Reversed shoulder arthroplasty for the treatment of proximal humerus fracture in the elderly

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1. Introduction

Treatment of proximal humerus fractures in the elderly has long been a topic of controversial discussion amongst trauma surgeons. Until RSA became available most surgeons favored conservative treatment even in, or especially in, severely comminuted fractures of the elderly because anatomic reduction and fixation is almost impossible to achieve in osteoporotic bone. Slight differences in functional outcome were reported by some but the overall impression gained from thorough literature research was largely in line with the results published by Hanson.¹

Since proximal humerus fractures of the elderly bear some comparable features with proximal femur fractures i.e. increased risk of head necrosis with higher grades of comminution, a joint replacing approach is most appealing but less successful.² In fact hemiarthroplasty has not proven to be superior to conservative or reconstructive treatment.³ The main factor for function of hemiarthroplasty as well as for fracture reconstruction is a functionable rotator cuff. The high prevalence of rotator cuff defects and its natural degeneration have been described in detail.³ The principle of a lateralized center of rotation together with an inverted joint orientation (proximal convex and distal concave) enables a wide range of shoulder motion through deltoid contraction alone. RSA has therefore been increasingly used for older patients over the last decade.

Further evaluations have shown that the outcome after RSA depends partially on patient perspective and assessment methods so we used physical tests as well as self-reporting evaluations.⁴ In our study we

focused on patients with RSA in view of range of motion, strength, Constant score and a standardized questionnaire.

2. Methods

2.1. Patients

Twenty three patients at the age of 52–90 years who were operated due to proximal humerus fractures from September 2011 to February 2017 were included in this retrospective study. All patients were provided with a DELTA XTEND prosthesis (DePuy Synthes). Indications for RSA were an extended rotator cuff defect and fracture displacement. An extended rotator cuff defect was defined as tears ≥ 5 cm or defects with two or more tendons involved.⁵ Rotator cuff defects were diagnosed by magnetic resonance imaging (MRI).

Patients with severe neurologic, cardiac or pulmonary comorbidities were excluded. All patients gave written informed consent to participate in the study. Ethics approval was obtained from the local ethics committee (No. D463/16).

2.2. DELTA XTEND prosthesis (DePuy Synthes)

The DELTA XTEND prosthesis is a total semi-constrained shoulder arthroplasty. The scapula-humeral joint center of rotation is moved medially and inferiorly, which increases the deltoid lever arm and deltoid tension.

Therefore the deltoid muscle can compensate for impaired rotator

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cuff strength. The surgical technique utilized the Delta Split/McKenzie approach. The prosthesis is composed of a humeral component and a glenoid baseplate component secured with the use of a central peg available in three sizes along with two variable angle locking and two compression screws. The humeral component consists of a cementless modular titanium hydroxyapatite (HA)-coated or Monobloc cobalt-chromium (Co–Cr) cemented stem. The humeral articulation offers various polyethylene (PE) cup thicknesses. The metaglene has a curved back to help with bone preservation and is placed at the inferior margin. The metaglene is smaller with a curved back to help with bone preservation and placed at the inferior edge of the glenoid with the intent to reduce scapular notching. All operation were performed by 4 surgeons.

2.3. Fracture classification

Pre- and postoperative X-rays were analyzed and fractures were classified according to Neer by CTscan. The Neer classification is probably the most frequently used along with the AO classification of proximal humerus fractures. The two major parts of the classification are number of fragments and displacement.⁶

2.4. Range of motion

All patients underwent an orthopedic examination of the upper limbs. Flexion, extension, abduction, adduction, internal rotation and external rotation as well as internal and external rotation in 90° abduction range of motion were measured in degrees using a goniometer. Internal and external rotations were also measured with the humerus abducted in the frontal plane to 90° and the elbow flexed to 90°. The unoperated side of every patient served as control.

2.5. Strength

Power was measured by a weight gage (Kern, Switzerland) in Kilograms (kg). The weight gage was attached to the floor and patients arm, 1 cm proximal of Processus styloideus radii and ulnae. Static power was measured in exact position. The unoperated side of every patient served as control.

2.6. Constant Score

The Constant Score is a 100-points scale composed of a number of individual parameters⁷

It measures Pain (15 points), Activities of Daily Life (ADL) (20 points), Range of Motion (40 points) and Power (25 points). The range of motion is divided in forward elevation, external rotation, abduction and internal rotation. Subjective findings (severity of pain, activities of daily living and working in different positions) sum up to 35 points and objective measurements (range of motion and strength) refer to 65 points.

