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Early dislocation after reverse total shoulder arthroplasty

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Background: Although instability can occur after reverse total shoulder arthroplasty (RTSA), the risk factors, the treatment, and ultimate fate of the implant in these patients remains poorly understood.
Methods: Demographics, acute treatment, and the need for revision were evaluated in all patients with RTSAs who sustained a subsequent dislocation within the first 3 months. Standardized outcome scores were collected preoperatively and at the final follow-up.
Results: Atraumatic instability occurred in 11 patients (incidence, 2.9%) treated with RTSA early (before 3 months postsurgery). The mean time to dislocation was 3.4 weeks. These patients tended to be previously operated-on (64%), male (82%), overweight (mean body mass index (BMI) of 32.2 kg/m^2, with 82% having a BMI $\geq$30 kg/m^2), and without a satisfactory subscapularis repair at initial RTSA (64%). Initial treatment included closed reduction in 9 patients, open reduction in 1, and open reduction with a thicker polyethylene insert in 1. Four experienced recurrent instability requiring a thicker polyethylene insert. Two additional patients were converted to hemiarthroplasty due to persistent instability. Visual analog pain scores ($P = .014$) and American Shoulder and Elbow Surgeons scores ($P = .018$) were significantly improved. Simple Shoulder Test scores trended towards improvement ($P = .073$).
Conclusions: Early dislocations of the RTSA prosthesis were uncommon. The most common associated factors were a BMI >30 kg/m^2, male gender, subscapularis deficiency, and previous surgery; in these patients, we now use an abduction orthosis. Closed reduction alone was successful in 4 of the 9 closed reductions (44%). Five of 11 RTSAs (45%) required polyethylene exchange. The RTSA was retained in 82%, 36% with the original implant.
Level of evidence: Level IV, Case Series, Treatment study.

Keywords: Reverse total shoulder arthroplasty; shoulder instability; revision; complication; dislocation

Since the introduction of the Grammont prosthesis,[3] reverse total shoulder arthroplasty (RTSA) has achieved widespread usage and is now regularly used for a variety of indications,[14,29] including sequelae of proximal humeral fractures,[4,5,19] rheumatoid arthritis,[35] and as a revision for failed TSA.[30] Although excellent short-term outcomes have been described in several large series, with restoration of painless range of motion,[9,12,13,17,20,21,23] an increasing body of literature has been devoted to the complications associated with RTSA.[1,7,8,11,29,33] Complications occur in 19% to 68% of patients[7,32] and include neurologic injury, instability, periprosthetic fracture, hematoma, infection, scapular notching, mechanical baseplate failure, and acromial fracture.[1,7,8,11,29,33] Prosthetic instability accounts for up to half of these complications in some series.[8,11] The most recent series and literature analyses estimate the risk of

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Table I Summary of the patients included in our series

Patient	Sex	Age (y)	Diagnosis	BMI (kg/m^2)	Previously operated on?	Time from RTSA to dislocation (wks)	Reduction method	Operative treatment
1	M	55.8	CDSL	40.7	Yes	1.0	Open	Open reduction alone
2	M	65.2	FRCR	25.8	Yes	3.0	Clinic	None
3	M	77.0	FTSA	30.3	Yes	1.9	Closed	None
4	M	60.4	FRCR	36.4	Yes	1.0	Closed	9-mm spacer and 3+ poly placed
5	M	73.6	GHOA	23.8	No	5.0	Closed	Conversion to HHR
6	F	56.5	FRCR	36.0	Yes	12.0	Revision	40-mm glenosphere, 9-mm spacer, and 3+ poly placed
7	M	73.5	CTA	34.9	No	2.6	Clinic	Conversion to HHR
8	M	76.3	GHOA	32.4	No	2.0	Closed	None
9	M	76.4	CTA	30.3	Yes	4.9	Clinic	None
10	F	79.5	CTA	31.3	No	2	Closed	9-mm spacer placed
11	M	54.2	FRCR	32.5	Yes	2	Closed	9-mm spacer and 3+ poly placed
Mean		68.0		32.5	64% yes	3.4		

BMI, body mass index; *CDSL,* chronic dislocation; *CTA,* rotator cuff tear arthropathy; *F,* female; *FRCR,* irreparable rotator cuff tear; *FTSA,* failed total shoulder arthroplasty; *GHOA,* glenohumeral osteoarthritis with a massive rotator cuff tear; *HHR,* humeral hemiarthroplasty; *M,* male; *PHFx,* failed open reduction and internal fixation of a proximal humeral fracture; *Poly,* polyethylene component; *RA,* rheumatoid arthritis with a massive rotator cuff tear; *RTSA,* reverse total shoulder arthroplasty.

