International Orthopaedics (2019) 43:2593–2600
https://doi.org/10.1007/s00264-019-04373-3

ORIGINAL PAPER

Reverse shoulder arthroplasty for rheumatoid arthritis since the introduction of disease-modifying drugs

Devin R. Mangold[1] · Eric R. Wagner[1] · Robert H. Cofield[1] · Joaquin Sanchez-Sotelo[1] · John W. Sperling[1]

Received: 26 July 2018 / Accepted: 28 June 2019 / Published online: 26 July 2019

Abstract

Purpose Rheumatoid arthritis has been associated with poor clinical outcomes in hemiarthroplasty and unconstrained total shoulder arthroplasty. The reverse shoulder arthroplasty can be utilized to address the shortcomings of hemiarthroplasty and unconstrained total shoulder arthroplasty in the inflammatory arthritis patient population. The objective of the present study was to retrospectively review clinical and radiographic outcomes of patients who underwent reverse shoulder arthroplasty for rheumatoid arthritis and other inflammatory arthropathies and provide a comprehensive analysis to identify factors that may alter patient outcomes.

Methods We identified 91 primary reverse shoulder arthroplasties performed between 2006 and 2013 in patients with inflammatory arthritis. Seventy-five had at least two years of follow up with an average follow-up of 4.0 years. The average age at the time of surgery was 70 years old. Peri-operative use of steroids, biologics, and methotrexate were reviewed. Outcomes evaluated included revision and reoperation rates, complications, American Shoulder and Elbow Surgeons (ASES) scores, simple shoulder test (SST) scores, component loosening, and scapular notching.

Results The two and five year implant revision-free survival was 99%. The two and five year re-operation-free survival was 97%. Eighteen (24%) glenoid components required augmentation with corticocancellous autograft from the humeral head. There were two cases of glenoid loosening with gross changes in position. Patients experienced significant pain relief with a 92% satisfaction rate. Shoulder elevation and external rotation improved from 65 and 21 degrees pre-operatively to 138 and 45 degrees post-operatively, respectively ($p < .01$). Average ASES and SST scores were 72 and 7.0, respectively. The use of prednisone, DMARDs, or biologic medications had no significant impact on outcomes.

Keywords Reverse · Shoulder · Arthroplasty · Inflammatory · Rheumatoid · DMARDs

Introduction

Rheumatoid arthritis (RA) can frequently cause significant joint destruction, bone loss, and symptomatic inflammation of the glenohumeral joint [1, 2]. Rheumatoid arthritis eventually involves the glenohumeral joint in 60–90% of patients and is an indication for unconstrained total shoulder arthroplasty (TSA) [3]. However, RA has been associated with glenoid component loosening and poor clinical outcomes in unconstrained TSA, which has been attributed to poor bone stock and rotator cuff insufficiency [4–8]. Meanwhile, hemiarthroplasty in patients with RA has been shown to provide less reliable pain relief and lower patient satisfaction scores compared to TSA [4].

The reverse shoulder arthroplasty (RSA) offers several solutions to the shortcomings of the unconstrained TSA in the inflammatory arthritis patient population. The RSA can compensate for rotator cuff insufficiency by medializing the centre

Investigation performed at the Mayo Clinic, Rochester, MN
Mayo Institutional Review Board ID no. 16-002807

✉ John W. Sperling
sperling.john@mayo.edu

Devin R. Mangold
mangold.devin@mayo.edu

Eric R. Wagner
erwagner@mgh.harvard.edu

Robert H. Cofield
cofield.robert@mayo.edu

Joaquin Sanchez-Sotelo
sanchezsotelo.joaquin@mayo.edu

[1] Department of Orthopedic Surgery, Mayo Clinic, 200 First Street S.W, Rochester, MN 55905, USA

of rotation of the shoulder leading to improved deltoid mechanical advantage particularly in early abduction and forward flexion [9]. Furthermore, the metal-backed glenoid component can help optimize fixation in patients with poor glenoid bone stock. However, there remains limited literature with varying results regarding RSA in RA.

The objective of the present study was to retrospectively review clinical and radiographic outcomes of patients who underwent RSA for RA and other inflammatory arthropathies and provide a comprehensive analysis to identify factors that may alter patient outcomes.

Materials and methods

After obtaining institutional review board approval, we identified our study sample through our institutional total joint registry that prospectively collects patient demographics, operative details, complications, re-operations, implant revisions, and clinical outcome scores on patients treated with total joint arthroplasty [10]. The remaining information that was not obtained through the registry was obtained through the electronic health record.

Patient demographics

From 2006 to 2013, there were 91 primary RSAs performed at our institution for patients who carried a diagnosis of inflammatory arthritis. Seven patients died prior to two years post-operatively. Of the 84 patients alive two years post-operatively, 75 (89%) had at least two years of follow-up.