2.7. EQ5D3L

Of all patients a Constant Score and an EQ5D3L questionnaire were obtained. Postoperative data of the operated shoulder were compared with the non-operated side.

The EQ5D3L questionnaire measures general health parameters. The outcome is differentiated into “descriptive” measures and a visual scale for health. The descriptive system comprises the following 5 subdivisions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Each subdivision has the following levels: no problems, some problems, extreme problems. The patient is asked to indicate the health state by placing a cross in the box against the most appropriate statement in each of the 5 subgroups.

The visual scale shows the patient's self-rated health on a vertical,

visual analogue scale. The endpoints are marked as ‘Best imaginable health state’ and ‘Worst imaginable health state’. This information can be used as a quantitative measure of health outcome as ranked by the individual patient.

2.7.1. Correlation of different parameters

Correlation was tested between results of Constant Score and EQ5D3L, abduction and strength in 45° abduction, abduction and strength in 90° abduction, age and results of Constant Score, time period postoperative and results of Constant Score.

2.7.2. Statistics

Statistics were calculated using SPSS 14.0 for Windows. We performed a descriptive analysis. Results are displayed as mean with standard deviation (SD). Differences were tested for significance using the Student-t-test. Associations between variables were quantified by means of Pearson's correlation coefficient. Significance was assumed, when $p \leq 0.05$.

3. Results

3.1. Overall

In our evaluation 20 patients (87.0%) were female and 3 patients (13.0%) were male.

The mean age was 86.0 ± 1.0 years in male patients and 78.85 ± 10.40 years in female patients. Concerning primary surgical treatment the mean age is 82.41 ± 6.36 years and concerning secondary treatment a mean value of 72.3 ± 14.79 years.

In terms of fracture classification we included 14 patients (61.0%) with a type Neer 4 fracture and 9 patients (39.0%) with a type Neer 3 fracture.

17 patients (74%) were primary operated with a RSA and 6 patients (26%) were secondary treated surgically after fracture displacement. 3 of these 6 patients were initially treated conservatively with a Gilchrist splint. Initially one patient received a targon nail one an anatomic shoulder prosthesis and one was stabilized with an angular stable locking plate (PHILOS) plate.

The time period (data not shown) between initial surgery and insertion of a RSA took in average 263.33 ± 202.86 days. In case of conservative treatment the time period took in average 92.33 ± 108.86 days until operation.

The mean operating time was 95.5 ± 28.21 min. For primary prosthesis it took 86.23 ± 16.23 min and for secondary prosthesis it took 121.83 ± 39.11 min.

Follow-up examination was performed after 28.40 ± 10.47 months. X-ray analysis were performed after operation, 6 weeks after operation, 3 months and 6 months after operation. During follow-up examination another X-ray was performed. Imaging did not show any complications like raised height of prosthesis or loosening signs.

3.2. Motion analysis

The range of motion was significantly reduced compared to the un-operated (control-) shoulder. For abduction values were $111^\circ \pm 31.6^\circ$ (Surgery) and $141.7^\circ \pm 22.18^\circ$ (control) (Fig. 1). The standard deviation of control values was lower than for the side treated with a reversed shoulder arthroplasty. For adduction the range of motion was $21.74^\circ \pm 10.18^\circ$ and $29.57^\circ \pm 5.42^\circ$ on the other side ($p < 0.01$) (Fig. 1). A significant difference could also be detected in anteversion (surgery: $114.6^\circ \pm 27.47^\circ$, un-operated shoulder $139.4^\circ \pm 16.4^\circ$; $p < 0.01$) and retroversion (surgery: $34.6^\circ \pm 10.3^\circ$, control: $46.74^\circ \pm 6.1^\circ$, $p < 0.01$) (Fig. 1).

The average range of motion for internal rotation (operated shoulder: $81.95^\circ \pm 21.04^\circ$, un-operated shoulder $89.78^\circ \pm 4.64^\circ$; $p > 0.05$) and external rotation (operated shoulder $12.2^\circ \pm 10.3^\circ$, un-

Fig. 1. Comparison of abduction and adduction, anteversion and retroversion, external and internal rotation, external and internal rotation in 90° abduction of operated and unoperated shoulder (control) of patients after reversed shoulder prosthesis.

operated shoulder $38.3^\circ \pm 11.2^\circ$; $p < 0.01$) showed also different results, whereat only the difference in external rotation was significant (Fig. 1).