instability as 0% to 8%.[9,15,31] The specific causes for dislocation after RTSA are incompletely understood; however, most authors believe that contributing factors include component malposition,[28] inadequate tensioning of the soft tissue envelope,[1,3,13,16] insufficient subscapularis tendon for repair,[11] and use of the deltopectoral approach vs the superolateral approach.[1,3,10,14,20,25,27]

Although instability is the most frequent complication in many series,[8,11] we are unaware of any clinical studies devoted to the presentation, evaluation, management, and prognosis of this complication. We therefore reviewed our own series of RTSAs to identify early (<3 months), atraumatic postoperative dislocations and describe the presentation, evaluation, management, and prognosis of this complication.

Materials and methods

This study was a retrospective record review of prospectively collected data. The operative log of the senior author (G.P.N.) was reviewed from 2004 until the present, and those patients who underwent RTSA who experienced an atraumatic radiographically documented dislocation within 3 months postoperatively were included in this study. Exclusion criteria included patients with incomplete medical records, patients in whom instability was the result of a direct trauma, such as a fall, and patients with less than 6 months of follow-up.

Data collection

Data were recorded in Excel X software (Microsoft, Redmond, WA, USA). The preoperative, operative, perioperative, and postoperative records for each patient were reviewed. Demographic and preoperative data collected included the age, sex, side of the surgery, side of hand dominance, body mass index (BMI), number and type of previous shoulder surgeries, and the diagnosis leading to RTSA. Operative data included the status and reparability of the subscapularis tendon at the initial RTSA as well as at all further operative interventions, the type and size of prosthesis implanted, and the need for adjunctive procedures at the time of RTSA, such as bone grafting or tendon transfer. Postoperative data included the time from RTSA to discovery of the dislocation, the inciting event, the initial treatment (open vs closed), the details of all further operative interventions, including any component exchanges or revisions, and any recurrence of instability after treatment. Clinical data collected preoperatively and at final follow-up were the visual analog pain (VAS) score, the simple shoulder test (SST),[18] and the American Shoulder and Elbow Surgeons (ASES) score.[24]

Radiographs at final follow-up were reviewed for all patients. The Nerot-Sirveaux system was used to classify scapular notching.[27] In this system, a grade 1 defect is contained within the inferior pillar, a grade 2 defect progresses to the level of the inferior screw, a grade 3 defect extends over the screw, and a grade 4 defect extends to the baseplate.

Statistical analysis

All statistical analyses were performed in SPSS 18 software (IBM, Armonk, NY, USA). Descriptive statistics are reported. Planned statistical analyses included Kolmogorov-Smirnov testing to determine whether parametric or nonparametric tests would be more appropriate, and then, paired Student t tests or Mann-Whitney U tests, as appropriate, were used to compare preoperative and postoperative VAS, SST, and ASES scores.

Results

Demographics

Of the 385 RTSAs performed during the study period, 11 met our inclusion criteria, for an instability rate of 2.9% (Table I). These patients were followed up for a mean of