Patient demographics as well as peri-operative use of steroids, biologics, and methotrexate are summarized in Table 1. Body mass index (BMI) was recorded at the time of surgery. The mean follow-up was 4.0 years (range, 2.0–10.0) or until revision surgery.

Surgical details

The surgeries were all performed through the deltopectoral approach. There were four different implant systems used, including three Encore Reverse Shoulder Prosthesis (DJO Surgical, Austin, TX), one Delta III and 21 Delta Xtend (Depuy Orthopedics, Warsaw, IN), 49 Comprehensive Reverse Shoulder (Biomet), and one Aequalis Reversed Shoulder (Tornier, Edina, MN). Eighteen (24%) glenoid components required augmentation with corticocancellous autograft from the humeral head. Cemented humeral components were used in 23 (31%) arthroplasties. RSA was performed when the rotator cuff or glenoid bone stock was determined by the operating surgeon to be insufficient for unconstrained TSA based on clinical, imaging, or intra-operative findings.

Table 1 Demographics ($n = 75$)

Variables	Value
Arthroplasties	75
Follow-up (years) (mean, range)	4.0 (2.0–10.0)
Age (years) (mean, range)	70 (51–88)
Females	62 (83%)
Laborer	3 (5%)
BMI (kg/m^2)	27 (17–49)
Smokers	2 (3%)
Diabetes mellitus	5 (7%)
Medications	
Methotrexate	19 (25%)
Steroids	24 (32%)
Biologics	19 (25%)
Prior proximal humerus fracture	5 (7%)
Prior rotator cuff surgery	15 (20%)
Cemented humeral component	23 (31%)
Glenoid bone autograft	18 (24%)

Clinical and radiographic assessment

Hard outcomes were assessed, including revision surgeries defined as removal of any component, re-operations, and complications. Clinical outcomes were available in all 74 patients who did not undergo revision surgery. Pain levels were graded as none, mild, moderate with daily activities, moderate at rest, or severe. The examining surgeon in clinic used goniometers to assess shoulder motion. At last follow-up, additional post-operative functional assessments including American Shoulder and Elbow Society (ASES), Simple Shoulder Test (SST), and patient satisfaction were available in 53 of 74 (72%) shoulders that had not undergone repeat revision surgery. The patient satisfaction was obtained by directly asking the patients if they were satisfied with the outcome of their surgery.

The routine postoperative radiographic evaluation included AP internal rotation and external rotation views, and axillary views. The radiographs were examined for humeral stem loosening or subsidence, as well as humeral subluxation or dislocation. Humeral periprosthetic lucency was classified as 0 (none), 1 (< 1 mm wide, incomplete), 2 (1 mm wide, complete), 3 (1.5 mm wide, incomplete), 4 (1.5 mm wide, complete), or 5 (2 mm wide, complete) [11, 12]. Furthermore, "at-risk" humeral components were identified if there was grade 4 or higher lucency, or a subsidence between immediate and late post-operative radiographs. Subluxation was classified as present (unstable) or not present (stable). Scapular notching was recorded and classified based on the classification system described by Sirveaux et al. [13]: type I, defect confined to pillar; type II, contact with the lower screw; type III, defect

extends over the lower screw, and type IV, defect extends under baseplate. Plain radiographs and computed tomography scan when available were reviewed for glenoid component loosening.

Statistical analysis

Univariate analyses were performed in the evaluation of outcomes associated with primary RSA in patients with inflammatory arthritis. The differences between dichotomous variables were tested using Fisher's exact test. Due to the small sample size, Wilcoxon rank-sum test was used to minimize small sample-size bias. The Kaplan-Meier method was used to assess implant survival, using the log-rank test and proportional hazards regression to compare groups/comorbidities. Univariate analysis identified the following four variables to be predictors of ASES and SST scores (BMI), cemented humeral component, postoperative pain, and if the patient was a labourer. These four variables were used to construct a standard least-squares multivariate model with ASES and SST scores as the dependent variables. Statistical significance was set at a P value < 0.05.

Source of funding

No external source of funding was used for this study.

Results

Intra-operative findings, outcomes, and complications

Significant glenoid bone loss was documented in the operative report in 21 cases. There was superior bone loss in ten cases, anterior bone loss in two cases, posterior bone loss in two cases, and three cases with central glenoid erosion (Fig. 1a–c). Sixty-four of 75 shoulders had significant rotator cuff tears. There were four (5%) non-displaced intra-operative fractures involving the greater tuberosity that occurred during implantation. All four (5%) fractures healed on x-rays by the last post-operative follow-up and did not have a significant impact on post-operative clinical outcomes.

The implant survival, re-operations, and post-operative complications

Follow-up data was available for all shoulders at a mean follow-up of 4.0 years (2.0–10.0) or just prior to revision surgery. Revision surgery was performed in one (1.4%) patient who sustained a displaced periprosthetic fracture involving the press-fit humeral component at 1.8 years postoperatively. The patient was treated with a revision RSA involving an allograft prosthetic composite. The overall implant revision-free survival at two and five years was 99% and 99%, respectively (Fig. 2). No variables analyzed had a significant impact on the rates of revision surgery.