A significant difference could also be seen for external rotation in 90° abduction (surgery $25.87^\circ \pm 19.11^\circ$, control $55.22^\circ \pm 12.01^\circ$, $p = < 0.01$), but not for internal rotation in 90° abduction (surgery $38.04^\circ \pm 16.22^\circ$, control $52.39^\circ \pm 12.14^\circ$, $p = < 0.01$) (Fig. 2). There were no significant results in view of internal rotation.

3.3. Muscular strength

Strength was measured with a custom made device and recorded for abduction in 90° and in 45°. The values were 1.87 ± 1.33 kg on the operated side versus 3.10 ± 1.0 kg on the counter-side ($n = 23$, $p < 0.01$) in 90° abduction. In 45° abduction the mean was 3.5 ± 1.55 vs. 4.65 ± 1.68 kg on the operated vs the counter-side respectively ($n = 23$, $p < 0.01$).

3.4. Primary and secondary implanted shoulder prostheses

3.4.1. Motion analysis

We further differentiated between primary and secondarily implanted shoulder prostheses. A range of motion of $114.71^\circ \pm 25.59^\circ$ for abduction was shown after primary RSA compared to $103.33^\circ \pm 46.76^\circ$ after secondary arthroplasty. Adduction of $22.06^\circ \pm 9.67^\circ$ could be detected for primary surgery and adduction of $20.83^\circ \pm 12.42^\circ$ after secondary surgery.

Minor differences were also detected for anteversion (primary surgery: $116.47^\circ \pm 19.75^\circ$; secondary surgery $109.17^\circ \pm 44.99^\circ$) and retroversion (primary surgery: $35.59^\circ \pm 7.26^\circ$; secondary surgery: $31.67^\circ \pm 16.93^\circ$).

External rotation was almost similar in both groups (primary surgery: $12.06^\circ \pm 10.62^\circ$; secondary surgery: $12.5^\circ \pm 10.37^\circ$). A higher variation was shown for internal rotation (primary surgery: $84.41^\circ \pm 12.73^\circ$; secondary surgery $75^\circ \pm 36.74^\circ$).

Values for external rotation in 90° abduction were similar after primary surgery ($26.47^\circ \pm 18.61^\circ$) compared to secondary surgery ($24.17^\circ \pm 22.23^\circ$). Major difference could be detected for internal rotation in 90° abduction (primary surgery: $41.18^\circ \pm 14.74^\circ$; secondary surgery: $29.17^\circ \pm 18.28^\circ$), but difference was not significant.

3.4.2. Muscular strength

There was no significant difference in strength between primary and secondary operation. The values were 3.62 ± 1.59 kg after primary surgery vs. 3.1 ± 1.51 kg after secondary surgery in 45° abduction and $1.89 \text{ kg} \pm 1.38$ after primary operation vs. 1.78 ± 1.31 kg in 90°.

3.4.3. Constant Score

The mean Constant score was 55 ± 13 for all operated patients ($n = 23$). The ADL scores for work, sport and sleep and hands movement were 2.5 ± 0.7 , 2.2 ± 0.6 , 1.95 ± 0.21 , 7.7 ± 1.8 , respectively. The range of motion scores for flexion, abduction, external rotation and internal rotation were 6.3 ± 1.74 ; 6.1 ± 1.76 ; 6.5 ± 3.58 ; 3.8 ± 2.08 ($n = 23$). The total mean strength score was 3.9 ± 3.02 .

The mean Constant Score for patients with primary RSA comprised 57 ± 12 ($n = 17$) and 52 ± 18 ($n = 6$) for patients with secondary arthroplasty (Fig. 2). The ADL scores for work, sport and sleep and hands movement were 2.5 ± 0.6 , 2.2 ± 0.66 , 1.9 ± 0.2 and 8 ± 1.9 (primary arthroplasty) and 2.7 ± 1.2 , 2 ± 0.41 and 7 ± 1.7 (secondary arthroplasty).

A mean range of motion score for flexion, abduction, external rotation and internal rotation of 6.5 ± 1.5 , 6.4 ± 1.46 ; 6.8 ± 3.6 ; 4 ± 2.24 ($n = 17$) could be generated for patients after primary RSA. After secondary done arthroplasty the scores were 5.7 ± 2.33 (flexion), 5.3 ± 2.42 (abduction), 5.7 ± 3.67 (external rotation), 3.3 ± 1.63 ($n = 6$).