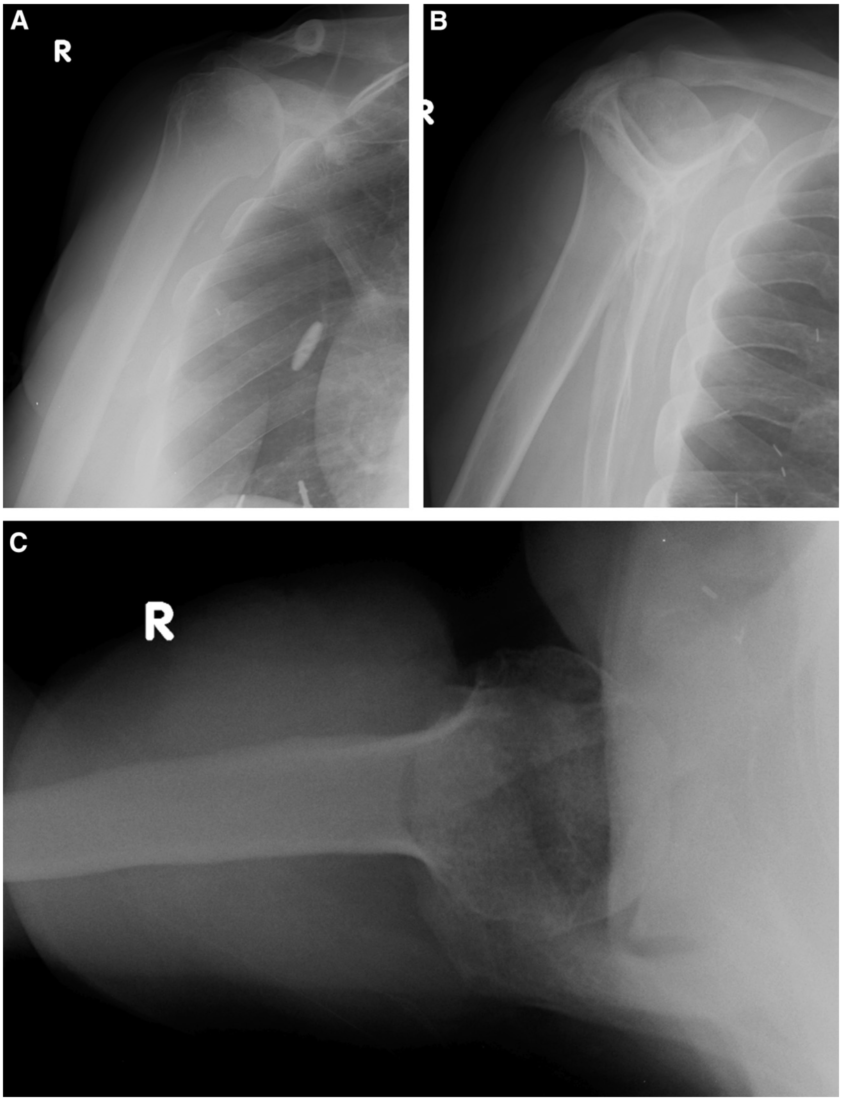

Figure 1 (**A**) Anteroposterior, (**B**) scapular-Y lateral, and (**C**) axillary lateral radiographs of patient 10, a 79-year-old obese woman who presented to our office with an end-stage rotator cuff tear arthropathy.

2.5 ± 2.4 years (range, 0.5-6.8 years). Our cohort included 2 women (18%) and 9 men (82%), with a mean age of 68.0 ± 9.8 years (range, 54.2-79.5 years). Eighty-eight percent of patients were right-hand dominant, and all but 2 underwent RTSA on their dominant extremity. Seven of the 11 (64%) had previous surgery, which included 4 with failed rotator cuff repairs (Fig. 1). One patient had also undergone a previous TSA complicated by periprosthetic sepsis and loosening of the glenoid component that was managed by staged treatment with an antibiotic-laden polymethylmethacrylate spacer. One patient had a failed rotator cuff repair that required manipulation due to stiffness, leading to an unrecognized chronic anterior shoulder dislocation. One patient had an undergone open reduction internal fixation of a surgical neck fracture.

The mean BMI was 32.2 ± 4.8 kg/m^2 (range, 23.8-40.7 kg/m^2), and thus, our cohort on average was obese class I as determined by current World Health Organization (WHO) BMI guidelines[34]: 82% were classified as obesity class I or greater, 27% as obesity class II or greater, and 9% as obesity class III or morbid obesity.

Operative factors

A variety of prostheses were used for the initial RTSAs. Ten patients (91%) underwent reconstruction with a Trabecular Metal Reverse Shoulder (Zimmer Inc, Warsaw, IN, USA), and 1 patient (9%) underwent reconstruction with a Delta III (Depuy Inc, Warsaw, IN, USA). During the study period, 20 Delta III prostheses, 45 Aequalis Reversed Shoulder prostheses (Tornier Inc., Bloomington, MN, USA), and 320 Zimmer Trabecular Metal Reverse Shoulder prostheses were implanted.

A deltopectoral approach was used in all cases. In all patients, the subscapularis tendon was tenotomized as a portion of the approach and, when possible, was repaired