There were ten complications representing a 13% complication rate following primary RSA in patients with inflammatory arthritis. There was only one post-operative complication requiring a re-operation in addition to periprosthetic fracture, but components were retained. Re-operation was performed for a deep periprosthetic infection at 1.5 years post-operatively that was treated with irrigation and debridement. The patient had a total hip arthroplasty infection simultaneously, also requiring irrigation and debridement, but component retention. The patient was on Plaquenil and prednisone at the time of the infection. The patient remained on antibiotic suppression through the remainder of their life (1.5 years). The two and five year re-operation-free survivals were both 97% (Fig. 3). Besides the patient requiring revision surgery, no other patients suffered a post-operative periprosthetic humerus fracture. Additional post-operative fractures included three (4%) scapular spine fractures and three (4%) acromial fractures, all of which were managed non-operatively and had no significant effect on clinical outcomes. There were no additional post-operative infections. No patient had any wound healing complications. There were two cases of glenoid component loosening, but both patients had minimal symptoms and did not wish to undergo revision surgery.

Clinical outcomes

Overall, there was a significant improvement in the patients' post-operative pain levels ($p < 0.001$), shoulder abduction ($p < 0.001$), and shoulder external rotation ($p = 0.001$). Furthermore, patients had good rates of satisfaction, as well as ASES and SST scores (Table 2). Univariate analysis identified higher SST scores with increasing BMI ($p < 0.02$) and with cemented humeral components ($p < 0.02$) (Fig. 4a–c). Additionally, labourers were found to have lower post-operative pain ($p < 0.05$) and higher ASES scores ($p < 0.05$). No other variables, including use of prednisone, DMARDs, or biologic medications, had a significant impact on post-operative shoulder motion, function, or pain levels. Multivariate analysis was performed using the standard least squares with ASES and SST as the dependent variables. For every unit increase in BMI, the SST score increased by 0.2 ± 0.07 points. ($p < 0.01$).

Radiographic outcomes

There were 2 (2.7%) grossly loose glenoid components with obvious changes in position (Fig. 5a–c). Both patients had minimal symptoms and did not wish to undergo revision surgery. Neither of these patients was on prednisone,

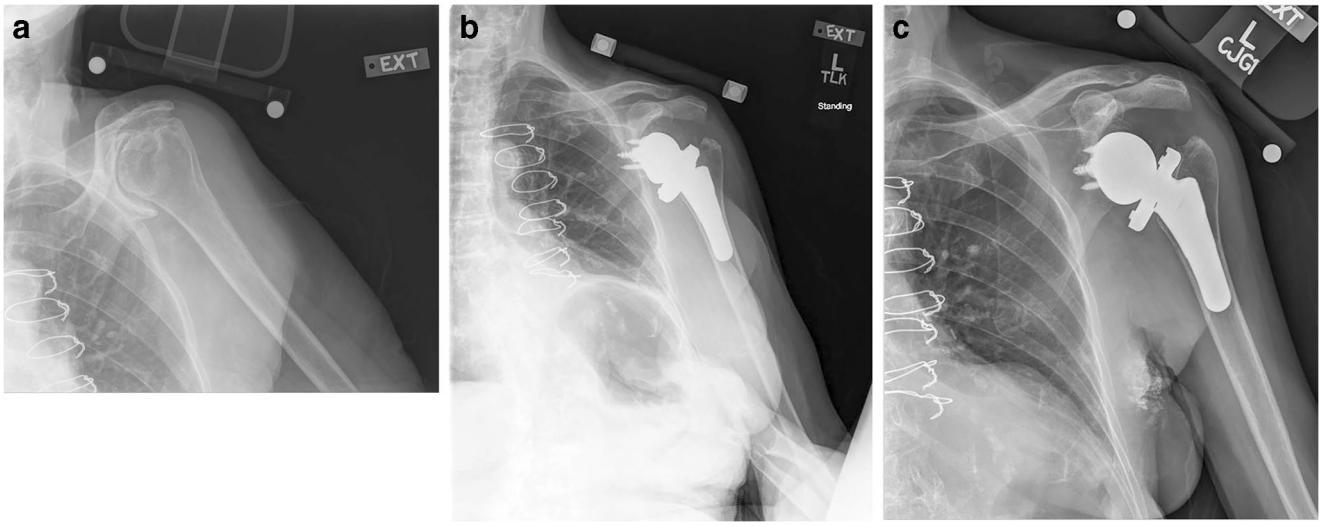

Fig. 1 Challenging case: **a** Pre-operative, **b** Initial post-operative, and **c** Final follow up (27 months post-surgery) x-rays of an 83-year-old female with significant glenoid bone loss requiring structural bone grafting to the posterior glenoid taken from the humeral head

methotrexate, or a biologic drug. There were no cases of humeral component loosening aside from the one revision case in which a patient sustained a periprosthetic humeral fracture resulting in loss of humeral fixation. There was no evidence of radiolucencies around the humeral component in the remainder of the arthroplasties. Scapular notching was observed in 11 (15%) shoulders, while grade 3 or higher scapular notching was demonstrated in four (5%) shoulders. No factors had a significant influence overall on glenoid component loosening or scapular notching.

