 reverse shoulder prostheses. Indications were: arthropathy by rupture of the rotator cuff, glenohumeral osteoarthritis, proximal humerus fracture and revision arthroplasty. We evaluated the patients from medical and radiographic points of view and analyzed them classified into different groups.

Results: The average follow-up was of 42 months (26-60) and the average age was 74.5 years old (56-90). The Constant score improved from 16.7 to 62.1 on average ($p<0.001$) and the ASES score, from 12.7 to 68.8 on average ($p<0.001$). Elevation increased from 80.5º to 111.5º ($p<0.001$). There was not significant improvement in internal and external rotation. Sixty patients (78.9%) reported great satisfaction/satisfaction. In 22 patients (27.8%) we found notches on the lower rim of the glenoid cavity. The complications rate was of 20%, and complications were more frequent in the fracture and revision arthroplasty groups.

Conclusions: Reverse shoulder prostheses improve significantly functional scores, anterior flexion and abduction, independently of surgical indications. However, it presents limitations with respect to postoperative external and internal rotations. It is a valid alternative in multiple shoulder conditions; nevertheless, complication rates are high; therefore, indications have to be precise, especially in patients treated due to fracture or in revision surgeries.

Key words: Reverse shoulder prosthesis; short-term results; complications.

Level of evidence: IV

Resultados a corto plazo de la prótesis invertida de hombro según la patología

Resumen

Objetivo: Analizar los resultados funcionales y las complicaciones a corto plazo de la prótesis invertida de hombro según diferentes patologías.

Materiales y Métodos: Entre 2009 y 2013, se colocaron 85 prótesis invertidas de hombro. Las indicaciones fueron: artropatía por ruptura del manguito rotador, artrosis glenohumeral, fracturas de húmero proximal y artroplastias de revisión. Se evaluó a los pacientes clínica y radiológicamente, y fueron analizados según los diferentes grupos.

Resultados: El seguimiento promedio fue de 42 meses (rango 26-60) y la media de la edad, de 74.5 años (rango 56-90). El puntaje de Constant mejoró de 16,7 a 62,1 en promedio ($p <0,001$) y el de ASES, de 12,7 a 68,8 en promedio ($p <0,001$).

Conflict of interests: The authors have reported none.

La elevación aumentó de 80,5° a 111,5° (p <0,001). No hubo mejoría significativa en las rotaciones interna ni externa. Sesenta pacientes (78,9%) refirieron estar muy satisfechos/satisfechos. En 22 pacientes (27,8%), se hallaron muescas en el borde inferior de la glena. La tasa de complicaciones fue del 20%, y estas fueron más frecuentes en el grupo de fracturas y artroplastias de revisión.

Conclusiones: La prótesis invertida de hombro mejora significativamente los puntajes funcionales, la flexión anterior y la abducción, independientemente de la indicación quirúrgica. Presenta limitaciones con respecto a las rotaciones externa e interna en el posoperatorio. Es una alternativa válida en múltiples patologías de hombro; sin embargo, la tasa de complicaciones es elevada, por lo que su indicación debe ser precisa, especialmente en pacientes tratados por fracturas o en cirugías de revisión.

Palabras clave: Prótesis invertida de hombro; resultados a corto plazo; complicaciones.
Nivel de Evidencia: IV

Introduction

Results in anatomic shoulder prostheses depend on a working rotator cuff.[1] In 1985, Grammont developed a new prosthetic concept inserting a concave component in the humerus—a cemented polyethylene cup, and a convex component in the glonoid cavity—a metallic spherical component, reverting the normal anatomic disposition (reverse prosthesis).[2]

The original humeral component was modified by adding a metallic stem and the glenoid cavity to a hemispheric design that positions the rotation center of the glenohumeral joint at the level of the interface between the glonoid component and the scapula. This results in prostheses with intrinsic stability where the point of application of force of the deltoid muscle is adequately related to the prosthesis rotation centre so as to generate compressive and rotational forces in the absence of the function of the rotator cuff.[3]

Although this implant has initially been used for patients with arthropathy due to rotator cuff deficits, the success of this design led surgeons to a rapid expansion of indications to cover any abnormality that involves the function of the rotator cuff, such as massive ruptures of the rotator cuff with no osteoarthritis, rheumatoid conditions, proximal humerus fractures, sequelas of proximal humerus fractures, and revision of failed previous anatomic prostheses.[413]

The aim of this study was to analyze short-term functional results and complications in reverse shoulder prosthesis, and to determine if these are influenced by the different shoulder conditions.

