Shoulder & Elbow

EOR | VOLUME 3 | FEBRUARY 2018
DOI: 10.1302/2058-5241.3.170044
www.efortopenreviews.org

EFORT open reviews

Reverse total shoulder arthroplasty

Filippo Familiari[1]
Jorge Rojas[2]
Mahmut Nedim Doral[3]
Gazi Huri[3]
Edward G. McFarland[2]

- Since the introduction of reverse total shoulder arthroplasty (RTSA) in 1987 (in Europe) and 2004 (in the United States), the number of RTSAs performed annually has increased.
- Although the main indication for RTSA has been rotator cuff tears, indications have expanded to include several shoulder conditions, many of which involve dysfunction of the rotator cuff.
- RTSA complications have been reported to affect 19% to 68% of patients and include acromial fracture, haematoma, infection, instability, mechanical baseplate failure, neurological injury, periprosthetic fracture and scapular notching.
- Current controversies in RTSA include optimal baseplate positioning, humeral neck-shaft angle (135° *versus* 155°), glenosphere placement (medial, lateral or bony increased offset RTSA) and subscapularis repair.
- Improvements in prosthesis design, surgeon experience and clinical results will need to occur to optimize this treatment for many shoulder conditions.

Keywords: reverse total shoulder arthroplasty; indications; contraindications; clinical outcomes; complications

Cite this article: *EFORT Open Rev* 2018;3:58–69
DOI: 10.1302/2058-5241.3.170044

Introduction

Traditionally, anatomical total shoulder arthroplasty (TSA) has been used to treat the shoulder joint with end-stage glenohumeral osteoarthritis (OA) and an intact rotator cuff. However, loosening of the glenoid component remains a common cause of failure after TSA, leading to revision surgery in 0.8% of TSAs per year.[1-3] Alternatives to TSA are cup arthroplasty, hemi-arthroplasty (HA) and interpositional allografts with HA. For patients without a rotator cuff or with rotator cuff tear arthropathy, the traditional treatment was HA. Unfortunately, HA for these indications provided unpredictable pain relief and little improvement in range of motion (ROM) or function.[4]

In the 1970s, Beddow and Alloy were using a prototype reverse shoulder arthroplasty in Liverpool for patients with rheumatoid arthritis but did not publish the results. In 1987, Grammont et al[5] introduced the reverse total shoulder arthroplasty (RTSA) to treat rotator cuff tear arthropathy. RTSA was approved by the US Food and Drug Administration in 2004,[6] and the number of RTSAs performed annually increased dramatically.[7] Approximately 10 000 RTSAs were performed in the USA in 2007, a fivefold increase over 2004. Estimates indicate that 30 000 RTSAs were performed in 2012.[7] To assess the contribution of RTSA to overall use of primary shoulder arthroplasty, Jain and Yamaguchi[8] used the Nationwide Inpatient Sample from 2009 through 2011. They found that the use of primary shoulder arthroplasty increased significantly during that period, with a major contribution from RTSA, which accounted for 42% of all primary shoulder arthroplasties in 2011.[8]

Indications and contraindications

Although the most common indication for RTSA is rotator cuff tear arthroplasty (Fig. 1), indications have expanded to include several conditions and situations that were difficult to treat with anatomical shoulder arthroplasty, such as acute proximal humerus fracture, chronic locked dislocation, chronic pseudoparalysis caused by irreparable rotator cuff without arthritis, glenohumeral arthritis with severe glenoid bone loss, immunological arthritis with or without associated rotator cuff tears, malunited/nonunited proximal humerus fracture, failed shoulder arthroplasty and tumours.[9-15] Many of these conditions involve dysfunction of the rotator cuff. Appropriate candidates for RTSA now include young patients, who have shown

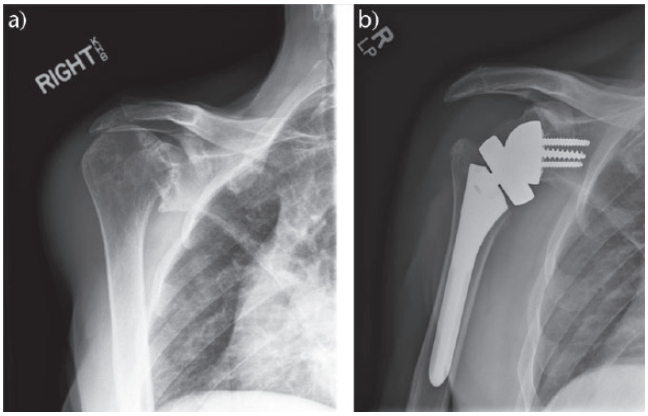

Fig. 1 a) Anteroposterior (AP) radiograph of a shoulder with rotator cuff tear arthropathy showing superior joint space narrowing; b) post-operative radiograph of RTSA.

excellent clinical improvement with high implant survivorship of up to 12 years.[16-21]

Contraindications to RTSA include axillary nerve damage, a non-functioning deltoid muscle, glenoid vault deficiency precluding baseplate fixation, infection and neuropathic joints.[22] Lädermann et al[23] showed that, in certain circumstances, pre-operative deltoid impairment is not an absolute contraindication to RTSA. Although mild deltoid dysfunction may be tolerated by patients who can experience pain relief from the procedure, it is important for patients to understand that their ROM and function may not improve.

Patients undergoing RTSA should be aware of its high rate of intra-operative and post-operative complications. There is also concern about clinical deterioration at approximately ten years after implantation of the Grammont-type prostheses.[24] Werner et al[25] showed that a higher baseline American Shoulder and Elbow Surgeons (ASES) score and an intact rotator cuff at the time of surgery correlated with little improvement after RTSA. Male sex, depression, total number of medical comorbidities, and receipt of workers compensation also correlated with little post-operative improvement.[25,26] Patient age and indication for surgery were not correlated with little improvement after RTSA.[25]

Clinical outcomes according to indication

Rotator cuff tear arthropathy

Rotator cuff tear arthropathy is one of the most reliable indications for RTSA.[26-30] Favard et al[28] retrospectively reviewed data from 506 patients with 527 RTSAs from 1985 through 2003 and reported an implant survivorship rate of 89% at ten years. Accordingly, in a study of 484 patients followed for a mean of 4.3 years, Favard et al[28] reported improvements in patient-reported outcomes (i.e. Constant-Murley score), significant improvements in pain relief and improved elevation from a mean of 71° to 130°. At a mean of 4.3 years after surgery, 90% of patients were satisfied or very satisfied with the outcome of surgery. Werner et al[30] retrospectively reviewed the results of 58 consecutive patients (mean age 68 years) who had undergone a Grammont-type RTSA. They reported significant improvements in patient-reported outcomes (i.e. subjective shoulder value and Constant-Murley score), improved elevation from a mean of 42° to 100° and improved abduction from a mean of 43° to 90°. Frankle et al[29] reported results of 60 patients (mean age 71 years) with 60 rotator cuff tear arthropathies treated with RTSA who were followed for a minimum of two years. They reported significant improvements in patient-reported outcomes (i.e. ASES score), improved abduction from a mean of 41° to 102° and improved elevation from a mean of 55° to 105°.

Pseudoparalysis caused by massive, irreparable rotator cuff tear without OA

Several studies have reported results of RTSA in patients with massive, irreparable rotator cuff tears without OA in whom the major symptom was severe loss of ROM (i.e. pseudoparalysis) (Fig. 2).[27,31,32]

Recently, a systematic review with meta-analysis and meta-regression reported that patients with massive, irreparable rotator cuff tears without OA have a high likelihood of achieving a painless shoulder and functional improvements after RTSA.[33] Wall et al[32] found no difference in outcomes among patients with massive rotator cuff tears and no associated arthritis *versus* those who underwent primary RTSA for rotator cuff tear arthropathy. Boileau et al[27] found that RTSA improved function for patients with pseudoparalysis and those with rotator cuff-deficient shoulders after failure of previous rotator cuff surgery, but results were inferior to those of primary RTSA for patients with massive rotator cuff tears or rotator cuff tear arthropathy.