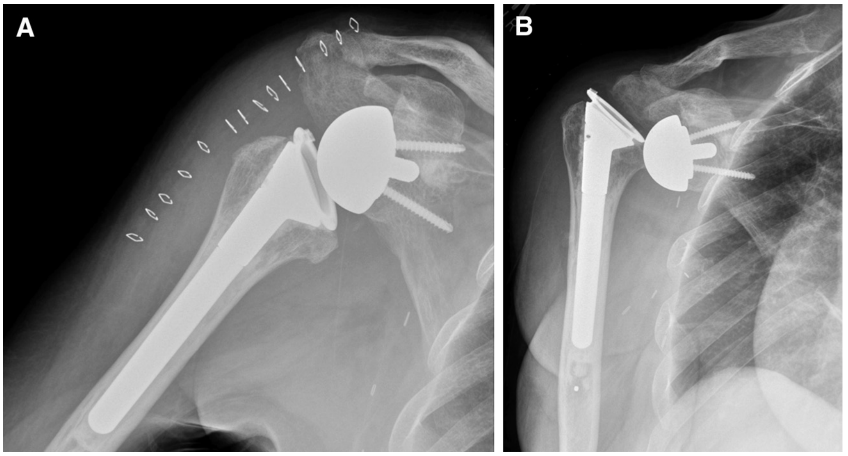

Figure 2 Patient 10, as shown in Figure 1, underwent reverse total shoulder arthroplasty and subsequentlly experienced a prosthetic dislocation. The patient was unaware of the dislocation and noted that she began having more difficulty moving her shoulder after turning in bed. (**A**) An anteroposterior view of the prothesis taken after closed reduction demonstrates concentric reduction of the prosthetic components with the arm in an abduction brace. (**B**) An anteroposterior view taken at the next postoperative visit demonstrates recurrence of superior dislocation of the reverse prosthesis without periprosthetic fracture.

with Ethibond sutures (Ethicon Inc, Somerville, NJ, USA). A repair was possible in 10 patients (91%), but in 4 (36%), the tendon was only partially reparable or was of poor quality.

In all cases, the glenoid was implanted with neutral version and a goal of 10° of inferior tilt. The humeral component was implanted with between 10° and 20° of retroversion. Two patients underwent concomitant transfer of the latissimus tendon, 1 underwent concomitant deltoid plasty, and 2 underwent concomitant glenoid bone grafting to fill a superior defect behind the baseplate. A 40-mm glenosphere was used in 8 patients (73%), and a 36-mm glenosphere was used in the remainder, depending on the size of the patient's native humeral head. An early superficial wound infection that developed in 1 patient was treated with irrigation and debridement, with component retention and resolution of the infection.

After the initial RTSA, all patients were immobilized in a sling for the first 4 postoperative weeks. No formal physical therapy was prescribed. All patients were allowed to use the hand and wrist in the sling for activities of daily living. Active range of motion and pendulums were not allowed within the first week. After the first week, the patients were allowed to begin pendulum exercises. At 4 weeks, patients were instructed on closed chain anterior deltoid exercises and a "hitchhiker" external rotation exercise to strengthen the teres minor.

Instability events

All 11 RTSAs dislocated anteriorly. Closed reduction was performed in 9 (Fig. 2), open reduction in 1 (it could not be reduced under anesthesia in closed fashion), and open reduction with placement of a thicker polyethylene spacer in 1. All patients were subsequently immobilized for 4 weeks in an abduction orthosis. They were then transitioned to a sling for 2 weeks. The patient who dislocated at 12 weeks had been experiencing, by patient history, a series of subluxation events. Because of the chronicity, open reduction with placement of a larger glenosphere and a thicker polyethylene insert was used as the initial treatment for this patient. After operative treatment, this patient remained stable.

Of the other 10 dislocated reverse total shoulders, 4 remained stable after the initial reduction. Three remained stable for another 3 months after being immobilized in the abduction orthosis, and then each patient experienced another dislocation. These patients underwent a revision to a thicker polyethylene insert at that time and have remained stable (Fig. 3). One other patient dislocated in the abduction orthosis, was revised to a thicker polyethylene insert, and now remains stable. Stability could not be achieved in 2 patients, and they were ultimately converted to a hemiarthroplasty. Thus, 82% of the early dislocations retained a RTSA. At the time of revision, the subscapularis was noted to be avulsed or severely deficient in all patients.

The mean time from RTSA to dislocation was 3.4 ± 3.2 weeks, with only 1 dislocation (9%) occurring after 5 weeks postoperatively. The only patient with instability occurring after 5 weeks postoperatively had undergone gastric bypass surgery approximately 5 months before the RTSA. There was rapid weight loss, and at surgery, there was an overabundance of loose soft tissue at the shoulder, possibly contributing to instability at 12 weeks postoperatively.

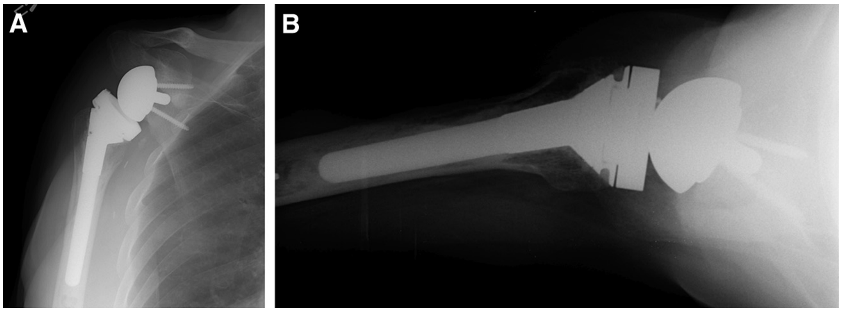

Figure 3 Patient 10, as shown in figures 1 and 2, subsequently underwent open revision and placement of a 9-mm metaphyseal spacer. (**A**) Anteroposterior and (**B**) axillary lateral views taken at the final follow-up demonstrate concentric reduction of the replacement with grade 1 inferior scapular notching.