Discussion

Glenohumeral joint destruction, concomitant rotator cuff insufficiency, and the poor bone stock observed in patients with RA contributes to proximal humeral migration, glenoid loosening, and suboptimal outcomes when using anatomic TSA in this population [6, 8, 14–16]. Recently, disease-modifying antirheumatic drugs (DMARDs) and biologic drugs have lessened the progression of the disease [17]. Nonetheless, many patients still develop end-stage glenohumeral arthritis, often associated with massive rotator cuff insufficiency and/or poor glenoid bone stock, leaving RSA as the only reliable option [18, 19]. Given the paucity of information examining the outcomes of the reverse prosthesis in RA, as well as the influence of various rheumatologic medications, we sought to examine the radiographic and clinical outcomes of patients with inflammatory arthritis treated with RSA. Additionally, a comprehensive analysis was performed to identify potential factors that may affect outcomes including the use of DMARDs and biologic agents.

In this large cohort of patients with RA undergoing RSA, patients experienced marked improvements in their pain and

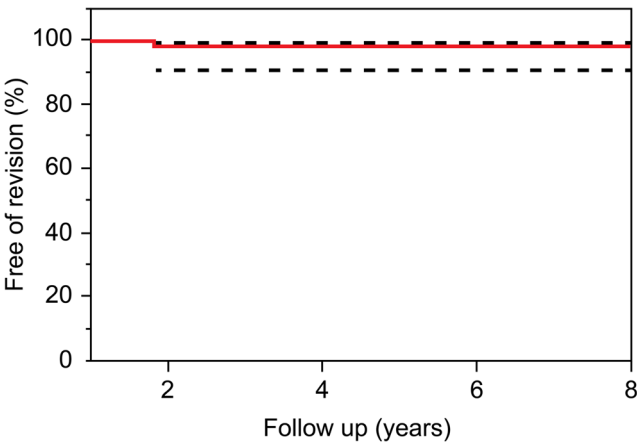

Fig. 2 Kaplan-Meier survival curve demonstrating a 2- and 5-year revision-free survival of 99% ± 1% and 99% ± 1%, respectively. Dashed line represents 95% confidence interval

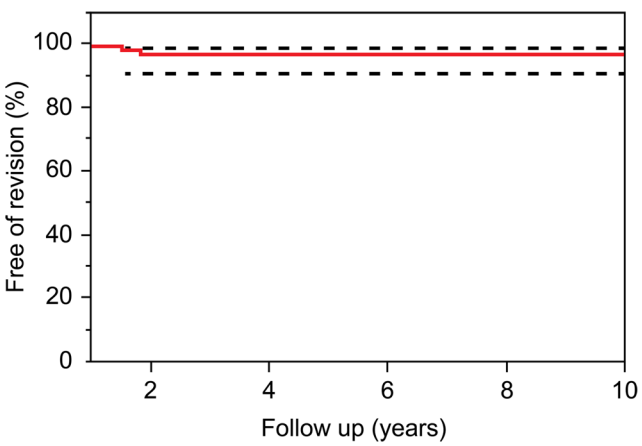

Fig. 3 Kaplan-Meier survival curve demonstrating a 2- and 5-year re-operation-free survival of 97% ± 2% and 97% ± 2%, respectively. Dashed line represents 95% confidence interval

Table 2 Clinical outcomes ($n = 65$)

Outcome measure	Rating	*P* value
[a]Shoulder elevation		< 0.01
Pre-operative	65° ± 5	
Post-operative	138° ± 4	
[a]Shoulder external rotation		< 0.01
Pre-operative	21° ± 2	
Post-operative	45° ± 4	
Pain (% none or mild)		< 0.01
Pre-operative	1%	
Post-operative	99%	
[a]ASES score	72 ± 2	
[a]Simple shoulder test	7.0 ± 0.4	
Satisfaction	69 (92%)	

[a] Values reported as mean ± standard error

shoulder motion. Despite the potentially higher risk for complications in patients with RA, the patients in this cohort had > 95% implant survival at five years with low rates of component loosening and infection. Overall, these findings suggest that RSA is a reliable option for the treatment of symptomatic glenohumeral destruction secondary to inflammatory arthritis despite the high rates of complications reported in several prior studies [2, 20, 21].