The strength score represented 4.2 ± 2.98 ($n = 17$) after primary performed RSA and 3.3 ± 3.33 ($n = 6$) after secondary performed shoulder arthroplasty. The pain was also measured through the Constant Score. 15 patients (65.0%) stated that they had no pain after surgery. 4 patients (17%) choose scale 1. Scale 3 was listed once (4%), scale 4 twice (9%) and scale 5 once (4%).

3.4.4. EQ5D3L

The mean value of the descriptive part of EQ5D3L achieved 6.6 ± 1.67 points for all operated patients. Primary operated patients got a mean value of 6.53 ± 1.37 points and secondary operated patients had a mean value of 6.83 ± 2.48 points (Fig. 2).

The visual part of EQ5D3L showed a result of 75.65% (difference value 24.35%), whereat the group of primary surgery had 75.31% (difference value 25.94%) and the group of secondary surgery had 79.28% (difference value 20.71%).

Fig. 2. Comparison of Constant Score and results of EQ5D3L after primary and secondary operation.

3.4.5. Correlation

Pearson correlation coefficient was analyzed for results of Constant Score and descriptive part of EQ5D3L $r = 0,889$ and for results of Constant Score and results of visual analogue scale EQ5D3L $r = 0,791$ (Fig. 3) (see Fig. 4).

We determined also a Pearson correlation between strength in 90° abduction and abduction ($r = 0,807$) and strength in 45° abduction and abduction $r = 0,665$ (Fig. 3). Correlation between age and Constant Score was also tested $r = 0,112$. Correlation analysis of months postoperative and results of Constant Score showed an $r = 0,451$ (Fig. 3).

4. Discussion

Proximal humerus fractures are the third most common fragility fracture and they are associated with a substantial limitation in mobility and impaired quality of daily life. While these fractures predominantly affect older patients and the older population continues to rise, the registered number of fractures is also increasing.⁸

Type of fracture, degree of fragment displacement and fracture

stability affect fracture treatment essentially. Especially in complex and displaced fractures the optimum treatment becomes less clear. The field of shoulder endoprothetics has undergone a rapid development in the last years. Displaced proximal humerus fractures, poor rotator cuff status and non-union of the tubercles in elderly patients have caused RSA growing popularity and showed promising results, even in comparison to angular stable plate fixation.⁹ RSA serves as potential solution especially for those patients who could not be managed effectively with a conventional total shoulder arthroplasty. The medialization and distalisation of the center of rotation increases the deltoid lever arm which causes a higher force of abduction.¹⁰ An intact rotator cuff is not necessary anymore.

In our study we focused on reversed shoulder arthroplasty and analyzed potential differences compared to the unoperated shoulder. The majority of patients were female as the incidence for proximal humerus fractures is precisely higher in the female population in general.⁸ Launonen et al. showed also, that the incidence for three- and four-part fractures is higher in females compared to males⁸ which emphasizes higher percentage in female patients with RSA.

Fig. 3. Correlation between Constant Score and EQ5D3L, Correlation between strength and abduction and Correlation between age and Constant Score and Constant Score and months postoperative after reversed shoulder arthroplasty.

Fig. 4. Correlations.

The range of motion differed significantly between the operated shoulder and the unoperated side in our evaluation. Simply no significant difference was shown for internal rotation. Irrespective of chosen technique after complex humerus fracture the range of motion is generally reduced compared to unoperated side.⁹

Some evaluations highlight better results after RSA compared to ORIF in elderly patients, which might also be explained by poor and degenerative rotator cuff status of elder patients.⁹ A meta-analysis comparing operative versus non-operative treatment of displaced humerus fractures in elderly patients showed no statistically significant difference in function, which might also assist the functional good results after RSA by now. A definite comparison of mean values of range of motion might be difficult somehow, because most of the evaluations differed in number of patients, mean age, type of prosthesis, approach, time point of physical examination and extent of physical examination. Some studies have not listed mean values of motion, because only results of Constant Score were documented.¹¹

Overall compared to current evaluations the postoperative range of motion was similar¹² and showed good postoperative results. Further the motional results seem to be improved compared to earlier studies,¹³ which might be caused by improved techniques and increasing know-how in RSA. In 2007 Bufquin et al. evaluated 43 cases with short-term follow-up after RSA, while a mean active anterior elevation of 97° and a mean active external rotation in abduction of 30° were evaluated.¹⁴ The mean Constant and the mean modified Constant Scores were 44% and 66%.¹⁴ Further evaluations by Cazeneuve et al. and Sirveaux et al. showed similar results after RSA.¹¹ RSA has been shown to produce acceptable outcomes in previous studies, which are comparable to hemiarthroplasty.