Most of the patients were unaware of the dislocation, and all reported that their shoulder pain increased or the shoulder began to feel different after using their shoulder during activities of daily living, such as while using the arm to rise from bed (while still wearing an abduction brace), lighting an outdoor grill, carrying a weight, reaching to shut off a light, reaching into a back pocket, or rolling over in bed. Two patients admitted to significant alcohol use around the time of the dislocation events.

Outcomes

Kolmogorov-Smirnov testing confirmed all scores to be normally distributed ($P > .05$ in all cases), and thus, paired Student t tests were performed. VAS pain scores significantly improved from 6 ± 2 preoperatively to 1 ± 1 at the final follow-up ($P = .014$, Fig. 4). SST scores trended towards improvement from 2 ± 1 to 9 ± 3 ($P = .073$, Fig. 4). ASES scores significantly improved from 33 ± 11 to 81 ± 17 ($P = .018$). Inferior scapular notching was present in 2 patients, of whom 1 had stage 1 notching and 1 had stage 3 notching.

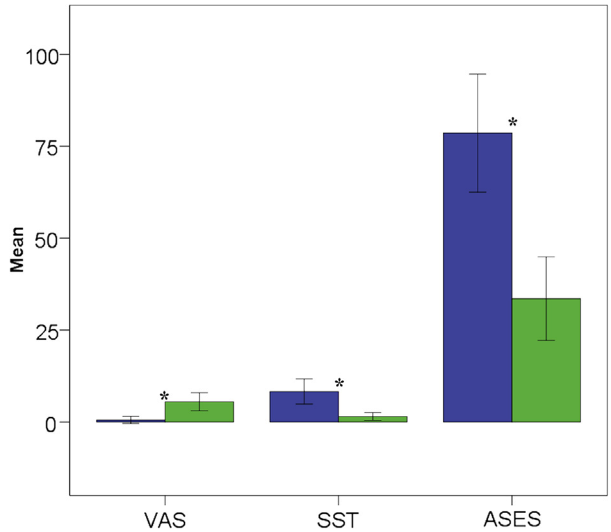

Figure 4 Mean outcomes scores ± 1 standard deviation. Preoperative scores are shown in *blue* and final follow-up scores are shown in *green*. Lower scores on the visual analog score (*VAS*) for pain denote less pain, with 10 being the worst pain imaginable ($P = .014$). Higher scores on the simple shoulder test (SST) denote a better overall shoulder outcome, with 10 being normal ($P = .073$). On the American Shoulder and Elbow Surgeons (*ASES*) assessment, higher scores denote a better overall shoulder outcome, with 100 being normal ($P = .018$).

Discussion

Although instability after RTSA does occur,[9,15,31] and several studies have addressed possible causes biomechanically[22,28] and clinically,[8,11] to the best of our knowledge, no previous authors have described the clinical outcomes of those patients with instability after an RTSA. Herein we reviewed our clinical experience in 11 patients with a mean follow-up of 2.5 years. Instability developed in most of these patients in the acute postoperative period, within 5 weeks. The only patient who developed late instability had rapid weight loss that likely contributed. There were a predominance of men, patients with prior operations, obese patients, and patients with poor subscapularis tendon tissue. These patients had heterogeneous indications for RTSA, and no single preoperative diagnosis predominated. These dislocations were largely unrecognized by the patients and tended to occur with activities of daily living.

Most of our patients required revision and exchange of modular components, but most were able to retain a RTSA. Despite this complication, these patients continued to experience benefits from RTSA compared with their preoperative state with respect to pain and function.

Instability remains a relatively uncommon complication of RTSA, likely due to the greater area for glenohumeral articulation, the nonanatomic 155° of inclination, and "constraint" provided by the implant design.[3,25] Our own brief analysis of series with greater than 40 patients reports an average postoperative instability in 0% to 8%, with an average of 4.3% (Table II). Possible causes of prosthetic

Table II Literature review*

First author	Year of publication	Patients No.	Patients with dislocations No. (% of patients)
Boileau[2]	2006	45	3 (6.7)
Cuff[9]	2008	94	4 (4.3)
Frankle[12]	2005	60	0 (0)
Guery[15]	2006	77	3 (3.9)
Mulieri[21]	2010	58	1 (1.7)
Seebauer[26]	2005	57	0 (0)
Sirveaux[27]	2004	88	0 (0)
Wall[31]	2007	191	15 (7.9)
Werner[32]	2005	58	5 (8.6)
Total		728	31 (4.3)