Acute proximal humerus fracture

HA was traditionally the treatment of choice for three- and four-part proximal humerus fractures.[34,35] Because of less than optimal results with this approach, open reduction and internal fixation (ORIF) gained popularity, especially for younger patients.[36] However, the results of both HA and ORIF are unpredictable because of dependence on anatomical tuberosity healing.[32,37,38] The complication and failure rates of ORIF to treat shoulder fractures can be high.[39] RTSA may be a more reliable treatment for complex proximal humerus fractures because its functional outcomes appear to depend less on tuberosity healing and rotator cuff integrity (Fig. 3).[40,41] However, some authors have suggested that tuberosity repair is associated with increased external rotation compared with no

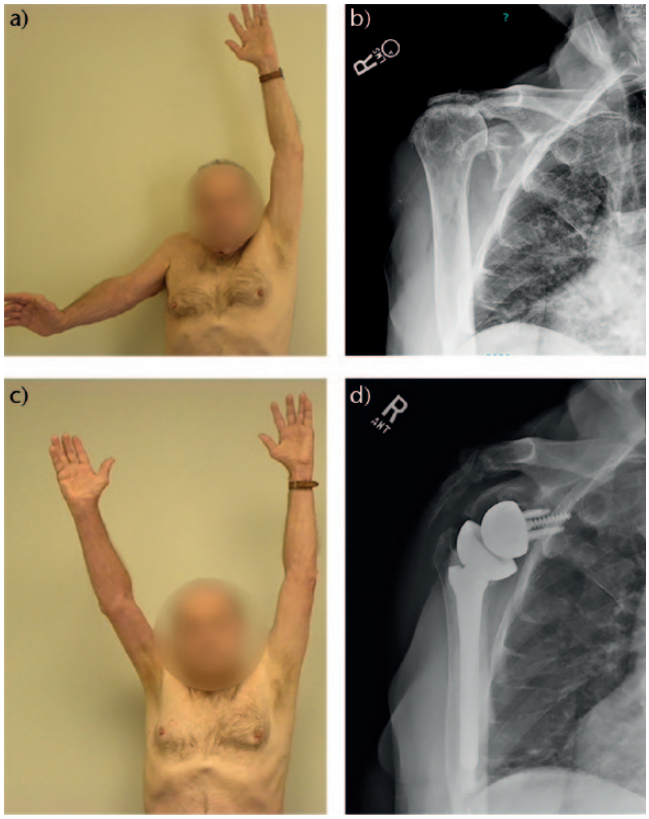

Fig. 2 a) Photograph of a man with superior subluxation of the right shoulder, typical of painless pseudoparalysis; b) radiographic appearance of the shoulder pre-operatively showing classical findings of cuff tear arthropathy; c) post-operative range of abduction after RTSA; d) AP radiograph of implanted RTSA.

repair.[38,40] RTSA can also be a valuable salvage procedure after failed ORIF of a proximal humerus fracture, with a relatively low revision rate.[42,43]

Several studies have reported favourable results of RTSA to treat proximal humeral fractures.[41,44-52] Two studies found no significant differences in the clinical results of patients with acute proximal humerus fractures treated with HA or RTSA.[46,52] However, other authors reported that RTSA appears to achieve better clinical outcomes than HA.[44,47,51,53] Ross et al[50] reported good clinical and radiographic outcomes of RTSA in elderly patients (mean age 79 years [range, 67 to 90 years]) with three- and four-part proximal humerus fractures and an extremely low complication rate (3.4%) with no dislocations, infections or prosthetic revisions. A recent meta-analysis showed that RTSA may produce more favourable clinical outcomes than HA for treating complex proximal humeral fractures.[54]

Several studies have cautioned that RTSA may not be the optimal treatment for patients with acute proximal humerus fractures.[15,41,55] Smith et al[15] reported that patients treated with RTSA had limited post-operative abduction (approximate range 90° to 100°), and that

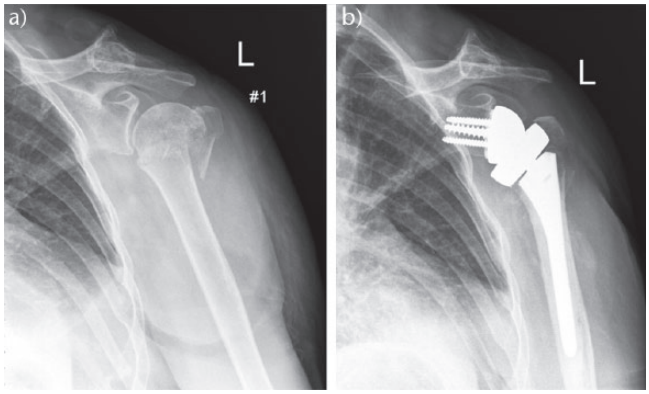

Fig. 3 a) AP radiograph of a proximal humerus fracture; b) post-operative radiograph of the fracture treated with RTSA.

recovery of external rotation and internal rotation varied widely. Cazeneuve and Cristofari[55] and Bufquin et al[41] showed various post-operative radiographic findings in patients with acute proximal humerus fractures treated with RTSA, and they cautioned that long-term results are required before RTSA can be recommended as a routine procedure for complex fractures of the proximal humerus in the elderly.

Malunited/nonunited proximal humerus fracture

Surgical options to address malunited proximal humerus fractures are determined largely by the existing deformity[56] and can be categorized broadly as humeral head-preserving techniques (e.g. osteotomies, soft-tissue releases and removal of bony protuberances) or humeral head-sacrificing techniques (e.g. HA, TSA and RTSA) (Fig. 4).[57]

Studies with short-term follow-up have reported high rates of patient satisfaction with RTSA for improving ROM, treating malunited proximal humerus fracture and reducing pain.[6,58,59] Boileau et al[60] recommended the use of RTSA to treat type-4 malunions (severe tuberosity malunion) when a greater tuberosity osteotomy was required. In a retrospective review, Martinez et al[58] reported improvement in Constant-Murley scores and ROM, as well as a high patient satisfaction rate (86%). Before surgery, patients should be informed that active external rotation might not be restored after RTSA, particularly if an osteotomy of the greater tuberosity is performed. Another approach to patients with painful, malunited proximal humeral fractures is to leave the tuberosities in place and insert the RTSA into the existing anatomy. Willis et al[59] did not perform a tuberosity osteotomy when placing the RTSA and recommended using the largest possible glenosphere to tension the soft tissue and prevent bony impingement.

Raiss et al[61] reported on 42 patients treated with RTSA for post-traumatic sequelae of the proximal part of the humerus with malunion of the tuberosities. Of those patients, 43% rated their result as very good, 45% as

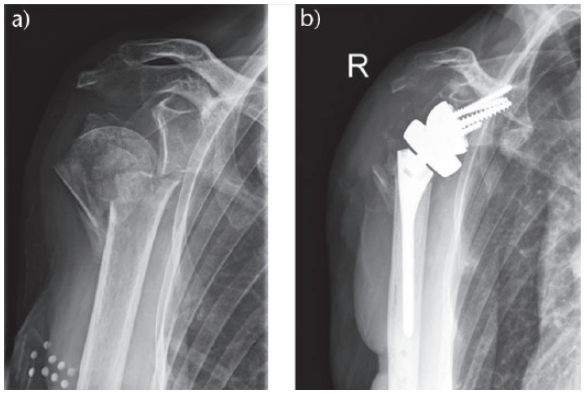

Fig. 4 a) AP radiograph of a malunited proximal humerus fracture; b) post-operative radiograph of the fracture treated with RTSA.