Materials and Methods

Between June 2009 and June 2013 we inserted 85 reverse shoulder prostheses in the Hospital Italiano of Buenos Aires. We use different models—Delta III/XtendTM (DePuy-Johnson&Johnson, Warsaw, IN, USA) in 43 patients, ARROW® (Palex Medical) in 24 patients, AequalisTM (Tornier) in 10 patients and Comprehensive® (Biomet) in 8 patients.

Indications of reverse shoulder prostheses included: arthropathy by rotator cuff in its different stages, primary glenohumeral osteoarthritis with impaired function of the rotator cuff, primary glenohumeral osteoarthritis with severe loss of glenoid bone stock, multifragmentary fractures in proximal humerus in elderly patients, and revision arthroplasties (Figure 1). We carried out 85 procedures in 82 patients (bilateral procedures in 3 patients). The patient's average age was 75.6 years old (ranging from 56 to 90). Two patients were operated on due to fracture non-union in proximal humerus; one, due to tumor in proximal humerus and, another one, due to joint damage secondary to rheumatoid osteoarthritis. These patients were excluded from the analysis because since they were so few, it was not possible to set up representative groups with these etiologies so as to make significant comparisons. On the other hand, one patient died before one-year follow-up and another one was lost to follow-up. Therefore, we analyzed 79 prostheses in 76 patients (Table 1).

Sixty-two procedures were carried out in females and 17, in males. We inserted 49 prostheses in the right shoulder and 30, in the left shoulder; in 62 patients, it was the dominant shoulder the one we operated on. Patients were grouped on the basis of the main condition in their affected shoulder.

The Hamada et al.'s[14] classification was used to group the patients with arthropathy by rotator cuff into different categories (Table 2).

According to this system, stage 1 is associated with minimal radiographic changes; stage 2 is characterized by a < 5mm decrease in the subacromial space; stage 3 shows an acromion erosion also called acromion "acetabulization", which is secondary to the upper migration of the humeral head; stage 4 already presents glenohumeral osteoarthritis and is divided into 4a—without acetabulization and 4b—with acetabulization; and stage 5 is characterized by the advanced damage of the humeral head.

The patients operated on due to proximal humerus fracture were >75 years old and had four-fragment fractures according to the Neer's classification.

Figure 1. Images of right shoulder in a 70-year old female with arthropathy by insufficiency of the rotator cuff treated with reverse shoulder prosthesis. **A.** Preoperative X-ray showing stage 3 in Hamada's Classification. **B.** Preoperative MRI showing arthropathy by insufficiency of the rotator cuff. **C.** Postoperative X-ray showing reverse shoulder prosthesis in the right shoulder. D. Five-year follow-up X-ray with no complications.

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Five patients were operated on due to primary osteoarthritis: two of them showed an association with insufficient rotator cuff, and three patients showed loss of glenoid bone stock associated with static posterior subluxation of the proximal humerus, which prevented surgeons from implanting a non-constrained glenoid component. All the patients who received a reverse shoulder prosthesis as revision surgery had previously undergone hemiarthroplasty (Table 1).

An examiner, who was not the treating surgeon, evaluated the patients before the surgery and postoperatively. They documented mobility, the Constant score[15] and the ASES (American Shoulder and Elbow Surgeons) score.[16]

Before the surgery we carried out CT scan and MRI studies to evaluate the quality of the rotator cuff and bone stock deficit in the glonoid cavity. In the postoperative evaluation we got A-P, Y-scapula and axillary glenohumeral X-rays.

Surgical technique

All the prostheses were inserted using the deltopectoral approach. The humeral stem was cemented in 64 cases. The number of screws we used for the fixation of the metaglene component was determined by the available bone stock and by the acting surgeon's preferences.

When the subscapularis muscle was available, we repaired it using trans-bone stitches with Tycron 5.0; when it was not, we left it unrepaired.

Postoperative rehabilitation

The shoulder was immobilized in a sling for a month. We allowed the patients to make flexion-extension movements at elbow and wrist levels, but we limited abduction and anterior flexion of the shoulder together with strength activities. After a month, patients started a rehabilitation program emphasizing the recovery of passive mobility, followed by exercises for muscle strengthening.

Statistical analysis

Continuous variables are presented with measures of central tendency and dispersion. The categorical variables are shown as absolute and relative frequencies. In the bivariate analysis we used the Student't t-test for coupled data, what allowed us to focus on the magnitude of the differences between averages (with normal distribution) in the comparison between groups III and IV and, by the development of notches in the scapula in two groups (Yes/No); we used the Wilcoxon signed-rank non parametric test (non-normal distribution), which focuses on the comparison between medians in the comparison between groups I and II. We considered values of $p<0.05$ as statistically significant. We used the version-13.0 STATA program for statistical analysis.