In contrast to our findings, several authors have reported concerns regarding RSA in the rheumatoid population, particularly due to high rates of component loosening. In 2001, Rittmeister et al. [2] reported outcomes on eight RSAs in seven patients with RA and noted an unfavourable complication profile. There were three cases of glenoid loosening: one case of septic loosening and two cases of aseptic loosening. All arthroplasties were performed through a transacromial approach, and there were three cases of failed osteosynthesis. These findings were attributed to poor bone stock and quality in patients with RA. Several other studies have also demonstrated high rates of component loosening and revision surgery in the rheumatoid population [20, 21]. More recently, lower rates of component loosening have been observed even in the setting of significant glenoid bone loss requiring bone grafting [22–24]. The rates of component loosening published in more recent studies parallel the low rates of humeral and glenoid loosening observed in our study population, which were 0% and 2.7%, respectively. It should be noted that fractures involving the scapular spine (4%) and acromion (4%) were relatively common in our series. This may be attributable to the inherently poor bone stock secondary to the disease itself or from prednisone use (32%) in this population. The rates of acromion and scapular spine fractures observed in this study parallel the rates seen in non-rheumatoid patients who undergo RSA ranging from less than 1% to nearly 7% [25–29]. The improved results in this series are likely multifactorial, including a combination of improved surgical technique and implant design, as well as medical control of the underlying disease process.

Pharmacologic control of the inflammatory process underlying the joint destruction likely contributes in a large part to our field's improved ability to surgically manage shoulder joint destruction with the RSA. Lower disease severity at presentation, better control, and prevention of disease progression post-operatively, and improved overall health of the patient has likely contributed to the improved surgical outcomes. As control of the inflammatory destruction of the soft tissue stabilizers around the joint improves, it undoubtedly improves the performance of the reverse components and surgical techniques.

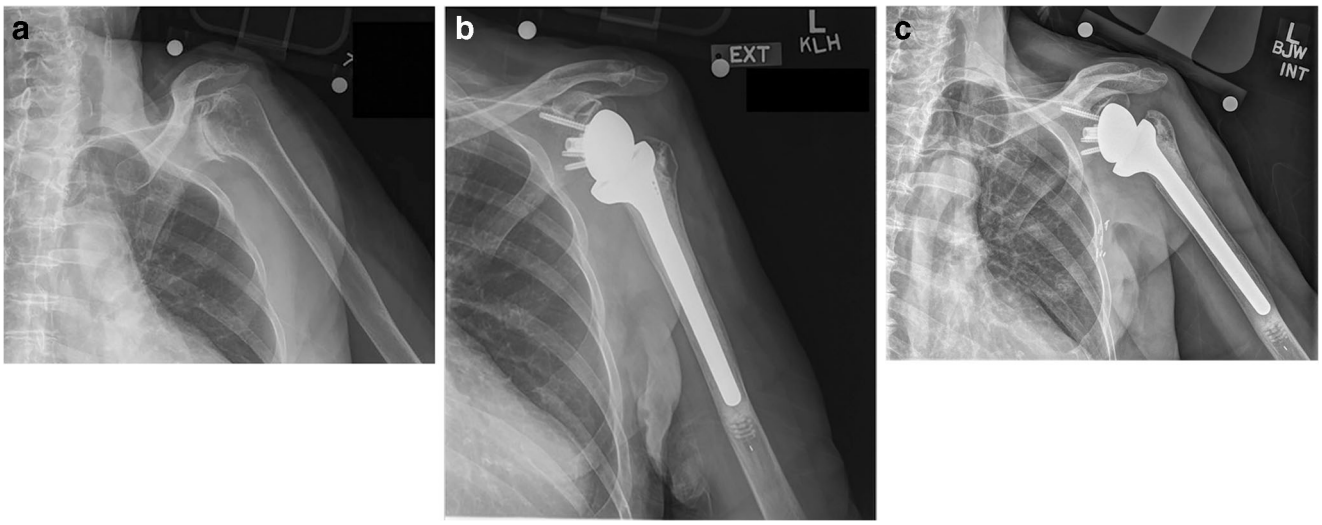

Fig. 4 Case example: **a** Preoperative, **b** Initial post-operative, and **c** Final follow up (72 months post-surgery) x-rays of a 68-year female treated with a reverse shoulder arthroplasty using a cemented humeral stem with excellent radiographic and clinical outcome