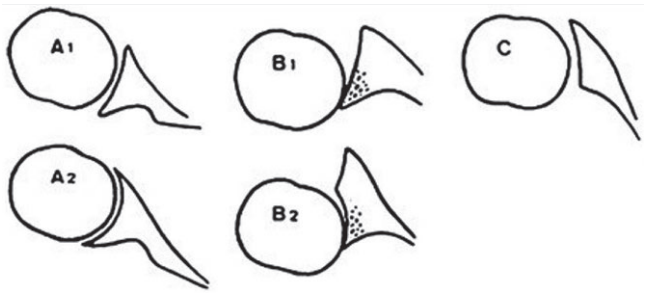

Fig. 5 Diagram of the Walch classification of glenoid erosion of primary glenohumeral arthritis. Reprinted with permission from Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. *J Arthroplasty* 1999;14:756-60.

good, 10% as satisfactory and 2% as unsatisfactory. Complications were one intra-operative humeral shaft fracture, one traumatic dislocation, one periprosthetic humeral fracture and one aseptic loosening of the humeral and glenoid components. The authors concluded that RTSA is a good treatment option for type-4 proximal humeral fracture sequelae that cannot be treated with anatomical TSA. In a study at the same institution, the use of RTSA for the treatment of nonunion of the surgical neck of the proximal part of the humerus (type-3 fracture sequelae) produced improvement in functional outcome but a high complication rate.[62] Dislocation was the most common complication and was associated with resection of the tuberosities of the proximal part of the humerus, which has been postulated to be necessary to provide a compressive force from the deltoid muscle.[45,63] Another reason for instability may be the removal of the rotator cuff to gain exposure and place the implants. Therefore, the authors recommended that the tuberosities and the attached rotator cuff should be preserved if possible to reduce the risk of dislocation.

Glenohumeral OA with severe glenoid bone loss

The use of RTSA in patients with severe glenoid bone loss and OA has been reported.[64] There are several classifications of glenoid bone loss that define various defects caused by OA. The most commonly used classification is that of Walch et al:[65] type A2, central bone loss; type B2, posterior bone loss; and type C, severe retroversion of the glenoid (Fig. 5).

Although glenoid bone grafting has been recommended for type-B2 and type-C glenoid wear, it has been shown that use of RTSA without glenoid bone grafting can be successful for patients with severe glenoid bone loss.[64,66] Excellent results have been reported in patients with OA, an intact rotator cuff and substantial glenoid bone loss treated with RTSA with[64] or without[66] bone grafting (Fig. 6). Long-term follow-up studies are needed before RTSA can be recommended in patients with severe glenoid bone loss.[11]

Chronic locked glenohumeral joint dislocation

Chronic locked glenohumeral dislocation presents many challenges caused by humeral and glenoid bone loss, concomitant soft-tissue contractures and rotator cuff lesions (Fig. 7).[67] In these patients the failure rate for TSA has increased, with increasing follow-up because of recurrent instability, glenoid loosening and graft subsidence.[68-70] Werner et al[67] reported on 21 patients treated with glenoid bone grafting with RTSA for neglected anterior dislocation with substantial glenoid bone loss at a mean follow-up of 4.9 years (range, 2 to 10 years). They reported an average 45% glenoid bone loss based on glenoid width measurements on pre-operative CT scans or MR images. Outcomes were rated as excellent by ten patients, good by eight patients and fair by three patients.[67]

Rheumatoid arthritis with or without associated rotator cuff tears

The use of RTSA for patients with rheumatoid arthritis has been studied by several authors.[14,71-74] Two studies have raised concerns about the high incidence of glenoid baseplate radiographic lucency at follow-up in this patient population.[14,73] However, excellent to satisfactory results have been reported in up to 95% of patients with rheumatoid arthritis who were treated with RTSA.[75]

Revision arthroplasty

The options for revision surgery after primary shoulder arthroplasty (i.e. HA, resurfacing arthroplasty or TSA) are limited by the challenges of rotator cuff deficiency, glenoid bone loss and soft-tissue contractures.[76] RTSA has solved many of these challenges and produced high patient satisfaction (Fig. 8).[77] However, although some of

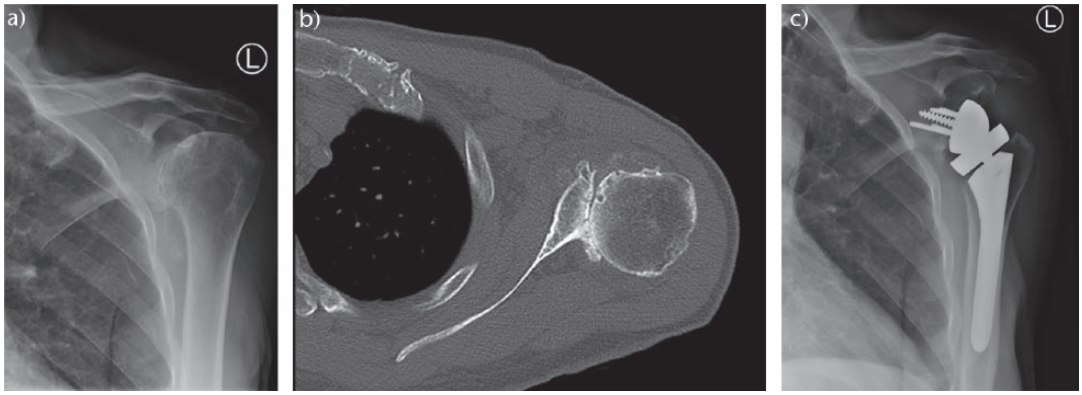

Fig. 6 a) AP radiograph of a shoulder with osteoarthritis, an intact rotator cuff and major glenoid bone loss; b) axial view of a CT scan of the shoulder showing 35° of retroversion; c) AP radiograph of the shoulder treated with RTSA without bone grafting.

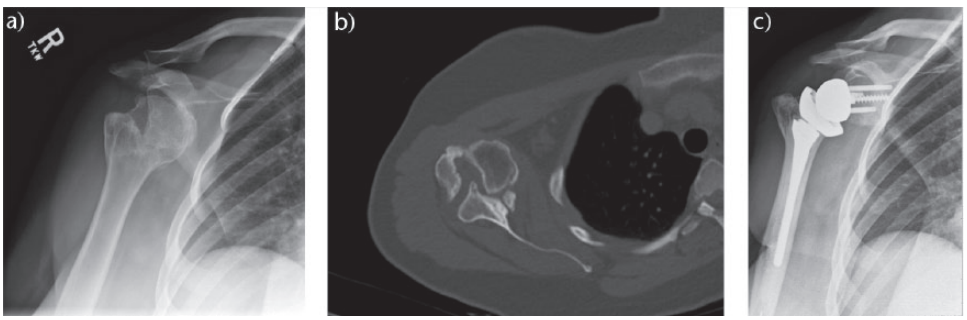

Fig. 7 a) AP radiograph of a locked dislocation; b) axial view of a CT scan of the same patient with glenoid bone loss; c) AP radiograph of the shoulder treated with RTSA.