Results

General medical results

The average Constant score improved from preoperative 16.7 to postoperative 62.1 at the follow-up time ($p<0.001$), and the average ASES score improved from 12.7 to 68.8 respectively ($p<0.001$) (Table 3). Considering all etiologies together, average elevation improved from 80.5º to 111.5º ($p<0.001$). There was not significant improvement in internal and external rotation (Table 4).

With respect to the patients' satisfaction degree, 16 of them (21.1%) reported great satisfaction with the procedure; 44 (57.8%), just satisfaction, and 16 (21.1%), no satisfaction at all.

Results by etiology

Improvement in the Constant and ASES scores was similar in the arthropathy by rotator cuff, the fracture and the osteoarthritis groups ($p=0.25$). The revision group, although showing significant improvement at the time of comparing preoperative and postoperative figures, did not reach final values similar to the other three groups', and this difference was significant ($p<0.03$). There were no significant differences in the patients' satisfaction levels between groups ($p=0.25$).

Table 1. Patients by condition

Condition	Nº of shoulders Total 79 (100%)
Arthropathy by rotator cuff	43 (54.4%)
Fractures	26 (33%)
Primary osteoarthritis	5 (6.3%)
Revision	5 (6.3%)

Table 2. Hamada's Classification

Hamada Stage	Nº of shoulders Total 43 (100%)
1 and 2	0
3	23 (53.4%)
4a	4 (9.3%)
4b	13 (30.2%)
5	3 (6.9%)

With respect to mobility, results were similar in the four groups. In all of them flexion and abduction improved significantly (p<0.01). External rotation did not improve significantly in any group. As regards internal rotation, improvement was not significant in any group, but that of arthropathy by rotator cuff (Table 4).

Radiographic results

Twenty-two (27.8%) patients had notches on the lower rim of their glenoid cavity (notching) at radiographic follow-up (Figure 2). The average postoperative Constant score in the patients with and without notches was 56.8 and 62.44, respectively (p=0.20), whereas the average postoperative ASES score in the patients with and without notches was 61.7 and 64.3, respectively (p=0.25). Average elevation was 109º in the patients with notches and 113º in those without notches.

Complications

There were 16 complications (20.2%), the most frequent ones among them being periprosthetic fracture (5 cases) and glonoid loosening (5 cases). Seven out of the 16 patients who suffered complications required revision surgery (9% in the series) (Table 5). The fractures group underwent the highest complications percentage (30.7%).

Table 3. Results in functional scores by condition

Condition	Constant		p	ASES		p
	Initial	Final		Initial	Final	
Arthropathy by rotator cuff	19.9	66.1	<0.001	19.8	69.7	<0.001
Fractures	-	64.5	-	-	64.8	-
Primary osteoarthritis	18.6	70.3	<0.001	18.6	71	<0.001
Revision	19.6	50	0.023	16.7	51.6	0.025
Total	16.7	62.1	<0.001	12.7	68.8	<0.001

Table 4. Initial and final ranges of motion by condition

Condition	Anterior flexion		p	Abduction		p	External rotation		p	Internal rotation		p
	Initial	Final		Initial	Final		Initial	Final		Initial	Final	
Arthropathy by rotator cuff	81.4º	130.7º	<0.001	55.5º	96.7º	<0.001	20.9º	28.1º	0.25	Buttocks	T12	<0.001
Fractures	-	108.5	-	-	86º	-	-	25º	-	-	Sacrum	-
Primary osteoarthritis	71.6º	96.1º	<0.001	51.1º	95.1º	<0.001	16.4º	20º	0.5	Sacrum	L3	0.42
Revision	76.6º	116.4º	<0.001	58.3º	86.1º	<0.001	21.6º	28.6º	0.5	Buttocks	Sacrum	0.42
Total	80.5º	111.5º	<0.001	55.5º	94.8º	<0.001	20.4º	27.1º	0.2	Buttocks	Sacrum	0.2

Complicaciones

Hubo 16 complicaciones (20,2%), las más frecuentes fueron las fracturas periprotésicas (5 casos) y el aflojamiento glenoideo (5 casos). Siete de los 16 pacientes que tuvieron complicaciones requirieron una cirugía de revisión (9% de la serie) (Tabla 5). El grupo de las fracturas sufrió el porcentaje más alto de complicaciones (30,7%).

