The role of reverse shoulder arthroplasty in management of proximal humerus fractures with fracture sequelae: a systematic review of the literature

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Abstract

Fracture sequelae of the proximal humerus poses a complex management decision due to the frequent deformity and its consequences on the peri-articular soft tissues. These patients are frequently elderly with significant medical comorbidities. Due to the age of the patient there is frequently rotator cuff deficiency and therefore the reverse shoulder arthroplasty (RSA) becomes the arthroplasty of choice. We have performed a systematic review of the literature and report nine studies presenting RSA for the treatment of fracture sequelae of the proximal humerus. It is clear that RSA can improve the range of movement and function following proximal humerus fracture sequelae. However, there is a risk of significant complications including dislocation (16.7%), infection (6.7%), intra-operative fracture (3%) and neurological injury (2.6%). There is a need to invest in future prospective comparative studies and randomised trials to further test RSA in fracture sequelae patients. This will provide us with information regarding the longevity of different prosthesis, outcomes and cost-effectiveness of treatment.

Introduction

Proximal humerus fractures are the third most common fracture in patients over 65 years after wrist and femoral neck fractures.[1] The incidence of proximal humerus fractures rapidly increases with age with women being affected twice as frequently as men.[2] This is most likely to be due to the increasing risk of osteoporosis with age and female sex.[2-4] A prospective study over a twenty-eight year period by Kannus *et al.* showed an increase in proximal humerus fractures by 15% per year in patients over the age of sixty, highlighting age as a risk factor.[5] Palvanen *et al.* estimated that the number of shoulder fractures to increase three fold in the next 30 years largely due to the increase in the elderly population.[6]

Management of these fractures in older patients can be difficult due to a variety of fracture patterns, coexisting rotator cuff pathology and associated arthrosis. Osteoporosis increases the complexity of the fracture configuration and is a reported risk factor for non-union.[2,7] The poor bone quality in the elderly can also challenge the reduction of the fracture and ability to achieve stable fixation.[5]

Patients who develop non-union or malunion typically report pain, stiffness, and disability associated with shoulder dysfunction.[8] Arthroplasty is a treatment option for reconstruction in this age group. The decision to perform unconstrained arthroplasty (hemiarthroplasty, total shoulder arthroplasty) is dependent on the degree of osteopenia, the viability of the humeral head, tuberosity integrity and the functional status of the rotator cuff.[9] Total shoulder replacement is considered in the setting of concomitant glenohumeral arthritis with a functional rotator cuff. Reverse shoulder arthroplasty (RSA) is a treatment option in proximal humerus nonunion or malunion with humeral head collapse and/or a non-functioning rotator cuff.[10] Few studies in the literature focus on RSA for proximal humerus non-union and established fracture sequelae.

Aims

Our aim is to perform a systematic review of the literature where RSA has been used following non-union and established fracture sequelae and review the key issues including the procedure, functional and reported outcomes as well as risk and complications experienced.

Literature search strategy

The literature review was conducted using the PubMed, Cochrane library database and Medline OVID database. The PRISMA 2009 checklist was followed for assessment of systematic reviews. Inclusion criteria included all studies using reverse shoulder arthroplasty to manage established proximal humerus fracture sequelae written in English between 2001 and July 2016. The search criteria used the following search terms; *Reverse shoulder arthroplasty*, *RSA*, *fracture sequelae*, *proximal humerus non-union* and *proximal humerus mal-union*. All articles were screened for eligibility by two independent authors (JH and TY). Articles focusing solely on the management of proximal humeral non-union using hemiarthroplasty, total shoulder arthroplasty, anatomic shoulder arthroplasty or rotator cuff impingement following proximal humeral fracture were excluded. Articles with less than five patients were also excluded from the search.