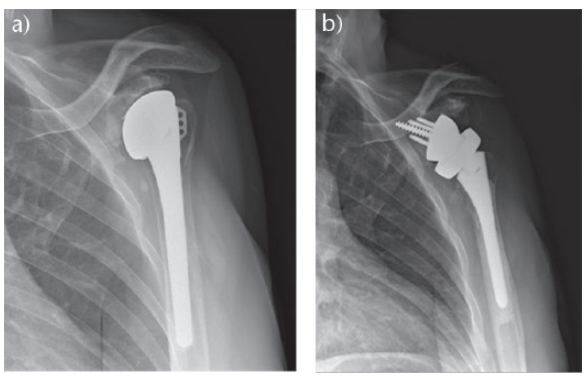

Fig. 8 a) AP radiograph of a failed TSA; b) AP post-operative radiograph after RTSA.

the clinical results have been excellent, the use of RTSA in these patients is associated with higher complication and failure rates compared with RTSA for patients without previous arthroplasty.[78]

The outcomes of RTSA for failed shoulder arthroplasty have been favourable.[12,13,16,79-81] Levy et al[12] retrospectively reported on outcomes of 29 RTSAs for the treatment of failed HA performed after proximal humeral fracture. They found significant improvements in the simple shoulder test (SST) and ROM but a complication rate of 28%. Another study of outcomes of RTSA after failed HA in 19 shoulders of 18 patients with glenohumeral arthritis and rotator cuff deficiency reported significant improvement in ROM, with 32% of patients undergoing revision for prosthesis-related complications.[13] Walker et al[81] evaluated 24 patients who underwent RTSA after failure of TSA. They found significant improvements in SST scores and ROM but an overall complication rate of 23%. Similarly, Melis et al[79] studied 34 patients who underwent revision RTSA for failed TSA and found that Constant-Murley scores and the ROM in forward flexion improved significantly. They reported a post-operative complication rate of 30%, and 22% of these patients underwent revision surgery. Patel et al[80] reported on 28 patients who underwent RTSA for treatment of a failed shoulder arthroplasty (i.e. HA, RTSA or TSA). They reported significant improvements in all outcome measures, including ASES score, University of California Los Angeles score, SST score and the visual analogue scale, with an overall complication rate of 10.7%. Black et al[16] reported on 32 patients aged younger than 65 years

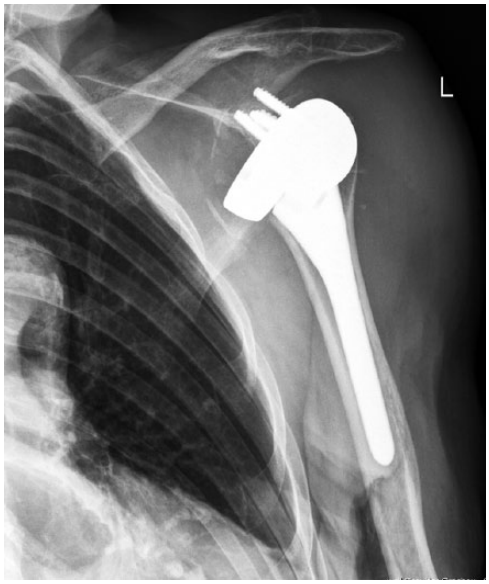

Fig. 9 AP radiograph of a dislocated RTSA.

treated with RTSA after failed shoulder arthroplasty. Results were compared with those of a similar cohort of 33 patients who underwent primary RTSA. Post-operatively, when comparing primary to revision RTSA, the visual analogue scale and ASES scores were not significantly different, whereas the subjective shoulder value was significantly better for the primary group. Although there were more complications in the revision group (28% *versus* 18%), the difference was not statistically significant.

Tumours

Several shoulder reconstruction techniques have been reported for patients after wide resection of the proximal humerus and rotator cuff tendons for malignant bone tumours, including allograft, arthrodesis and shoulder arthroplasties.[82] However, a prerequisite for the ability to implant a RTSA in these cases requires preservation of the axillary nerve and deltoid muscle to be successful.[6,83]

Bonnevialle et al[82] reported on eight patients treated for malignant tumours of the proximal humerus with transarticular resection of the tumour and shoulder reconstruction with RTSA. They reported improvement in all outcome scores and concluded that RTSA is an acceptable option to preserve function after resection of a malignant tumour of the proximal humerus.

Complications

Reported complication rates after RTSA are in the range of 19% to 68% and include acromial fracture, haematoma, infection, instability, mechanical baseplate failure, neurological injury, periprosthetic fracture and scapular notching.[30,84-89] These rates are influenced by the indications for RTSA and the proportion of revision procedures included in each study.[90] Other factors influencing complication rates include component design and surgeon experience.[6,32,88] Wall and Walch[91] reported a 13% complication rate for primary RTSA and a 37% complication rate for revision RTSA. Wierks et al[89] reported 33 complications in 15 patients; the most frequent complications were neuropathy, intra-operative fracture and dislocation, with the primary cause for revision surgery being dislocation. Other authors have reported complication rates as high as 68% for primary RTSA.[32] Walch et al[88] reported the incidence of complications to be 19% for primary RTSAs and 24% for revision RTSAs. For revision RTSA, the reported complication and revision rates in a meta-analysis by Zumstein et al[92] were 24% and 10%, respectively. Saltzman et al[93] reported overall complication rates of 25% after primary RTSA and 69% after revision RTSA.

Instability

Dislocation after RTSA is a major concern (Fig. 9). The incidence of post-operative instability has been reported to be in the range of 2% to 31%.[92,94,95] Patient risk factors for dislocation include body mass index > 30, male sex, previous surgery and subscapularis deficiency.[96,97] Surgical factors contributing to instability include inadequate soft-tissue and deltoid tensioning,[6,84,94,98] malpositioned implants,[99] mechanical impingement, insufficiency of the subscapularis[87] and use of the deltopectoral approach compared with the anterosuperior approach.[6,32,84,92,100] The instability rate has also been associated with prosthesis design; prostheses with a head-neck angle of -155° have been shown to have a higher instability rate than those with a more horizontal head-neck angle of 135° (Fig. 10).[101]

Teusink et al[97] reported that instability of RTSA often occurs within six months after surgery, with half of cases occurring within three months. When dislocation occurred within three months, a surgical error was considered the most likely cause and closed reduction was typically unsuccessful. Conversely, late dislocation (> 1 year after surgery) can usually be treated successfully with closed reduction.[100]

Infection

Reported rates of infection after RTSA are in the range of 1% to 15%, which is higher than the infection rate after anatomical TSA.[90,100] In one of the few comparison studies, Barco et al[90] found the infection rate after primary RTSA to be significantly higher than that after primary TSA. In a systematic review including primary and revision RTSA, Zumstein et al[92] reported a mean infection rate of

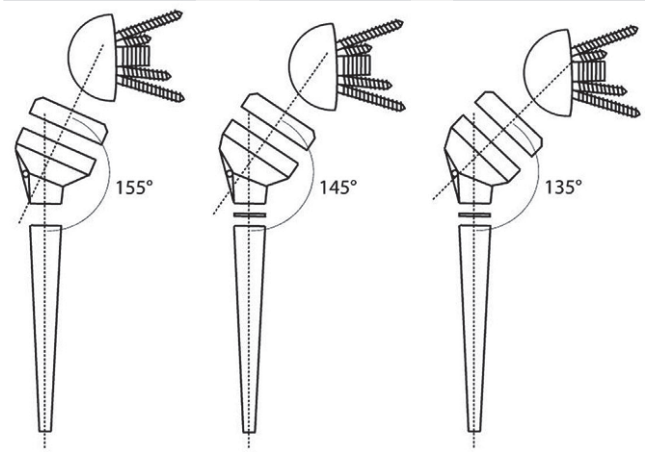

Fig. 10 Diagram showing the different head-neck angles of Grammont-type prostheses *vs* a more horizontal head-neck angle seen in more recent designs. Reprinted with permission from Oh JH, Shin SJ, McGarry MH, Scott JH, Heckmann N, Lee TQ. Biomechanical effects of humeral neck-shaft angle and subscapularis integrity in reverse total shoulder arthroplasty. *J Shoulder Elbow Surg* 2014;23:1091-8.

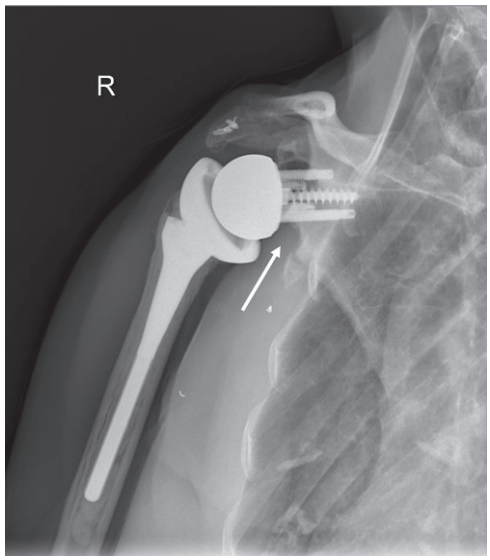

Fig. 11 AP radiograph of notching of the inferior glenoid (arrow) after RTSA.