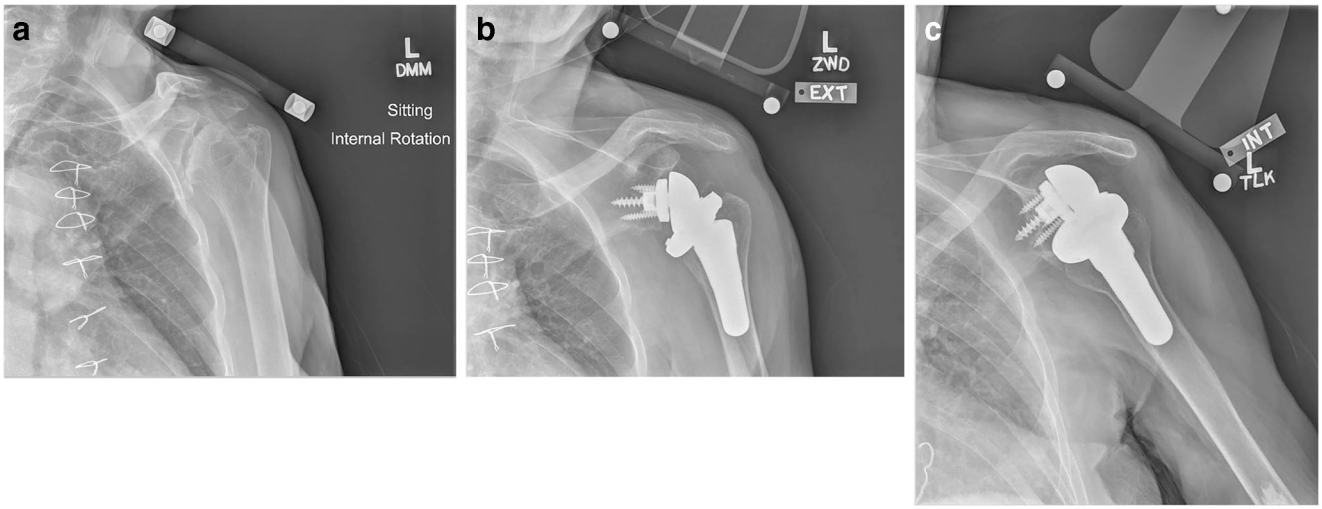

Fig. 5 Complication example: **a** Pre-operative, **b** initial post-operative, and **c** final follow-up X-rays of a 78-year-old with glenoid loosening and component displacement at most recent follow up (25 months post-surgery). Patient elected to not undergo revision surgery

Several other studies in the rheumatoid population have reported good clinical outcomes, potentially from better control of the disease process [24, 30–33]. In 2003, Woodruff et al. [21] reviewed the results of 13 RSAs using the Delta III prosthesis, and despite glenoid loosening in five shoulders and humeral loosening in all cases, good clinical outcomes were observed. Ekelund et al. [30] published in 2012 on 23 RSAs with a mean follow-up of 56 months. Significant improvements were noted in pain, function, and clinical outcome scores. Though these results may be a manifestation of improved disease control perioperatively, in this study, there was no difference observed between patients on different medication regimens to control their disease. However, there were no true control groups used for comparison and there was no formal algorithm for pharmacologic management of disease. Future outcomes in the inflammatory arthritis population will likely be directly correlated with improved disease control.

While medical management can improve disease control, one concern with the use of DMARDs, biologic medications, prednisone, or patients with RA in general is a potentially increased risk of infection and problems with wound healing. Salt et al. [34] performed a retrospective, case-control study and found male gender, RA, diabetes mellitus, obesity, gout, and prednisone use to be risk factors for prosthetic joint infections in patients undergoing total hip, knee, or shoulder arthroplasty. Morris et al. [35] performed a retrospective review of 301 RSAs and found age < 65 and conversion to RSA for failed hemiarthroplasty to be risk factors for prosthetic joint infection. Meanwhile, RA was not associated with increased rates of infection. In the present study, nearly 43% of patients were on steroids, methotrexate, a biologic, or a combination thereof. Despite the use of these immunomodulating medications, there were no wound healing problems and there was only one (1%) prosthetic joint infection with component retention, which is a similar infection rate compared to the rates observed in primary RSA for other etiologies [36–39].

Despite improved disease control through pharmacologic means, shoulder arthroplasty remains one of the primary treatment options for symptomatic glenohumeral arthritis. Hemiarthroplasty has been shown to lead to inconsistent pain relief and poorer patient outcomes [21]. Anatomic TSA in rheumatoid patients has been shown to lead to suboptimal outcomes often times related to component loosening [4–8]. Although RA is not technically an absolute indication for RSA, given the poor bone stock and frequently compromised soft tissues, it is often preferred in this patient population. The present study suggests that RSA is a reliable treatment option for glenohumeral arthritis in patients with inflammatory arthritis. The superiority over unconstrained TSA and hemiarthroplasty may be related to the in-growth glenoid fixation and biomechanics that can compensate for a torn or tenuous rotator cuff.

There are several limitations to our study including limited short-term follow-up, relatively small numbers, and other similar inherent limitations of a retrospective study. The low number of events of interest limits the statistical power in our analyses and therefore limits our ability to extrapolate clinically significant factors for clinical outcomes. This is often a weakness of the orthopaedic literature and warrants longer follow-up and larger studies [40]. Furthermore, all of these surgeries were performed at a tertiary care centre and referral bias likely had an effect on the clinical profile of our patient cohort [41]. Additionally, 11% of patients were lost to follow-up and multiple implant systems were used in this study adding additional confounding factors to the outcomes. Lastly, because there were five different surgeons, there was no established algorithm for treating the inflammatory arthritis

patient, and the indications for RSA were not standardized in this patient population and were at the discretion of the individual surgeon.