* A review of those series of reverse total shoulder arthroplasties with >40 patients, with the number of dislocations and the percentage of patients that were complicated by dislocation.

instability include poor implant positionining,[5,28] failure to properly tension the deltoid and conjoint tendon,[1,3,13,16] subscapularis incompetency,[11] and the deltopectoral approach.[1,3,10,14,20,25,27] Most patients in our series were unaware that their prosthesis was dislocated, and thus, it behooves the surgeon to obtain radiographs throughout the acute postoperative period, even in patients who are clinically doing well.

The most frequently cited cause for instability is inadequate tensioning of the deltoid and conjoint tendon.[1,3,13,16,32] A biomechanical analysis has confirmed soft tissue tension as more important than polyethylene depth or glenosphere size in prosthetic stability.[16] Our own series reflects this trend, with instability resolving in most patients after placement of an insert of increased thickness and with instability occurring after late loss of soft tissue tension in 1 patient. In this patient we also increased the glenosphere diameter; in all other patients, increasing glenosphere size was unnecessary to achieve stability.

We hypothesize that obesity likely contributes through a similar mechanism that prevents the surgeon from accurately assessing intraoperative soft tissue tensioning. The obesity and large soft tissue bulk may also create a decoaptation of the ball and socket when the arm is at the side, which, when coupled with muscle imbalance and fatigue in the early postoperative period, lead to a dislocation.

Methods to more accurately recreate anatomic length-tension relationships for the soft tissue envelope, such as measurement of the lateral and vertical offset and total upper segment length compared with the contralateral extremity, are recommended in patients at risk for prosthetic instability.[1,7] In our series and in several previous series, at-risk patients included men, previously operated-on patients,[1,3,19] and obese patients. In particular, our own series included a preponderance of technically challenging patients, with post-traumatic sequelae, deltoid-plasty, concomitant bone grafting, and concomitant latissimus transfer. In at-risk patients, the surgeon may also wish to alter component position to achieve anatomic offset by changing the level of the humeral osteotomy, by creating a more valgus humeral osteotomy, by retroverting or anteverting the humeral component, depending on the direction of instability,[14,28] by using an allograft-prosthetic composite on the humeral site to increase humeral length,[6] by bone grafting the glenoid to increase the lateral offset,[1,12,17] or by placing the glenoid baseplate inferiorly.[1] If these are inadequate to achieve stability intraoperatively, then a thicker polyethylene insert could be trialed.[1]

However, these exchanges are trade-offs, because increased soft tissue tension may place increased shear stress on the glenoid base plate and may increase the risk of glenoid loosening as well as placing increased traction/shear forces on the acromion and possibly increasing the risk of an acromial stress fracture.[2,3] Increased socket depth is also a trade-off, because deeper inserts decrease the impingement-free arc of motion.[16] Polyethylene cold flow and inferior wear[22] may rapidly obviate the benefit obtained from a deeper polyethylene component.[26] Of note, despite these mechanical instability etiologies, 4 of the 9 attempted closed reductions (44%) were successful. These results suggest select patients may exist in a "grey zone" with sufficient laxity to lead to instability in the postoperative period but insufficient laxity to lead to recurrent instability after prosthesis encapsulation, scar formation, and restoration of physiologic muscle function, free of postoperative inhibition.

Comparative studies have differed about whether repair of the subscapularis tendon plays a role in the prevention of prosthetic instability.[8,11,13,31] Anecdotally, many of the patients in our series had poor subscapularis tissue quality or irreparable tears, supporting repair of the subscapularis. Some authors have advocated not tenotomizing the subscapularis to decrease the risk of instability and of axillary nerve injury, but without a subscapularis tenotomy, inferior visualization can be very poor, thus preventing the surgeon from removing inferior tissue bulk, which can cause impingement, levering, and dislocation.[7] In some cases, the increased lateral offset in the RTSA may preclude subscapularis repair. Depending on the patient's anatomy, with the relative humeral lengthening of an RTSA, the subscapularis, can be translated inferior to the axis of the articulation and may not play a role in stabilization. Overall, the role of the subscapularis in the development of postoperative instability remains controversial. Of note, retention of the posterior rotator cuff can play a similar role.[1]