Data extraction and statistical analysis

Data was extracted from each of the selected articles. This focused on the type of study, number of patients in the study, age of the participants, follow up, the prosthesis, surgical approach, outcome and scoring methods used. Where possible we collected data related to the functional assessment of the individuals in the study including abduction, forward flexion, internal and external rotation, the primary outcome score used and documented any complications that were reported. The mean/median and range were provided where possible as well as P values. All statistical analysis was performed using IBM SPSS Statistics Version 22 (IBM SPSS Statistics for MAC, Version 22., IBM Corp., Armonk, NY, USA). Assessment of normally distributed data was performed using means.

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Contributions: JH was involved in the literature review, synthesis of the information and writing of the paper; TY was involved in the literature review and data analysis; GA, consultant surgeon, provided professional experience in the shoulder arthroplasty and review of drafts and editing; OL, lead consultant of the department, provided expertise into the field of RSA and editing and reviewing of the manuscript.

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Study identification

Two authors (JH and TY) reviewed the title and abstract from each study from the results list independently. Any disagreement was resolved by discussion with the senior author. Full text papers of relevant studies were subsequently obtained and reviewed against the eligibility criteria (Figure 1).

Critical appraisal

Two authors using the Critical Appraisal Skills Program checklist independently appraised eligible studies. For the purpose of narrative review, relevant studies were included irrespective of methodology or level of evidence.

Risk of bias

A summary of the articles reviewed is present in Table 1. Each article was reviewed for its risk of bias. In 2007 Willis *et al.* had a small study (16 patients), which was a single surgeon series.[11] There was some alteration of the surgical technique for the prosthesis in that retroversion of the humeral components was greater than 30 degrees to accommodate the boney deformity. Although not a true bias it may influence the longevity of the implant and may have contributed to the two reported accounts of radiological loosening.

Kilic *et al.* reviewed 55 patients but only 19 received RSA with the other receiving anatomic prosthesis.[12] The main bias being that RSA was only used for fracture sequelae types 3 and 4 whereas anatomic prosthesis was used in types 1 and 2. Conclusions were then made that anatomic prosthesis were better for types 1 and 2 fractures and RSA for 3 and 4 although they were not directly comparable.

Raiss *et al.* reviewed 32 patients with RSA for fracture sequelae.[13] The study has disclosed that one or more of the authors

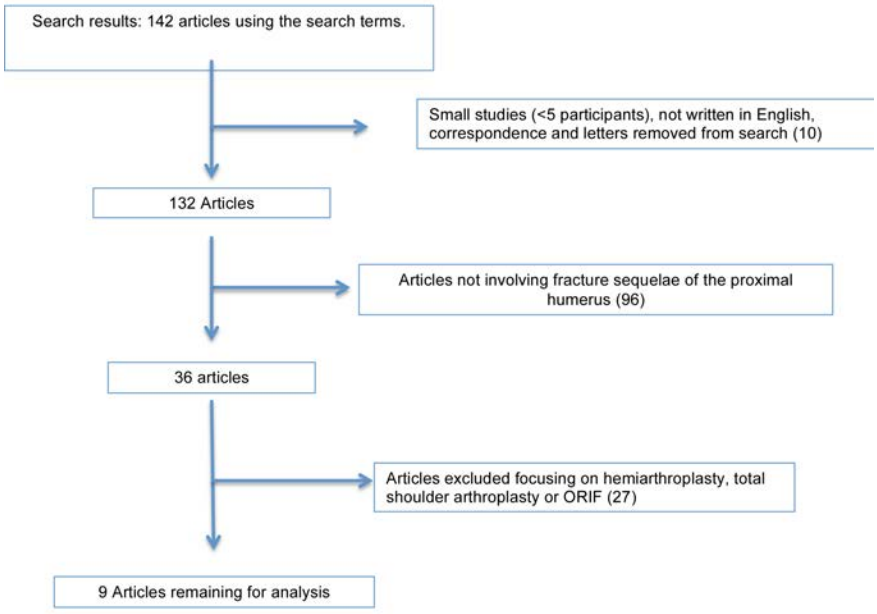

Figure 1. Flow diagram to represent the search process.