Conclusions

In concordance with recent literature on RSA in RA, our study demonstrates that RSA can provide excellent pain relief and function for patients with inflammatory arthropathies. There were minimal complications with very good pain relief and functional outcomes. However, the role of the reverse prosthesis and its indications in the setting of the DMARD and biologic era has yet to be established. Studies such as this one will potentially lay the framework for future evaluations of specific medication regimens peri-operatively, as well as implant choice in RA patients.

Compliance with ethical standards

Conflict of interest Dr. Sperling has a conflict not related to this paper with Biomet; Dr. Cofield has a conflict not related to this paper with Smith-Nephew. Drs. Mangold, Wagner, and Sanchez-Sotelo have no conflicts to disclose.

References

1. Lehtinen JT, Kaarela K, Belt EA, Kautiainen HJ, Kauppi MJ, Lehto MU (2000) Incidence of glenohumeral joint involvement in seropositive rheumatoid arthritis. A 15 year endpoint study. J Rheumatol 27:347–350
2. Rittmeister M, Kerschbaumer F (2001) Grammont reverse total shoulder arthroplasty in patients with rheumatoid arthritis and nonreconstructible rotator cuff lesions. J Shoulder Elb Surg 10: 17–22
3. Gartsman GM, Edwards TB (eds) (2008) Shoulder arthroplasty. Saunders (Elsevier), Philadelphia
4. Barlow JD, Yuan BJ, Schleck CD, Harmsen WS, Cofield RH, Sperling JW (2014) Shoulder arthroplasty for rheumatoid arthritis: 303 consecutive cases with minimum 5-year follow-up. J Shoulder Elb Surg 23:791–799
5. Ennevaara K (1967) Painful shoulder joint in rheumatoid arthritis. A clinical and radiological study of 200 cases, with special reference to arthrography of the glenohumeral joint. Acta Rheumatol Scand Suppl 11:1–116
6. Khan A, Bunker TD, Kitson JB (2009) Clinical and radiological follow-up of the Aequalis third-generation cemented total shoulder replacement: a minimum ten-year study. J Bone Joint Surg (Br) 91: 1594–1600
7. Lehtinen JT, Belt EA, Lyback CO et al (2000) Subacromial space in the rheumatoid shoulder: a radiographic 15-year follow-up study of 148 shoulders. J Shoulder Elb Surg 9:183–187
8. Sneppen O, Fruensgaard S, Johannsen HV, Olsen BS, Sojbjerg JO, Andersen NH (1996) Total shoulder replacement in rheumatoid arthritis: proximal migration and loosening. J Shoulder Elb Surg 5:47–52
9. Berliner JL, Regalado-Magdos A, Ma CB, Feeley BT (2015) Biomechanics of reverse total shoulder arthroplasty. J Shoulder Elb Surg 24:150–160
10. Berry DJ, Kessler M, Morrey BF (1997) Maintaining a hip registry for 25 years. Mayo Clinic experience. Clin Orthop Relat Res 344: 61–68
11. Deutsch A, Abboud JA, Kelly J et al (2007) Clinical results of revision shoulder arthroplasty for glenoid component loosening. J Shoulder Elb Surg 16:706–716
12. Sperling JW, Cofield RH, Rowland CM (1998) Neer hemiarthroplasty and Neer total shoulder arthroplasty in patients fifty years old or less. Long-term results. J Bone Joint Surg Am 80: 464–473
13. Sirveaux F, Favard L, Oudet D, Huquet D, Walch G, Mole D (2004) 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) 86:388–395
14. Collins DN, Harryman DT 2nd, Wirth MA (2004) Shoulder arthroplasty for the treatment of inflammatory arthritis. J Bone Joint Surg Am 86:2489–2496
15. Franklin JL, Barrett WP, Jackins SE, Matsen FA 3rd (1988) Glenoid loosening in total shoulder arthroplasty. Association with rotator cuff deficiency. J Arthroplast 3:39–46
16. Trail IA, Nuttral D (2002) The results of shoulder arthroplasty in patients with rheumatoid arthritis. J Bone Joint Surg (Br) 84:1121–1125
17. Jamsen E, Virta LJ, Hakala M, Kauppi MJ, Malmivaara A, Lehto MU (2013) The decline in joint replacement surgery in rheumatoid arthritis is associated with a concomitant increase in the intensity of anti-rheumatic therapy: a nationwide register-based study from 1995 through 2010. Acta Orthop 84:331–337
18. Baulot E, Chabemaud D, Grammont PM (1995) Results of Grammont's inverted prosthesis in omarthritis associated with major cuff destruction. Apropos of 16 cases. Acta Orthop Belg 61(Suppl 1):112–119
19. Grammont PM, Baulot E (1993) Delta shoulder prosthesis for rotator cuff rupture. Orthopedics 16:65–68
20. Guery J, Favard L, Sirveaux F, Oudet D, Mole D, Walch G (2006) Reverse total shoulder arthroplasty. Survivorship analysis of eighty replacements followed for five to ten years. J Bone Joint Surg Am 88:1742–1747
21. Woodruff MJ, Cohen AP, Bradley JG (2003) Arthroplasty of the shoulder in rheumatoid arthritis with rotator cuff dysfunction. Int Orthop 27:7–10
22. Holcomb JO, Hebert DJ, Mighell MA et al (2010) Reverse shoulder arthroplasty in patients with rheumatoid arthritis. J Shoulder Elb Surg 19:1076–1084
23. John M, Papa G, Angst F et al (2010) Short-term results after reversed shoulder arthroplasty (Delta III) in patients with rheumatoid arthritis and irreparable rotator cuff tear. Int Orthop 34:71–77
24. Young AA, Smith MM, Bacle G, Moraga C, Walch G (2011) Early results of reverse shoulder arthroplasty in patients with rheumatoid arthritis. J Bone Joint Surg Am 93:1915–1923
25. Boileau P, Watkinson D, Hatzidakis AM, Hovorka I (2006) The Grammont reverse shoulder prosthesis: results in cuff tear arthritis, fracture sequelae, and revision arthroplasty. J Shoulder Elb Surg 15: 527–540
26. Cuff D, Pupello D, Virani N, Levy J, Frankle M (2008) Reverse shoulder arthroplasty for the treatment of rotator cuff deficiency. J Bone Joint Surg Am 90:1244–1251
27. Cuff DJ, Virani NA, Levy J et al (2008) The treatment of deep shoulder infection and glenohumeral instability with debridement, reverse shoulder arthroplasty and postoperative antibiotics. J Bone Joint Surg (Br) 90:336–342
28. Frankle M, Siegal S, Pupello D, Saleem A, Mighell M, Vasey M (2005) 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 87:1697–17705