Outcomes in our series were generally good, with little influence of the dislocation event on the eventual outcome in most patients. Numerous previous series have also described these findings.[2,9,15,31,32] However, 18% of patients did require conversion to a humeral hemiarthroplasty for instability not responsive to all operative and nonoperative measures. Similar to these 2 patients, several series have described poor outcomes in patients with instability after RTSA. Martinez et al[19] described 44 patients who underwent RTSA for sequelae of proximal humeral fractures followed up for a mean of 48 months, with 6 subsequent dislocations (13.6%), all of whom were dissatisfied with their results. Similarly, Gallo et al[13] described 57 patients who underwent RTSA for a variety of indications, 9 of which were subsequently complicated by instability. At final follow-up, only 3 of these patients had retained a reduced RTSA and all were left with significant functional deficits. However, 4 of these patients had concomitant periprosthetic sepsis. This series represents the first patients who underwent this particular procedure at that institution, and the surgical learning curve, well described for RTSA,[29,33] may have played a role in these poor outcomes.

Our study has several limitations. Similar to other retrospective case reviews, the quality of our data is limited to what is available in the medical record. Our sample size is relatively limited. Given that this is a relatively infrequent complication of a relatively infrequently performed procedure, developing a large cohort of patients with this condition will likely require a multicenter effort. Our study is hindered by lack of a comparison group of patients who did not experience dislocations after RTSA, which would allow a better understanding of the pain and dysfunction created by this complication. In addition, without a control group, our study cannot comment on the risk factors for instability but only on the outcome of this complication.

Our study is also hindered by relatively short-term follow-up. It is possible that with an increased length of follow-up, more negative sequelae of these dislocation events will be demonstrated; however, given that most dislocations occurred very early in the postoperative course, it seems unlikely that any late effects would occur.

Conclusion

Early dislocations of the RTSA prosthesis were uncommon. The most common associated factors were a BMI exceeding 30 kg/m^2, male sex, subscapularis deficiency, and previous surgery; in these patients, we now use an abduction orthosis postoperatively. Closed reduction alone was successful in 4 of the 9 closed reductions (44%). Five of 11 RTSAs (45%) required polyethylene exchange. Eighty-two percent were able to retain a reverse TSA, 36% with the original implant.

Disclaimer

Dr Nicholson is a paid consultant for Tornier, receives research support from Tornier, Ossur, and Smith & Nephew, and receives royalties from Innomed Inc. Dr Romeo receives royalties from Arthrex Inc; is on the speakers bureau for Arthrex Inc.; is a paid consultant for Arthrex Inc; receives research support from Arthrex Inc., DJO Surgical, Smith & Nephew, and Ossur; received other financial support from Arthrex Inc and DJO Surgical; receives publishing royalties from Saunders/Mosby-Elsevier; serves on the editorial board for the *Journal of Shoulder and Elbow Surgery* and SLACK Inc, and serves as a board member for the American Orthopaedic Society for Sports Medicine, the American Shoulder and Elbow Surgeons, the Arthroscopy Association of North America, and *Techniques in Shoulder and Elbow Surgery*, and is current editor of *Orthopaedics Today*. The other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Affonso J, Nicholson GP, Frankle MA, Walch G, Gerber C, Garzon-Muvdi J, et al. Complications of the reverse prosthesis: prevention and treatment. Instr Course Lect 2012;61:157-68.
2. 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;15:527-40. http://dx.doi.org/10.1016/j.jse.2006.01.003
3. 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-61S. http://dx.doi.org/10.1016/j.jse.2004.10.006
4. 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. http://dx.doi.org/10.1302/0301-620X.89B4.18435
5. 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. http://dx.doi.org/10.1302/0301-620X.92B4.22450
6. Chacon A, Virani N, Shannon R, Levy JC, Pupello D, Frankle M. Revision arthroplasty with use of a reverse shoulder prosthesis-allograft composite. J Bone Joint Surg Am 2009;91:119-27. http://dx.doi.org/10.2106/JBJS.H.00094
7. 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.
8. Clark JC, Ritchie J, Song FS, Kissenberth MJ, Tolan SJ, Hart ND, 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. http://dx.doi.org/10.1016/j.jse.2011.04.009
9. Cuff D, Pupello D, Virani N, Levy J, Frankle M. Reverse shoulder arthroplasty for the treatment of rotator cuff deficiency. J Bone Joint Surg Am 2008;90:1244-51. http://dx.doi.org/10.2106/JBJS.G.00775
10. De Wilde LF, Van Ovost E, Uyttendaele D, Verdonk R. [Results of an inverted shoulder prosthesis after resection for tumor of the proximal humerus]. Rev Chir Orthop Reparatrice Appar Mot 2002;88:373-8.