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Figure 2. Images of left shoulder in a 75-year old female with arthropathy by insufficiency of the rotator cuff treated with reverse shoulder prosthesis, who presents wear in the glenoid lower rim—notching, during follow-up. **A.** Preoperative X-ray showing stage 4a in Hamada's Classification. **B/C.** Preoperative MRI showing arthropathy by insufficiency of the rotator cuff. **D.** Postoperative X-ray showing reverse shoulder prosthesis in the left shoulder. **E.** Three-year follow-up X-ray showing notching with no signs of prosthetic loosening.

Table 5. Complications by condition

Complication	Total	Arthropathy by rotator cuff	Fractures	Primary osteoarthritis	Revision
	16/79 (20.2%)	7/43 (16%)	8/26 (30.7%)	0/5	1/5 (20%)
Periprosthetic fracture	5	–	4	–	1
Glenoid loosening	5	2	3	–	–
Instability/Dislocation	2	2	–	–	–
Radial nerve neuropraxia	1	1	–	–	–
Deep infection	1	1	–	–	–
Superficial infection	1	1	–	–	–
Heterotopic ossification	1	–	1	–	–

Discussion

Most series showed very good short-term results with reverse shoulder prosthesis.[17-20] In our series, the average improvement in the Constant score was 46, whereas in the ASES score was 50, with 31º-improvement in elevation. These figures are comparable to previous reports on the treatment of arthropathy by rotator cuff with reverse shoulder prosthesis.[17-20]

On the other hand, coincidentally with what previous studies show, improvement in 0º-arm-abduction shoulder internal and external rotation was not significant, and this is mainly due to two factors—the first one is the prosthesis design (due to the decreased offset and the medialized rotator center), and the second one is related to the degree of atrophy and fatty infiltration of the subscapularis and teres minor muscles.[21]

In our study, the patients treated with reverse shoulder prosthesis as revision of hemiarthroplasty had worse results than those operated on due to other etiologies. Although improvement in scores in these patients' mobility and pain was significant when compared to preoperative standards, the final averages of postoperative scores did not increase as much as they did in the remaining conditions dealt with. Previous studies suggest that results in reverse shoulder prosthesis as revision procedures are less predictable than they are when procedures are carried out as primary procedures.[20-21]

Although in our series the patients' postoperative function is kept in the short term, previous publications with longer follow-up show that, despite good prosthesis duration, function decreases as time goes by.[22,23]

In a revision of 484 prosthesis, Favard et al. showed 10-year survival of 89%; however, when a <30% Constant score (what represents poor results) was considered as failure of treatment, survival rates decrease to 72%.[24]

The studies that analyze the use of hemiartrhroplasty to treat arthropathy by rupture of the rotator cuff show that this procedure not always is effective at eliminating the patients' pain, and they achieve an average active elevation from 85º to 120º.[25-28] Comparatively in our study 42 patients reported no pain at last follow-up, and other 29 reported just mild pain. In addition, patients with rotator cuff conditions achieved a postoperative average active elevation of 130.7º (ranging from 85º to 180º).

This study shows that reverse shoulder prostheses were effective at recovering active elevation and function in patients with irreparable rupture of the rotator cuff in early arthropathy stages. Other previous studies also show that reverse shoulder prostheses represent an effective method so as to reach these goals.[29-31]

At analyzing the functional results of reverse shoulder prostheses in proximal humerus fractures, most studies describe an anterior elevation of approximately 95º to 145º, external rotation of 0º to 25º and a 50-to-65 Constant score.[6,32-34] In a series of 30 patients who received a reverse shoulder prosthesis for 3- and 4-frament fractures, with a minimal two-year follow-up, they found an average anterior flexion of 139º, external rotation of 27º and an ASES score of 78.3.[32] In a similar study carried out in 27 patients, also with a minimal two-year follow-up, the authors reported an anterior flexion of 112º, abduction of 97º, external rotation of 12.7º and a Constant score of 55.6. In our series, we got similar results with an aver-

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age postoperative Constant score of 64.5 in this group, an ASES score of 64.8, anterior flexion of 108º, and external rotation of 25º.

As regards complication rates (20%) in this study, they were similar to those published in previous studies. [17,19,29-31] On the one hand, the percentages of complications in the arthropathy and fracture groups (16% and 30% respectively) are similar to those published in previous series. [6,25-28,32-34] On the contrary, complication rates in the osteoarthritis and revision groups (0% and 20% respectively) were lower than those previously published.[20,21] However, we believe that this might be due to the small number of patients with such conditions that have been analyzed in this series.