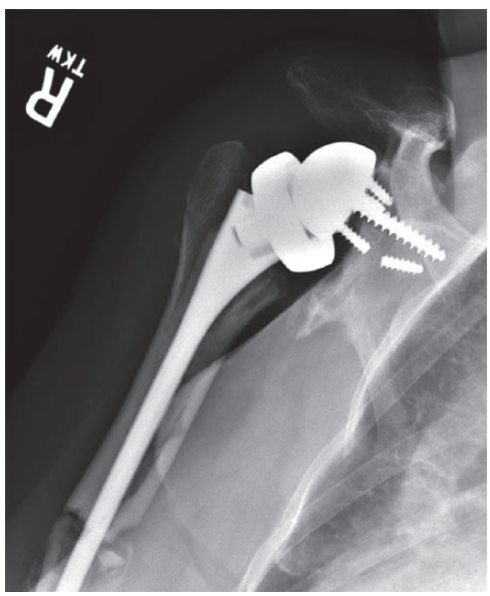

Fig. 12 AP radiograph of a baseplate failure after RTSA.

3.8%, with a higher rate of infection after revision surgery than after primary surgery. In a study of 3906 patients, Richards et al[102] reported a sixfold greater risk of infection after RTSA compared with an anatomical TSA. A history of shoulder trauma or failed HA has also been shown in some studies to be a risk factor for infection.[102,103]

Scapular notching

Scapular notching is a complication unique to RTSA, with a reported incidence of 50% to 96% (Fig. 11).[14,30] Scapular notching typically occurs within six months after surgery and appears to stabilize in most cases.[104,105] However, some studies report an apparent increase in incidence and severity of notching with increasing follow-up.[100] The rate of notching in RTSAs with a medialized centre of rotation has been reported to be 47%; however, systematic review has reported rates of up to 97%.[90] The reported rate of notching when using lateralized RTSAs (4.6%) is significantly lower compared with medialized designs.[90] The major concern with notching is that it may lead to baseplate failure, but that concern remains controversial (Fig. 12).

Although some authors have suggested an increased risk of baseplate loosening with scapular notching,[30,106-108] others have not found such a relationship.[32,92,109-111] The clinical implications of notching are controversial; some authors have reported no associations with clinical outcomes,[32,110,111] whereas others have reported that high grades of notching may be associated with worse clinical outcomes.[32,104,110,111] The use of an anterosuperior approach, a high position of the baseplate on the glenoid and superior tilting have all been associated with higher rates of notching caused by mechanical impingement with the arm in adduction.[110] Eccentric glenospheres with an inferior offset and glenoid components with a more lateral offset (bony or metal) can reduce the risk of notching.[112,113] Mizuno et al[114] analysed the influence of an eccentric glenosphere in 47 consecutive cases compared with an historical group treated by the same surgeon. The rates of notching were not different but the severity of notching was less when using an eccentric glenosphere. Other authors have reported a negligible rate of notching when using an inferior offset component.[115]

Heterotopic ossification

Heterotopic ossification after RTSA is a relatively common finding of unknown clinical importance.[116] In a 164-patient cohort of primary and revision RTSAs, Ko et al[116] found an overall rate of heterotopic ossification of the long head of the triceps tendon of 62%. They found that men had a higher rate of heterotopic ossification than women, and that heterotopic ossification was associated with worse post-operative ROM.[116] The exact cause of heterotopic ossification in the long head of the triceps tendon after RTSA is unknown. It has been postulated to be caused by releases, traction on the triceps and more extensive exposure of the glenoid than is typically done in anatomical TSA.[116]

Neurological injury

Neurological injury is a known complication of shoulder arthroplasty of all types, with reported incidence in the range of 1% to 4%.[117,118] Nerves from the brachial plexus can undergo stretch injuries at the extremes of motion that occur during intra-operative positioning of the arm.[118,119] Brachial plexus palsies have been shown to be more common in RTSA than in TSA, possibly because of the lengthening effect on the arm during RTSA and the need for greater glenoid exposure.[120]

Scapular fractures

Scapular fractures are a well-recognized complication of RTSA, and they have been reported in 0.8% to 7.2% of cases.[121] Postulated causes include excessive tensioning of the deltoid,[90] placement of a superior screw in the baseplate[122] and stress of the implants on osteoporotic bone.[123] Insufficiency fractures of the acromion or displacement of the os acromiale after RTSA can be painful and can limit ROM.[90,100,124] Conversely, scapular spine fractures lead to painful dysfunction and may require ORIF.[100] Post-operative scapular fractures have been associated with inferior clinical results and increased risk of revision.[121] Bilateral scapular fractures[125] and clavicle stress fractures[126] after RTSA have also been reported.

Conclusions

RTSA has revolutionized the treatment of shoulder disorders that previously had no easy or acceptable solution. Patient satisfaction with RTSA can be high, and most patients experience pain relief and improved function. Although the short-term implant survival rate appears to be acceptable, the long-term results are unknown. RTSA is associated with a higher rate and more diverse spectrum of complications than is desirable. Improvements in prosthesis design, surgeon experience and clinical results will need to occur to optimize this treatment for many shoulder conditions.

AUTHOR INFORMATION

[1]Department of Orthopaedics and Traumatology, Villa del Sole Clinic, Italy.
[2]Division of Shoulder Surgery, Department of Orthopaedic Surgery, The Johns Hopkins University, USA.
[3]Department of Orthopaedics and Traumatology, Hacettepe University, Turkey.

Correspondence should be sent to: G. Huri, Hacettepe University School of Medicine, Orthopaedics and Traumatology Department, Hacettepe University, Ankara 06100, Turkey.
Email: gazihuri@yahoo.com

ICMJE CONFLICT OF INTEREST STATEMENT

E. McFarland reports personal fees from Stryker; grants from DePuy Mitek, activity outside the submitted work.

FUNDING STATEMENT

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES

1. Bohsali KI, Wirth MA, Rockwood CA Jr. Complications of total shoulder arthroplasty. *J Bone Joint Surg [Am]* 2006;88:2279-92.

2. Papadonikolakis A, Neradilek MB, Matsen FA III. Failure of the glenoid component in anatomic total shoulder arthroplasty: A systematic review of the English-language literature between 2006 and 2012. *J Bone Joint Surg [Am]* 2013;95:2205-12.

3. Torchia ME, Cofield RH, Settergren CR. Total shoulder arthroplasty with the Neer prosthesis: long-term results. *J Shoulder Elbow Surg* 1997;6:495-505.

4. 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-A:1814-22.

5. Grammont P, Trouilloud P, Laffay J, Deries X. Concept study and realization of a new total shoulder prosthesis [in French]. *Rhumatologie* 1987;39:407-18.

6. Boileau P, Watkinson DJ, Hatzidakis AM, Balg F. Grammont reverse prosthesis: design, rationale, and biomechanics. *J Shoulder Elbow Surg* 2005;14:147S-61S.

7. Kim SH, Wise BL, Zhang Y, Szabo RM. Increasing incidence of shoulder arthroplasty in the United States. *J Bone Joint Surg Am* 2011;93:2249-54.

8. Jain NB, Yamaguchi K. The contribution of reverse shoulder arthroplasty to utilization of primary shoulder arthroplasty. *J Shoulder Elbow Surg* 2014;23:1905-12.

9. Austin L, Zmistowski B, Chang ES, Williams GR Jr. Is reverse shoulder arthroplasty a reasonable alternative for revision arthroplasty? *Clin Orthop Relat Res* 2011;469:2531-7.

10. Guery J, Favard L, Sirveaux F, et al. Reverse total shoulder arthroplasty. Survivorship analysis of eighty replacements followed for five to ten years. *J Bone Joint Surg [Am]* 2006;88:1742-7.

11. Hyun YS, Huri G, Garbis NG, McFarland EG. Uncommon indications for reverse total shoulder arthroplasty. *Clin Orthop Surg* 2013;5:243-55.