11. Edwards TB, Williams MD, Labriola JE, Elkousy HA, Gartsman GM, O'Connor DP. Subscapularis insufficiency and the risk of shoulder dislocation after reverse shoulder arthroplasty. J Shoulder Elbow Surg 2009;18:892-6. http://dx.doi.org/10.1016/j.jse.2008.12.013
12. 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;87:1697-705. http://dx.doi.org/10.2106/JBJS.D.02813
13. Gallo RA, Gamradt SC, Mattern CJ, Cordasco FA, Craig EV, Dines DM, et al. Instability after reverse total shoulder replacement. J Shoulder Elbow Surg 2011;20:584-90. http://dx.doi.org/10.1016/j.jse.2010.08.028
14. Gerber C, Pennington SD, Nyffeler RW. Reverse total shoulder arthroplasty. J Am Acad Orthop Surg 2009;17:284-95.
15. 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;88:1742-7. http://dx.doi.org/10.2106/JBJS.E.00851
16. Gutiérrez S, Keller TS, Levy JC, Lee WE, Luo Z-P. Hierarchy of stability factors in reverse shoulder arthroplasty. Clin Orthop Relat Res 2008;466:670-6. http://dx.doi.org/10.1007/s11999-007-0096-0
17. Klein SM, Dunning P, Mulieri P, Pupello D, Downes K, Frankle MA. Effects of acquired glenoid bone defects on surgical technique and clinical outcomes in reverse shoulder arthroplasty. J Bone Joint Surg Am 2010;92:1144-54. http://dx.doi.org/10.2106/JBJS.I.00778
18. Lippitt S, Harryman D 2nd, Matsen F 3rd. A practical tool for evaluating function: the Simple Shoulder Test. In: Matsen F 3rd, Fu FH, Hawkins RJ, editors. The shoulder: a balance of mobility and stability. Rosemont, IL: The American Academty of Orthopaedic Surgeons; 1993. p. 545-59.
19. 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. http://dx.doi.org/10.1007/s00776-011-0185-5
20. Mole D, Favard L. [Excentered scapulohumeral osteoarthritis]. Rev Chir Orthop Reparatrice Appar Mot 2007;93(6 Suppl):37-94.
21. 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. http://dx.doi.org/10.2106/JBJS.I.00912
22. Nam D, Kepler CK, Nho SJ, Craig EV, Warren RF, Wright TM. Observations on retrieved humeral polyethylene components from reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2010;19:1003-12. http://dx.doi.org/10.1016/j.jse.2010.05.014
23. Nolan BM, Ankerson E, Wiater JM. Reverse total shoulder arthroplasty improves function in cuff tear arthropathy. Clin Orthop Relat Res 2011;469:2476-82. http://dx.doi.org/10.1007/s11999-010-1683-z
24. Richards RR, An KN, Bigliani LU, Friedman RJ, Gartsman GM, Gristina AG, et al. A standardized method for the assessment of shoulder function. J Shoulder Elbow Surg 1994;3:347-52. http://dx.doi.org/10.1016/S1058-274680019-0
25. Seebauer L. Total reverse shoulder arthroplasty: European lessons and future trends. Am J Orthop (Belle Mead NJ) 2007;36(12 Suppl 1):22-8.
26. Seebauer L, Walter W, Keyl W. Reverse total shoulder arthroplasty for the treatment of defect arthropathy. Oper Orthop Traumatol 2005;17:1-24. http://dx.doi.org/10.1007/s00064-005-1119-1
27. Sirveaux F, Favard L, Oudet D, Huquet D, Walch G, Molé 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;86:388-95. http://dx.doi.org/10.1302/0301-620X.86B3.14024
28. Stephenson DR, Oh JH, McGarry MH, Rick Hatch GF, Lee TQ. Effect of humeral component version on impingement in reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2011;20:652-8. http://dx.doi.org/10.1016/j.jse.2010.08.020
29. Walch G, Bacle G, Lädermann A, Nové-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. http://dx.doi.org/10.1016/j.jse.2011.11.010
30. Walker M, Willis MP, Brooks JP, Pupello D, Mulieri PJ, Frankle MA. The use of the reverse shoulder arthroplasty for treatment of failed total shoulder arthroplasty. J Shoulder Elbow Surg 2012;21:514-22. http://dx.doi.org/10.1016/j.jse.2011.03.006
31. 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;89:1476-85. http://dx.doi.org/10.2106/JBJS.F.00666
32. 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. http://dx.doi.org/10.2106/JBJS.D.02342
33. 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. http://dx.doi.org/10.1007/s11999-008-0406-1
34. World Health Organization. BMI classification. Global database on body mass index 2012. Available at: http://apps.who.int/bmi/. Accessed November 23, 2012.
35. 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. http://dx.doi.org/10.2106/JBJS.J.00300