We evaluated 17 patients with primary operated RSA and 6 patients with secondary provided indication for reversed arthroplasty. Indication for secondary arthroplasty were fracture dislocation, implantat failure or osteonecrosis. Secondary arthroplasty correlates with lower tuberosity healing rate and reduced external rotation compared to primary operation¹⁵ wherefore we examined primary and secondary RSA separately.

There were also slight differences in range of motion after primary and secondary RSA, but differences were not significant. Our results come along with previous findings, while acute and secondary RSA can yield successful outcome and acute RSA.¹⁵

We also focused on Constant Score, which is one of the most applicable scoring systems in the follow-up of shoulder injuries. It was compared to different other objective outcome scores and showed the strongest correlation with function of the shoulder.¹⁶

In our evaluation the mean Constant Score was 55 ± 13 for all operated patients. Results of different postoperative evaluations showed high discrepancy. Roy et al. differed in a deficiency of 40% or less compared to age-matched normative data, which were considered as a good functional outcome.⁴ The group $\leq 40\%$ had a mean Constant Score of 62 ± 13 , whereas the group $\geq 40\%$ had a mean Constant Score of 28 ± 14 .⁴ Simovitch et al. evaluated 678 patients who received RSA and found full improvement especially in Constant Score and active forward flexion by 24 months, although the majority of improvements were achieved in the first 6 months.¹⁷ Latest follow-up for Constant Score was 71.2 ± 14.7 , which might be caused by younger mean age and inclusion of degenerative disease.¹⁷ Younger patients have generally a higher range of motion, extended activity in daily life and more power compared to elder patients. In contrast Boyer et al. evaluated patients provided with RSA and trauma-specific locked stem for 3- and 4-part proximal humeral fractures with a mean Constant Score of 77.6 (28.8–119).¹⁸ Mersch et al. evaluated 34 patients with a mean Constant Score 54 ± 9 after a mean follow-up of 23 ± 10.6 months.¹⁹

Hartel et al. found a Constant Score of 31.1 ± 18.7 , the mean follow-up was obtained after 41 ± 31 months (range: 10–113) at a mean age of 69 ± 10 years (range: 46–83),²⁰ but only revision operations were evaluated. In our evaluation, patients with primary RSA showed a mean Constant Score of 57 ± 12 ($n = 17$), whereas patients showed a mean Constant Score of 52 ± 18 ($n = 6$) after secondary arthroplasty. Generally discrepancy of results might be caused by subjective part of Constant Score. Different sense of pain can cause discrepancy in scoring. There were also slight differences in strength

measurement and used equipment. We used a modified method of strength measurement with the utilization of a static box van (Kern, Switzerland), which allows a static measurement in exact position and with limited reduction in effectiveness. This fact might cause more accurate results compared to other studies. Another important point might be the point of time of examination, which differed in several evaluations.^{19,20} Since outcomes are stable after two years,⁴ our follow-up examinations were performed after 28.4 ± 10.47 months.

Complication rate can also affect results of Constant Score and complication rates following RSA have been shown to be close to 25%.²¹ However patients in our evaluation did not show any complications.

Generally patient-reported outcome measures allow comparison of health-related quality of life across populations and pathologies.²² We used the questionnaire of EQ5D3L for our evaluation, which had not been used for RSA studies before. In our study, we found a mean value of the descriptive part of 6.6 points and 75.65% of the visual part of all operated patients. In general patients showed a high satisfaction. The mean value of the descriptive part showed 6.63 points for primary operated patients and 6.57 points for secondary operated patients. The visual part showed a result of 75.31% (difference value 25.94%) for patient after primary surgery and 79.28% (difference value 20.71%) after secondary surgery. It seems to be surprising, that satisfaction of patients after secondary surgery was even higher compared to primary surgery.

This might be caused by higher dissatisfaction, pain and limited mobility caused by complications before secondary operation. Irrespective of condition before fracture, patient dissatisfaction before secondary operation was higher compared to primary operation.