12. Levy J, Frankle M, Mighell M, Pupello D. The use of the reverse shoulder prosthesis for the treatment of failed hemiarthroplasty for proximal humeral fracture. *J Bone Joint Surg [Am]* 2007;89:292-300.

13. Levy JC, Virani N, Pupello D, Frankle M. Use of the reverse shoulder prosthesis for the treatment of failed hemiarthroplasty in patients with glenohumeral arthritis and rotator cuff deficiency. *J Bone Joint Surg [Br]* 2007;89:189-95.

14. Rittmeister M, Kerschbaumer F. Grammont reverse total shoulder arthroplasty in patients with rheumatoid arthritis and nonreconstructible rotator cuff lesions. *J Shoulder Elbow Surg* 2001;10:17-22.

15. Smith CD, Guyver P, Bunker TD. Indications for reverse shoulder replacement: A systematic review. *J Bone Joint Surg [Br]* 2012;94:577-83.

16. Black EM, Roberts SM, Siegel E, et al. Reverse shoulder arthroplasty as salvage for failed prior arthroplasty in patients 65 years of age or younger. *J Shoulder Elbow Surg* 2014;23:1036-42.

17. Ek ET, Neukom L, Catanzaro S, Gerber C. Reverse total shoulder arthroplasty for massive irreparable rotator cuff tears in patients younger than 65 years old: Results after five to fifteen years. *J Shoulder Elbow Surg* 2013;22:1199-208.

18. Muh SJ, Streit JJ, Wanner JP, et al. Early follow-up of reverse total shoulder arthroplasty in patients sixty years of age or younger. *J Bone Joint Surg [Am]* 2013;95:1877-83.

19. Otto RJ, Clark RE, Frankle MA. Reverse shoulder arthroplasty in patients younger than 55 years: 2- to 12-year follow-up. *J Shoulder Elbow Surg* 2017;26:792-7.

20. Sershon RA, Van Thiel GS, Lin EC, et al. Clinical outcomes of reverse total shoulder arthroplasty in patients aged younger than 60 years. *J Shoulder Elbow Surg* 2014;23:395-400.

21. Walters JD, Barkoh K, Smith RA, Azar FM, Throckmorton TW. Younger patients report similar activity levels to older patients after reverse total shoulder arthroplasty. *J Shoulder Elbow Surg* 2016;25:1418-24.

22. Drake GN, O'Connor DP, Edwards TB. Indications for reverse total shoulder arthroplasty in rotator cuff disease. *Clin Orthop Relat Res* 2010;468:1526-33.

23. Ladermann A, Walch G, Denard PJ, et al. Reverse shoulder arthroplasty in patients with pre-operative impairment of the deltoid muscle. *Bone Joint J* 2013;95-B: 1106-13.

24. Bacle G, Nove-Josserand L, Garaud P, Walch G. Long-term outcomes of reverse total shoulder arthroplasty: A follow-up of a previous study. *J Bone Joint Surg [Am]* 2017;99:454-61.

25. Werner BC, Wong AC, Mahony GT, et al. Causes of poor postoperative improvement after reverse total shoulder arthroplasty. *J Shoulder Elbow Surg* 2016;25:e217-22.

26. Morris BJ, Haigler RE, Laughlin MS, et al. Workers' compensation claims and outcomes after reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 2015;24:453-9.

27. Boileau P, Gonzalez JF, Chuinard C, Bicknell R, Walch G. Reverse total shoulder arthroplasty after failed rotator cuff surgery. *J Shoulder Elbow Surg* 2009;18:600-6.

28. Favard L, Levigne C, Nerot C, et al. Reverse prostheses in arthropathies with cuff tear: Are survivorship and function maintained over time? *Clin Orthop Relat Res* 2011;469:2469-75.

29. Frankle M, Siegal S, Pupello D, et al. 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;87:1697-705.

30. Werner CML, Steinmann PA, Gilbart M, Gerber C. Treatment of painful pseudoparesis due to irreparable rotator cuff dysfunction with the Delta III reverse-ball-and-socket total shoulder prosthesis. *J Bone Joint Surg [Am]* 2005;87:1476-86.

31. 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;92:2544-56.

32. Wall B, Nove-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;89:1476-85.

33. Sevivas N, Ferreira N, Andrade R, et al. Reverse shoulder arthroplasty for irreparable massive rotator cuff tears: A systematic review with meta-analysis and meta-regression. *J Shoulder Elbow Surg* 2017;26:e265-77.

34. Neer CS II. Displaced proximal humeral fractures. I. Classification and evaluation. *J Bone Joint Surg [Am]* 1970;52:1077-89.

35. Neer CS II. Displaced proximal humeral fractures. II. Treatment of three- part and four-part displacement. *J Bone Joint Surg [Am]* 1970;52:1090-103.

36. Solberg BD, Moon CN, Franco DP, Paiement GD. Surgical treatment of three and four-part proximal humeral fractures. *J Bone Joint Surg Am* 2009;91:1689-97.

37. Boileau P, Krishnan SG, Tinsi L, et al. Tuberosity malposition and migration: reasons for poor outcomes after hemiarthroplasty for displaced fractures of the proximal humerus. *J Shoulder Elbow Surg* 2002;11:401-12.

38. Chun YM, Kim DS, Lee DH, Shin SJ. Reverse shoulder arthroplasty for four-part proximal humerus fracture in elderly patients: Can a healed tuberosity improve the functional outcomes? *J Shoulder Elbow Surg* 2017;26:1216-21.

39. Jost B, Spross C, Grehn H, Gerber C. Locking plate fixation of fractures of the proximal humerus: Analysis of complications, revision strategies and outcome. *J Shoulder Elbow Surg* 2013;22:542-9.

40. Anakwenze OA, Zoller S, Ahmad CS, Levine WN. Reverse shoulder arthroplasty for acute proximal humerus fractures: A systematic review. *J Shoulder Elbow Surg* 2014;23:e73-80.

41. 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;89:516-20.

42. Dezfuli B, King JJ, Farmer KW, Struk AM, Wright TW. Outcomes of reverse total shoulder arthroplasty as primary versus revision procedure for proximal humerus fractures. *J Shoulder Elbow Surg* 2016;25:1133-7.

43. Grubhofer F, Wieser K, Meyer DC, et al. Reverse total shoulder arthroplasty for failed open reduction and internal fixation of fractures of the proximal humerus. *J Shoulder Elbow Surg* 2017;26:92-100.

44. Boyle MJ, Youn SM, Frampton CMA, Ball CM. Functional outcomes of reverse shoulder arthroplasty compared with hemiarthroplasty for acute proximal humeral fractures. *J Shoulder Elbow Surg* 2013;22:32-7.

45. 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;92:535-9.

46. 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;95:48-55.

47. Garrigues GE, Johnston PS, Pepe MD, et al. Hemiarthroplasty versus reverse total shoulder arthroplasty for acute proximal humerus fractures in elderly patients. *Orthopedics* 2012;35:e703-8.

48. Klein M, Juschka M, Hinkenjann B, Scherger B, Ostermann PAW. Treatment of comminuted fractures of the proximal humerus in elderly patients with the Delta III reverse shoulder prosthesis. *J Orthop Trauma* 2008;22:698-704.

49. Lenarz C, Shishani Y, McCrum C, et al. Is reverse shoulder arthroplasty appropriate for the treatment of fractures in the older patient? Early observations. *Clin Orthop Relat Res* 2011;469:3324-31.

50. Ross M, Hope B, Stokes A, et al. Reverse shoulder arthroplasty for the treatment of three-part and four-part proximal humeral fractures in the elderly. *J Shoulder Elbow Surg* 2015;24:215-22.

51. Sebastia-Forcada E, Cebrian-Gomez R, Lizaur-Utrilla A, Gil-Guillen V. Reverse shoulder arthroplasty versus hemiarthroplasty for acute proximal humeral fractures. A blinded, randomized, controlled, prospective study. *J Shoulder Elbow Surg* 2014;23:1419-26.