It is worth highlighting that, within the group of patients who suffered complications (16/79, 20%), seven of these 16 (42%) required revision surgery.

This study has limitations worth pointing out. First, it is a retrospective study; therefore, it was not possible to make comparisons between reverse shoulder arthroplasty and other types of treatments for the conditions dealt with. On the other hand, the different types of prostheses that we used, (Delta III/XtendTM, ARROW®, AequalisTM, Comprehensive®) may have influenced on the results we got. Finally, by dividing the series into different conditions, some groups ended up formed by a small number of patients, what has an influence on the interpretation of results.

Conclusions

Reverse shoulder prostheses improve significantly functional scores, anterior flexion and abduction, independently of surgical indications; however, it has limitations with respect to postoperative external and internal rotation. It is a valid alternative in multiple shoulder conditions; nevertheless, complication rates are high; therefore, indications have to be precise, especially in patients who will be treated because of fracture or in revision surgeries.

Bibliography

1. Smith CD, Guyver P, Bunker TD. Indications for reverse shoulder replacement: a systematic review. *J Bone Joint Surg Br* 2012; 94(5):577-583.
2. Grammont PM, Trouilloud P, Laffay JP, Deries X. Etude et réalisation d'une nouvelle prothèse d'épaule. *Rhumatologie* 1987; 10:407-418.
3. Grammont PM, Baulot E. Delta shoulder prosthesis for rotator cuff rupture. *Orthopedics* 1993;16:65-68.
4. Acevedo DC, Vanbeek C, LazarusMD, Williams GR, Abboud JA. Reverse shoulder arthroplasty for proximal humeral fractures: update on indications, technique, and results. *J Shoulder Elbow Surg* 2014;23:279-289.
5. Gallinet D, Adam A, Gasse N, Rochet S, Obert L. Improvement in shoulder rotation in complex shoulder fractures treated by reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 2013;22:38-44.
6. Valenti P, Katz D, Kilinc A, Elkholti K, Gasiunas V. Mid-term outcome of reverse shoulder prostheses in complex proximal humeral fractures. *Acta Orthop Belg* 2012;78:442-449.
7. Young AA, Smith MM, Bacle G, Moranga C, Walch G. Early results of reverse shoulder arthroplasty in patients with rheumatoid arthritis. *J Bone Joint Surg Am* 2011;93:1915-1923.
8. Ekelund A, Nyberg R. Can reverse shoulder arthroplasty be used with few complications in rheumatoid arthritis? *Clin Orthop Relat Res* 2011;469:2483-2488.
9. Hattrup SJ, Sanchez-Sotelo J, Sperling JW, Cofield RH. Reverse shoulder replacement for patients with inflammatory arthritis. *J Hand Surg Am* 2012;37:1888-1894.
10. Holcomb JO, Hebert DJ, Mighell MA, Dunning PE, Pupello DR, Pliner MD, et al. Reverse shoulder arthroplasty in patients with rheumatoid arthritis. *J Shoulder Elbow Surg* 2010;19:1076-1084.
11. Kelly JD 2nd, Zhao JX, Hobgood ER, Norris TR. Clinical results of revision shoulder arthroplasty using the reverse prosthesis. *J Shoulder Elbow Surg* 2012;21:1516-1525.
12. Patel DN, Young B, Onyekwelu I, Zuckerman JD, Kwon YW. Reverse total shoulder arthroplasty for failed shoulder arthroplasty. *J Shoulder Elbow Surg* 2012;21:1478-1483.
13. Boileau P, Watkinson D, Hatzidakis AM, Hovorka I. Neer Award 2005: the Grammont reverse shoulder prosthesis: results in cuff tear arthritis, fracture sequelae, and revision arthroplasty. *J Shoulder Elbow Surg* 2006;15:527-540.
14. Hamada K, Fukuda H, Mikasa M, Kobayashi Y. Roentgenographic findings in massive rotator cuff tears. A long-term observation. *Clin Orthop Relat Res* 1990;254:92-96.

15. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res* 1987;214:160-164.

16. Richards RR, An KN, Bigliani L, Friedman RJ, Gartsman GM, Gristina AG, et al. A standardized method for the assessment of shoulder function. *J Shoulder Elbow Surg* 1994;3:347-352.