Some authors declare, that satisfaction of patients with their care rating is a poor indicator of shoulder function.^{4,23} By contrast, we found a positive correlation between Constant Score and EQ5D3L. Besides range of motion, Constant Score considers pain, strength and activities of daily life. These parameters are essential for patients' satisfaction, which might be an explanation for the positive correlation. Alta et al. showed a significant correlation between activity, mobility and strength, and external rotation torques for RSA.²⁴

We also found a positive correlation between Constant Score and patient age, which has been shown for rotator cuff before.²⁵ Significant decrease of range of motion is associated with increase of age. Shoulder flexion of patients without a fracture decreases 25% from peak range of motion at about 10 years of age to the age of 70 years. This loss of flexibility is closely related to parallel loss of muscle strength,²² which we found also in our evaluation in 90° abduction and 45° abduction. Higher satisfaction in case of higher morbidity and higher strength in case of higher mobility seems to be a logical assignment.

As we focused on the age group over 65 years, there were no large variation to Constant Score in this group, but a slight positive correlation. Rotator cuff problems are frequent in this age group, while daily life activities and range of motion is reduced compared to younger patients. Constant Score and months postoperative showed also a slight positive correlation, as postoperative results are stable after 2 years.⁴

5. Conclusion

It is known that conclusions on the success of RSA depend on the particular outcome modality chosen.⁴ Therefore, we evaluated range of motion, strength, Constant Score and EQ5D3L. Strength was measured with a modified method, so that sheer static measure was possible, which is important in daily living. Main findings were significant better results in range of motion, strength and Constant Score compared to the unoperated side.

Patients showed significant better results in range of motion, strength and Constant Score after primary operation compared to secondary operated group. Only results of EQ5D3L were significant better in the secondary operated group.

We found a positive correlation between Constant Score and EQ5D3L, strength and abduction, age and Constant Score and time period postoperative and Constant Score. Different outcome measures showed consensus in terms of functional outcome after primary and secondary operation. Despite concerns about self-report measures, we found high correlation between independent expert global assessment and self-reported evaluation. The combination of Constant Score and EQ5D3L seems to be a good supplementation for follow-up evaluation after RSA.

Ethics approval

The Ethical Committee Kiel, Schleswig-Holstein examined and approved the study (No. D463/16).

Consent for publication

All Patients gave their consent in collecting data. All data were collected at the UKSH, Campus Kiel. Information about publications of data were disclosed to all participants. All patients gave their agreement.

Availability of data and material

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request. All data generated or analyzed during this study are included in this published article. The manuscript, including related data, figures and tables have not been previously published and are not under consideration elsewhere.

Conflicts of interest

All authors declare that there are no financial or non-financial competing interests.

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Authors' contributions

We declare, that all authors have made substantial contributions to the conception and design of the study, acquisition of data, analysis and interpretation of data. EM, SL and SFO designed the study. SFO, PB, JF, JS, CB and SL analyzed the data and drafted the manuscript. MW and JF also made significant contributions in drafting of the manuscript. AS supervised the study. All authors read and approved the final manuscript. There was no writing assistance. Each author has participated sufficiently in the work to take public responsibility for appropriate portions of the content. Each author agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Acknowledgements

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Conflicts of interest

All authors disclose any financial and personal relationships with other people or organisations that could inappropriately influence the work.