52. Young SW, Segal BS, Turner PC, Poon PC. Comparison of functional outcomes of reverse shoulder arthroplasty versus hemiarthroplasty in the primary treatment of acute proximal humerus fracture. *ANZ J Surg* 2010;80:789-93.

53. van der Merwe M, Boyle MJ, Frampton CMA, Ball CM. Reverse shoulder arthroplasty compared with hemiarthroplasty in the treatment of acute proximal humeral fractures. *J Shoulder Elbow Surg* 2017;26:1539-45.

54. Shukla DR, McAnany S, Kim J, Overley S, Parsons BO. Hemiarthroplasty versus reverse shoulder arthroplasty for treatment of proximal humeral fractures: A meta-analysis. *J Shoulder Elbow Surg* 2016;25:330-40.

55. Cazeneuve JF, Cristofari DJ. Grammont reversed prosthesis for acute complex fracture of the proximal humerus in an elderly population with 5 to 12 years follow-up. *Orthop Traumatol Surg Res* 2014;100:93-7.

56. Pinkas D, Wanich TS, DePalma AA, Gruson KI. Management of malunion of the proximal humerus: current concepts. *J Am Acad Orthop Surg* 2014;22:491-502.

57. Beredjiklian PK, Iannotti JP, Norris TR, Williams GR. Operative treatment of malunion of a fracture of the proximal aspect of the humerus. *J Bone Joint Surg [Am]* 1998;80:1484-97.

58. Martinez AA, Calvo A, Bejarano C, Carbonel I, Herrera A. The use of the Lima reverse shoulder arthroplasty for the treatment of fracture sequelae of the proximal humerus. *J Orthop Sci* 2012;17:141-7.

59. Willis M, Min W, Brooks JP, et al. Proximal humeral malunion treated with reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 2012;21:507-13.

60. Boileau P, Chuinard C, Le Huec JC, Walch G, Trojani C. Proximal humerus fracture sequelae: Impact of a new radiographic classification on arthroplasty. *Clin Orthop Relat Res* 2006;442:121-30.

61. Raiss P, Edwards TB, Collin P, et al. Reverse shoulder arthroplasty for malunions of the proximal part of the humerus (type-4 fracture sequelae). *J Bone Joint Surg [Am]* 2016;98:893-9.

62. Raiss P, Edwards TB, da Silva MR, et al. Reverse shoulder arthroplasty for the treatment of nonunions of the surgical neck of the proximal part of the humerus (type-3 fracture sequelae). *J Bone Joint Surg [Am]* 2014;96:2070-6.

63. Frankle MA, Mighell MA. Techniques and principles of tuberosity fixation for proximal humeral fractures treated with hemiarthroplasty. *J Shoulder Elbow Surg* 2004;13:239-47.

64. Mizuno N, Denard PJ, Raiss P, Walch G. Reverse total shoulder arthroplasty for primary glenohumeral osteoarthritis in patients with a biconcave glenoid. *J Bone Joint Surg [Am]* 2013;95:1297-304.

65. Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. *J Arthroplasty* 1999;14:756-60.

66. McFarland EG, Huri G, Hyun YS, Petersen SA, Srikumaran U. Reverse total shoulder arthroplasty without bone grafting for severe glenoid bone loss in patients with osteoarthritis and intact rotator cuff. *J Bone Joint Surg [Am]* 2016;98:1801-7.

67. Werner BS, Bohm D, Abdelkawi A, Gohlke F. Glenoid bone grafting in reverse shoulder arthroplasty for long-standing anterior shoulder dislocation. *J Shoulder Elbow Surg* 2014;23:1655-61.

68. Hill JM, Norris TR. Long-term results of total shoulder arthroplasty following bone-grafting of the glenoid. *J Bone Joint Surg [Am]* 2001;83:877-83.

69. Matsoukis J, Tabib W, Guiffault P, et al. Primary unconstrained shoulder arthroplasty in patients with a fixed anterior glenohumeral dislocation. *J Bone Joint Surg [Am]* 2006;88:547-52.

70. Scalise JJ, Iannotti JP. Bone grafting severe glenoid defects in revision shoulder arthroplasty. *Clin Orthop Relat Res* 2008;466:139-45.

71. Ekelund A, Nyberg R. Can reverse shoulder arthroplasty be used with few complications in rheumatoid arthritis? *Clin Orthop Relat Res* 2011;469:2483-8.

72. Holcomb JO, Hebert DJ, Mighell MA, et al. Reverse shoulder arthroplasty in patients with rheumatoid arthritis. *J Shoulder Elbow Surg* 2010;19:1076-84.

73. Woodruff MJ, Cohen AP, Bradley JG. Arthroplasty of the shoulder in rheumatoid arthritis with rotator cuff dysfunction. *Int Orthop* 2003;27:7-10.

74. Young AA, Smith MM, Bacle G, Moraga C, Walch G. Early results of reverse shoulder arthroplasty in patients with rheumatoid arthritis. *J Bone Joint Surg [Am]* 2011;93:1915-23.

75. Gee EC, Hanson EK, Saithna A. Reverse shoulder arthroplasty in rheumatoid arthritis: A systematic review. *Open Orthop J* 2015;9:237-45.

76. Crosby LA, Wright TW, Yu S, Zuckerman JD. Conversion to reverse total shoulder arthroplasty with and without humeral stem retention: The role of a convertible-platform stem. *J Bone Joint Surg [Am]* 2017;99:736-42.

77. Ortmaier R, Resch H, Matis N, et al. Reverse shoulder arthroplasty in revision of failed shoulder arthroplasty-outcome and follow-up. *Int Orthop* 2013;37:67-75.

78. Farshad M, Grogli M, Catanzaro S, Gerber C. Revision of reversed total shoulder arthroplasty. Indications and outcome. *BMC Musculoskelet Disord* 2012;13:160.

79. Melis B, Bonnevialle N, Neyton L, et al. Glenoid loosening and failure in anatomical total shoulder arthroplasty: Is revision with a reverse shoulder arthroplasty a reliable option? *J Shoulder Elbow Surg* 2012;21:342-9.

80. Patel DN, Young B, Onyekwelu I, Zuckerman JD, Kwon YW. Reverse total shoulder arthroplasty for failed shoulder arthroplasty. *J Shoulder Elbow Surg* 2012;21:1478-83.

81. Walker M, Willis MP, Brooks JP, et al. The use of the reverse shoulder arthroplasty for treatment of failed total shoulder arthroplasty. *J Shoulder Elbow Surg* 2012;21:514-22.

82. Bonnevialle N, Mansat P, Lebon J, Laffosse JM, Bonnevialle P. Reverse shoulder arthroplasty for malignant tumors of proximal humerus. *J Shoulder Elbow Surg* 2015;24:36-44.

83. De Wilde LF, Plasschaert FS, Audenaert EA, Verdonk RC. Functional recovery after a reverse prosthesis for reconstruction of the proximal humerus in tumor surgery. *Clin Orthop Relat Res* 2005;430:156-62.

84. Affonso J, Nicholson GP, Frankle MA, et al. Complications of the reverse prosthesis: prevention and treatment. *Instr Course Lect* 2012;61:157-68.

85. Cheung E, Willis M, Walker M, Clark R, Frankle MA. Complications in reverse total shoulder arthroplasty. *J Am Acad Orthop Surg* 2011;19:439-49.

86. Clark JC, Ritchie J, Song FS, et al. Complication rates, dislocation, pain, and postoperative range of motion after reverse shoulder arthroplasty in patients with and without repair of the subscapularis. *J Shoulder Elbow Surg* 2012;21:36-41.

87. Edwards TB, Williams MD, Labriola JE, et al. Subscapularis insufficiency and the risk of shoulder dislocation after reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 2009;18:892-6.