Table 1. Summarizing an overview of the reviewed articles.[11-18,20]

Study	Willis *et al.*[11]	Kilic *et al.*[12]	Wall *et al.*[15]	Raiss *et al.*[13]	Hattrup *et al.*[17]	Martinez *et al.*[18]	Zafra *et al.*[16]	Hussey *et al.*[20]	Raiss *et al.*[14]
Type	Retrospective	Retrospective	Retrospective	Retrospective	Retrospective	Retrospective	Prospective	Prospective	Retrospective
Case series	Single surgeon	Many surgeons	2 surgeons	Multicentre, many surgeons	Multicentre, many surgeons	Not stated	3 surgeons	Single surgeon + center	Multicentre, many surgeons
Patients (n)	16	19	33	32	20	18	35	19	42
Mean age, years (range)	65 (52-83)	70.1 (60-81)	75.3 (26-86)	68 (48-83)	67 (31-89)	78.8 (75-84)	69 (46-83)	66 (52-82)	68 (27-83) (median 70 years)
Mean follow up, months (range)	37 (24-62)	18.3 (8-56)	42 (24-97)	48 (24-144)	44 (27-97)	28 (24-32)	51 (24-99)	36 (25-60)	48 (4) (2-13) (median 3.5 years)
Pathology	FS	FS	FS	FS	FS	FS	FS	FS	FS
Prosthesis used	RSA (delta III)	RSA (delta III)	RSA (delta III in 209/ aequalis system in 31)	RSA aequalis 26/ delta 6	Delta 9, delta Xtend 7, biomet comprehensive 6, zimmer trabecular metal 4	Lima	Delta III	DJO surgical reverse shoulder prosthesis (RSP)	Aequalis reversed shoulder system for 37 patients, delta in 5 cases
Surgical approach	Delto-pectoral approach	Delto-pectoral approach	Delto-pectoral approach	Delto-pectoral approach	Delto-pectoral approach	Delto-pectoral approach	Delto-pectoral approach	Delto-pectoral approach	Delto-pectoral approach
Primary clinical scores	ASES	Constant score	Constant score	Constant score	ASES	Constant score	Constant score	VAS, ASES, SST	Constant score
Other outcome measures	VAS, simple shoulder test complications, radiological assessment, satisfaction score	Complications	Complications Radiological	Radiological Complications	Neer score, simple shoulder test complications	Complications	Radiological Complications	Radiological Complications	Radiological Complications

FS, fracture sequelae; RSA, reverse shoulder arthroplasty; DJO, DJO Global, Vista, CA, USA; RSP, reverse shoulder prosthesis; ASES, American shoulder and elbow surgeons score; VAS, visual analogue score; SST, simple shoulder test.

received payments or services either directly or indirectly from a third party and at least one author had a financial relationship prior to submission of the work. Although the disclosure is clear, the risk of bias exists. Raiss *et al.* also declared royalties and one author received stock options for this study.[14] One or more of the authors had a financial relationship or activities that could be perceived to influence the study. The article by Wall *et al.* used two different RSA brands and had not accounted for this in the analysis.[15] Zafra *et al.*, Kilic *et al.*, Raiss *et al.* and Hattrup *et al.* are all multi-surgeon and multi-centre studies which can have bias to surgery, rehabilitation and follow up.[12-14,16,17] Indeed this does highlight that RSA is a relatively infrequent procedure and often requires multi-centre data to account for a modest study number. Martinez *et al* did not provide information regarding the surgeon or study centre, which may be of interest given the high rate of complications (27.7% overall complication rate).[18]

The retrospective nature of the studies (except Zafra *et al.,* which was prospective) also causes an inbuilt element of bias and a threat to validity of the data due to the lack of comparison or control group.[19]

Literature review results

All reviewed articles were case series (level 4 evidence) (Table 1). In total there were 234 patients included across 9 studies, all for fracture sequelae. The mean age across the reviewed articles was 69.7 years with a mean follow up time of 39 months. A delto-pectoral approach was used in all cases.