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References

1. Hanson B, Neidenbach P, de Boer P, Stengel D. Functional outcomes after

- nonoperative management of fractures of the proximal humerus. *J Shoulder Elb Surg*. 2009 Jul-Aug;18(4):612–621.
2. Boesmueller S, Wech M, Gregori M, et al. Risk factors for humeral head necrosis and non-union after plating in proximal humeral fractures. *Injury*. 2016 Feb;47(2):350–355.
 3. Teratani T. Comparison of the epidemiology and outcomes of traumatic and nontraumatic rotator cuff tears. *J Orthop*. 2017;14:166–170.
 4. Roy JS, Macdermid JC, Goel D, Faber KJ, Athwal GS, Drosdowech DS. What is a successful outcome following reverse total shoulder arthroplasty? *Open Orthop J*. 2010 Apr 23;4:157–163.
 5. Gerber C, Fuchs B, Hodler J. The results of repair of massive tears of the rotator cuff. *J Bone Joint Surg Am*. 2000;82(4):505–515.
 6. Kilcoyne RF, Shuman WP, Matsen FA, et al. The Neer classification of displaced proximal humeral fractures: spectrum of findings on plain radiographs and CT scans. *AJR Am J Roentgenol*. 1990;154(5):1029–1033.
 7. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res*. 1987 Jan(214):160–164.
 8. Launonen AP, Lepola V, Saranko A, Flinkkilä T, Laitinen M, Mattila VM. Epidemiology of proximal humerus fractures. *Arch Osteoporos*. 2015;10:209.
 9. Giardella A, Ascione F, Mocchi M, et al. Reverse total shoulder versus angular stable plate treatment for proximal humeral fractures in over 65 years old patients. *Muscles Ligaments Tendons J*. 2017 Sep 18;7(2):271–278.
 10. De Wilde LF, Audenaert EA, Berghs BM. Shoulder prostheses treating cuff tear arthropathy: a comparative biomechanical study. *J Orthop Res*. 2004;22:1222–1230.
 11. 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 Apr;92(4):535–539.
 12. Longo UG, Petrillo S, Berton A, Denaro V. Reverse total shoulder arthroplasty for the management of fractures of the proximal humerus: a systematic review. *Musculoskelet Surg*. 2016 Aug;100(2):83–91.
 13. Gallinet D, Clappaz P, Garbuio P, Tropet Y, Obert L. Three or four parts complex proximal humerus fractures: hemiarthroplasty versus reverse prosthesis: a comparative study of 40 cases. *Orthop Traumatol Surg Res*. 2009 Feb;95(1):48–55.
 14. Bufquin T, Hersan A, Hubert L, Massin P. Reverse shoulder arthroplasty for the treatment of three- and four-part fractures of the proximal humerus in the elderly: a prospective review of 43 cases with a short-term follow-up. *J Bone Joint Surg Br*. 2007 Apr;89(4):516–520.
 15. Seidl A, Sholder D, Warrender W, et al. Early versus late reverse shoulder arthroplasty for proximal humerus fractures: does it matter? *Arch Bone Jt Surg*. 2017 Jul;5(4):213–220.
 16. Sabesan VJ, Lombardo DJ, Khan J, Wiater JM. Assessment of the optimal shoulder outcome score for reverse shoulder arthroplasty. *J Shoulder Elb Surg*. 2015 Oct;24(10):1653–1659.
 17. Simovitch RW, Friedman RJ, Cheung EV, et al. Rate of improvement in clinical outcomes with anatomic and reverse total shoulder arthroplasty. *J Bone Joint Surg Am*. 2017 Nov 1;99(21):1801–1811.
 18. Boyer E, Menu G, Loisel F, et al. Cementless and locked prosthesis for the treatment of 3-part and 4-part proximal humerus fractures: prospective clinical evaluation of hemi- and reverse arthroplasty. *Eur J Orthop Surg Traumatol*. 2017 Apr;27(3):301–308.
 19. Merschin D, Stangl R. Proximal humeral fractures in the elderly: quality of life, clinical results and institutionalization following primary reverse fracture arthroplasty. *Der Unfallchirurg*. 2016 Dec;119(12):1015–1022.
 20. Hartel BP, Alta TD, Sewnath ME, Willems WJ. Difference in clinical outcome between total shoulder arthroplasty and reverse shoulder arthroplasty used in hemiarthroplasty revision surgery. *Int J Shoulder Surg*. 2015 Jul-Sep;9(3):69–73.
 21. Bohsali KI, Wirth MA, Rockwood CA. Complications of total shoulder arthroplasty. *J Bone Joint Surg Am*. 2006 Oct;88(10):2279–2292.
 22. Evans J, Dattani R, Ramasamy V, Patel V. Responsiveness of the EQ-5D-3L in elective shoulder surgery: does it adequately represent patient experience? *J Orthop Surg*. 2018 May-Aug;26(2) 2309499018774922.
 23. 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 Jul;89(7):1476–1485.
 24. Alta TD, Veeger DH, de Toledo JM, Janssen TW, Willems WJ. Isokinetic strength differences between patients with primary reverse and total shoulder prostheses: muscle strength quantified with a dynamometer. *Clin Biomech*. 2014 Nov;29(9):965–970.
 25. Oh JH, Kim SH, Kang JY, Oh CH, Gong HS. Effect of age on functional and structural outcome after rotator cuff repair. *Am J Sports Med*. 2010 Apr;38(4):672–678.