88. Walch G, Bacle G, Ladermann A, Nove-Josserand L, Smithers CJ. Do the indications, results, and complications of reverse shoulder arthroplasty change with surgeon's experience? *J Shoulder Elbow Surg* 2012;21:1470-7.

89. Wierks C, Skolasky RL, Ji JH, McFarland EG. Reverse total shoulder replacement. Intraoperative and early postoperative complications. *Clin Orthop Relat Res* 2009;467:225-34.

90. Barco R, Savvidou OD, Sperling JW, Sanchez-Sotelo J, Cofield RH. Complications in reverse shoulder arthroplasty. *EFORT Open Rev* 2016;1:72-80.

91. Wall B, Walch G. Reverse shoulder arthroplasty for the treatment of proximal humeral fractures. *Hand Clin* 2007;23:425-30, v-vi.

92. Zumstein MA, Pinedo M, Old J, Boileau P. Problems, complications, reoperations, and revisions in reverse total shoulder arthroplasty: A systematic review. *J Shoulder Elbow Surg* 2011;20:146-57.

93. Saltzman BM, Chalmers PN, Gupta AK, Romeo AA, Nicholson GP. Complication rates comparing primary with revision reverse total shoulder arthroplasty. *J Shoulder Elbow Surg* 2014;23:1647-54.

94. Gallo RA, Gamradt SC, Mattern CJ, et al. Instability after reverse total shoulder replacement. *J Shoulder Elbow Surg* 2011;20:584-90.

95. Kohan EM, Chalmers PN, Salazar D, et al. Dislocation following reverse total shoulder arthroplasty. *J Shoulder Elbow Surg* 2017;26:1238-45.

96. Chalmers PN, Rahman Z, Romeo AA, Nicholson GP. Early dislocation after reverse total shoulder arthroplasty. *J Shoulder Elbow Surg* 2014;23:737-44.

97. Teusink MJ, Pappou IP, Schwartz DG, Cottrell BJ, Frankle MA. Results of closed management of acute dislocation after reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 2015;24:621-7.

98. Gutierrez S, Keller TS, Levy JC, Lee WE III, Luo ZP. Hierarchy of stability factors in reverse shoulder arthroplasty. *Clin Orthop Relat Res* 2008;466:670-6.

99. Stephenson DR, Oh JH, McGarry MH, Rick Hatch GF III, Lee TQ. Effect of humeral component version on impingement in reverse total shoulder arthroplasty. *J Shoulder Elbow Surg* 2011;20:652-8.

100. Gerber C, Pennington SD, Nyffeler RW. Reverse total shoulder arthroplasty. *J Am Acad Orthop Surg* 2009;17:284-95.

101. Oh JH, Shin SJ, McGarry MH, et al. Biomechanical effects of humeral neck-shaft angle and subscapularis integrity in reverse total shoulder arthroplasty. *J Shoulder Elbow Surg* 2014;23:1091-8.

102. Richards J, Inacio MCS, Beckett M, et al. Patient and procedure-specific risk factors for deep infection after primary shoulder arthroplasty. *Clin Orthop Relat Res* 2014;472:2809-15.

103. Trappey GJ, IV, O'Connor DP, Edwards TB. What are the instability and infection rates after reverse shoulder arthroplasty? *Clin Orthop Relat Res* 2011;469:2505-11.

104. Simovitch RW, Zumstein MA, Lohri E, Helmy N, Gerber C. Predictors of scapular notching in patients managed with the Delta III reverse total shoulder replacement. *J Bone Joint Surg [Am]* 2007;89:588-600.

105. Sirveaux F, Favard L, Oudet D, et al. 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;86:388-95.

106. 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;25:129-33.

107. Nyffeler RW, Werner CML, Simmen BR, Gerber C. Analysis of a retrieved delta III total shoulder prosthesis. *J Bone Joint Surg [Br]* 2004;86:1187-91.

108. Vanhove B, Beugnies A. Grammont's reverse shoulder prosthesis for rotator cuff arthropathy. A retrospective study of 32 cases. *Acta Orthop Belg* 2004;70:219-25.

109. Alentorn-Geli E, Guirro P, Santana F, Torrens C. Treatment of fracture sequelae of the proximal humerus: Comparison of hemiarthroplasty and reverse total shoulder arthroplasty. *Arch Orthop Trauma Surg* 2014;134:1545-50.

110. Levigne C, Boileau P, Favard L, et al. Scapular notching in reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 2008;17:925-35.

111. Melis B, DeFranco M, Ladermann A, et al. An evaluation of the radiological changes around the Grammont reverse geometry shoulder arthroplasty after eight to 12 years. *J Bone Joint Surg [Br]* 2011;93:1240-6.

112. Boileau P, Moineau G, Roussanne Y, O'Shea K. Bony increased-offset reversed shoulder arthroplasty: Minimizing scapular impingement while maximizing glenoid fixation. *Clin Orthop Relat Res* 2011;469:2558-67.

113. Cuff D, Clark R, Pupello D, Frankle M. Reverse shoulder arthroplasty for the treatment of rotator cuff deficiency: A concise follow-up, at a minimum of five years, of a previous report. *J Bone Joint Surg [Am]* 2012;94:1996-2000.

114. Mizuno N, Denard PJ, Raiss P, Walch G. The clinical and radiographical results of reverse total shoulder arthroplasty with eccentric glenosphere. *Int Orthop* 2012;36:1647-53.

115. De Biase CF, Delcogliano M, Borroni M, Castagna A. Reverse total shoulder arthroplasty: Radiological and clinical result using an eccentric glenosphere. *Musculoskelet Surg* 2012;96 Suppl 1:S27-34.

116. Ko JK, Tompson JD, Sholder DS, Black EM, Abboud JA. Heterotopic ossification of the long head of the triceps after reverse total shoulder arthroplasty. *J Shoulder Elbow Surg* 2016;25:1810-5.

117. Baulot E, Sirveaux F, Boileau P. Grammont's idea: The story of Paul Grammont's functional surgery concept and the development of the reverse principle. *Clin Orthop Relat Res* 2011;469:2425-31.

118. Ladermann A, Lubbeke A, Melis B, et al. Prevalence of neurologic lesions after total shoulder arthroplasty. *J Bone Joint Surg [Am]* 2011;93:1288-93.

119. Hilibrand AS, Schwartz DM, Sethuraman V, Vaccaro AR, Albert TJ. Comparison of transcranial electric motor and somatosensory evoked potential monitoring during cervical spine surgery. *J Bone Joint Surg [Am]* 2004;86:1248-53.

120. Lenoir H, Dagneaux L, Canovas F, et al. Nerve stress during reverse total shoulder arthroplasty: A cadaveric study. *J Shoulder Elbow Surg* 2017;26:323-30.

121. Teusink MJ, Otto RJ, Cottrell BJ, Frankle MA. What is the effect of postoperative scapular fracture on outcomes of reverse shoulder arthroplasty? *J Shoulder Elbow Surg* 2014;23:782-90.

122. Kennon JC, Lu C, McGee-Lawrence ME, Crosby LA. Scapula fracture incidence in reverse total shoulder arthroplasty using screws above or below metaglene central cage: Clinical and biomechanical outcomes. *J Shoulder Elbow Surg* 2017;26: 1023-30.

123. Otto RJ, Virani NA, Levy JC, et al. Scapular fractures after reverse shoulder arthroplasty: Evaluation of risk factors and the reliability of a proposed classification. *J Shoulder Elbow Surg* 2013;22:1514-21.

124. Familiari F, Huri G, Gonzalez-Zapata A, McFarland EG. Diagnosis: scapula fracture and os acromiale after reverse total shoulder arthroplasty. *Orthopedics* 2014;37:434, 492-5.

125. Stevens CG, Murphy MR, Stevens TD, Bryant TL, Wright TW. Bilateral scapular fractures after reverse shoulder arthroplasties. *J Shoulder Elbow Surg* 2015;24:e50-5.

126. Anakwenze OA, Pifer MA, Singh A. Clavicle stress fracture after reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 2014;23:e170-2.