29. Werner CM, Steinmann PA, Gilbart M, Gerber C (2005) 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 87:1476–1486
30. Ekelund A, Nyberg R (2011) Can reverse shoulder arthroplasty be used with few complications in rheumatoid arthritis? Clin Orthop Relat Res 469:2483–2488
31. Hattrup SJ, Sanchez-Sotelo J, Sperling JW, Cofield RH (2012) Reverse shoulder replacement for patients with inflammatory arthritis. J Hand Surg [Am] 37:1888–1894
32. Postacchini R, Carbone S, Canero G, Ripani M, Postacchini F (2016) Reverse shoulder prosthesis in patients with rheumatoid arthritis: a systematic review. Int Orthop 40(5):965–973
33. John M, Pap G, Angst F, Flury MP, Lieske S, Schwyzer HK, Simmen BR (2010) Short-term results after reversed shoulder arthroplasty (Delta III) in patients with rheumatoid arthritis and irreparable rotator cuff tear. Int Orthop 34(1):71–77
34. Salt E, Wiggins AT, Rayens MK et al (2017) Moderating effects of immunosuppressive medications and risk factors for post-operative joint infection following total joint arthroplasty in patients with rheumatoid arthritis or osteoarthritis. Semin Arthritis Rheum 46: 423–429
35. Morris BJ, O'Connor DP, Torres D, Elkousy HA, Gartsman GM, Edwards TB (2015) Risk factors for periprosthetic infection after reverse shoulder arthroplasty. J Shoulder Elb Surg 24:161–166
36. Bacle G, Nove-Josserand L, Garaud P, Walch G (2017) Long-term outcomes of reverse total shoulder arthroplasty: a follow-up of a previous study. J Bone Joint Surg Am 99:454–461
37. Brorson S, Salomonsson B, Jensen SL, Fenstad AM, Demir Y, rasmussen JV (2017) Revision after shoulder replacement for acute fracture of the proximal humerus. Acta Orthop 88:446–450
38. Mellano CR, Kupfer N, Thorsness R et al (2017) Functional results of bilateral reverse total shoulder arthroplasty. J Shoulder Elb Surg 26:990–996
39. Villacis D, Sivasundaram L, Pannell WC, Heckmann N, Omid R, Hatch GF 3rd (2016) Complication rate and implant survival for reverse shoulder arthroplasty versus total shoulder arthroplasty: results during the initial 2 years. J Shoulder Elb Surg 25:927–935
40. Abdullah L, Davis DE, Fabricant PD, Baldwin K, Namdari S (2015) Is there truly "no significant difference"? Underpowered randomized controlled trials in the orthopaedic literature. J Bone Joint Surg Am 97:2068–2873
41. Bayona CEA, Somerson JS, Matsen FA 3rd (2018) The utility of international shoulder joint replacement registries and databases: a comparative analytic review of two hundred and sixty one thousand, four hundred and eighty four cases. Int Orthop 42(2):351–358