17. Sirveaux F, Favard L, Oudet D, Huquet D, Walch G, Mole D. Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive rupture of the cuff. Results of a multicentre study of 80 shoulders. *J Bone Joint Surg Br* 2004;86:388-395.

18. Boulahia A, Edwards TB, Walch G, Baratta RV. Early results of a reverse design prosthesis in the treatment of arthritis of the shoulder in elderly patients with a large rotator cuff tear. *Orthopedics* 2002;25:129-133.

19. Frankle M, Siegal S, Pupello D, Saleem A, Mighell M, Vasey M. The reverse shoulder prosthesis for glenohumeral arthritis associated with severe rotator cuff deficiency. A minimum two-year follow-up study of sixty patients. *J Bone Joint Surg Am* 2005;87:1697-1705.

20. Werner CM, Steinmann PA, Gilbart M, Gerber C. Treatment of painful pseudoparesis due to irreparable rotator cuff dysfunction with the Delta III reverse-balland-socket total shoulder prosthesis. *J Bone Joint Surg Am* 2005;87:1476-1486.

21. Boileau P, Watkinson DJ, Hatzidakis AM, Balg F. Grammont reverse prosthesis: design, rationale, and biomechanics. *J Shoulder Elbow Surg* 2005;14(1 Suppl S):147S-161S.

22. Valenti PH, Boutens D, Nérot C. Delta 3 reversed prosthesis for osteoarthritis with massive rotator cuff tear: long term results. En: Walch G, Boileau P, Molé D (eds.) 2000 *Prothèses d'Épaule...recul de 2 à 10 ans – 2000 Shoulder Prostheses… two to ten year follow-up,* Paris: Sauramps Médical; 2001:253-259.

23. Guery J, Favard L, Sirveaux F, Oudet D, Mole D, Walch G. Reverse total shoulder arthroplasty. Survivorship analysis of eighty replacements followed for five to ten years. *J Bone Joint Surg Am* 2006;88:1742-1747.

24. Favard L, Levigne C, Nerot C, Gerber C, De Wilde L, Mole D. Reverse prostheses in arthropathies with cuff tear: are survivorship and function maintained over time? *Clin Orthop Relat Res* 2011;469:2469-2475.

25. Williams GR Jr, Rockwood CA Jr. Hemiarthroplasty in rotator cuff-deficient shoulders. *J Shoulder Elbow Surg* 1996;5:362-367.

26. Sanchez-Sotelo J, Cofield RH, Rowland CM. Shoulder hemiarthroplasty for glenohumeral arthritis associated with severe rotator cuff deficiency. *J Bone Joint Surg Am* 2001;83:1814-1822.

27. Zuckerman JD, Scott AJ, Gallagher MA. Hemiarthroplasty for cuff tear arthropathy. *J Shoulder Elbow Surg* 2000;9:169-172.

28. Sarris IK, Papadimitriou NG, Sotereanos DG. Bipolar hemiarthroplasty for chronic rotator cuff tear arthropathy. *J Arthroplasty* 2003;18:169-173.

29. Wall B, Nové-Josserand L, O'Connor DP, Edwards TB, Walch G. Reverse total shoulder arthroplasty: a review of results according to etiology. *J Bone Joint Surg Am* 2007;89:1476-1485.

30. Mulieri P, Dunning P, Klein S, Pupello D, Frankle M. Reverse shoulder arthroplasty for the treatment of irreparable rotator cuff tear without glenohumeral arthritis. *J Bone Joint Surg Am* 2010;92:2544-2556.

31. Boileau P, Gonzalez JF, Chuinard C, Bicknell R, Walch G. Reverse total shoulder arthroplasty after failed rotator cuff surgery. *J Shoulder Elbow Surg* 2009;18:600-606.

32. Cazeneuve JF, Cristofari DJ. The reverse shoulder prosthesis in the treatment of fractures of the proximal humerus in the elderly. *J Bone Joint Surg Br* 2010;92(4):535-539.

33. Sirveaux F, Navez G, Favard L, Boileau P, Walch G, Mole D. Reverse prosthesis for acute proximal humerus fracture, the multicentric study. En: Walch G, Boileau P, Mole D (eds). *Reverse Shoulder Arthroplasty: Clinical Results, Complications, Revision*, Montpellier, France: Sauramps Medical; 2006:73-80.

34. Lenarz C, Shishani Y, McCrum C, Nowinski RJ, Edwards TB, Gobezie R. Is reverse shoulder arthroplasty appropriate for the treatment of fractures in the older patient? Early observations. *Clin Orthop Relat Res* 2011;469(12):3324-3331.

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