Patient outcomes for all the reviewed articles are shown in Table 2. From the literature review all studies reported an improvement in forward flexion from pre-operative scores and were statistically significant with a mean change of 38-71 degrees (Figure 2). Abduction was recorded in five of the nine studies with modest but statistically significant improvement from pre-operative scores of between 50 and 57.3 degrees. External rotation improved in each of the studies ranged between 2 and 39

Table 2. Comparing the average range of movement, outcome score and complications across the literature review.[11-18,20]

Study	Willis *et al.*[11]	Kilic *et al.*[12]	Wall *et al.*[15]	Raiss *et al.*[13]	Hattrup *et al.*[17]	Martinez *et al.*[18]	Zafra *et al.*[16]	Hussey *et al.*[20]	Raiss *et al.*[14]
Abduction pre-post operation (degrees)	Pre: 48 Post: 105 (mean) (P=0.002) (P<0.001)	Pre: 36.4 Post: 86.4 (median) (P<0.001)	Not tested Not tested	Not tested Not tested	Not tested Not tested	Pre: 35 Post: 85 (mean) (P<0.0001)	Pre: 38.8 (Post: 96.1 (mean) (P<0.0001)	Pre: 58.7 Post: 89.1 (mean) (P=0.012)	Not tested Not tested
Forward flexion (degrees)	Pre: 53 Post: 105 (mean) (P=0.002)	Pre: 41 Post: 91 (median) (P<0.001)	Pre: 77 Post: 115 (mean) (P<0.001)	Pre: 43 Post: 110 (mean) (P<0.001)	Pre: 41 Post: 137 (mean) (P<0.001)	Pre: 35 Post: 90 (mean) (P<0.0001)	Pre: 45.4 Post: 116.7 (mean) (P<0.001)	Pre: 58.7 Post: 101.1 (mean) (P=0.001)	Pre: 53.6 Post: 120.5 (mean) (P<0.0001)
Average external rotation pre-post operation (degrees)	Pre: 5 (mean) Post: 30 (mean) (P=0.015)	Pre: 1.5 (median) Post: 6.1 (median) (P<0.001)	Pre: 4 at 0 degrees 22 at 90 degrees (mean) Post: 6 at 0 degrees 35 at 90 degrees (mean)	Pre: 0.5 (mean) Post: 13.1 (mean) (P<0.005)	Pre: 0 (mean) Post: 39 (mean) (P=0.0002)	Pre: 15 (mean) Post: 30 (mean) (P<0.0001)	Pre :4.55 (mean) Post: 15.5 (mean) (P<0.001)	Pre: 10.7 (mean) Post: 23.1 (mean) (P=0.043)	Pre: -5.4 (mean) Post: 8.5 (mean)
Internal rotation	Pre: S1 Post: L3 (mean) (P=0.015)	Not tested Not tested	Pre: sacrum Post: L4 (mean)	Pre: 2 Post: 6 (buttock to waist) (mean) (P<0.001)	Not tested	Pre: 25 Post: 55 (mean) (P<0.0001)	Pre: 1 Post: 1 (median) (P=0.1796)	Pre: 1.5 Post: 2.6 (mean) (change in vertebral levels)	Pre: 3.1 Post: 4.0 (mean) (change in vertebral levels)
Outcome score	ASES pre: 28 (mean) ASES post: 63 (mean) (P=0.001)	Constant score (median) pre: 9 Constant score (median) post: 47.5 (P<0.001)	Constant score (mean) pre:19.7 Constant score (mean) post: 53	Constant score pre: 14.1 Constant score post: 46.6 (P<0.001)	ASES pre: -/ASES post: 65 (mean) SST: 6 post operation (mean)	Constant score pre: 26 (mean) Constant score post: 55 (mean) (P<0.0001)	Constant score pre: 23 (mean) Constant score post: 65.5 (mean) (P<0.001)	ASES: 27.8, VAS: 6.8, SST: 0.7 (mean) ASES: 50.1 (0.019), VAS: 4.3 (P=0.012), SST: 3.2 (P=0.020)	Constant score pre:19.7 Constant score post: 54.9 (P<0.001)
Complications	2 radiological pieces of evidence of loosening (not clinical signs) =12.5%	Overall complication rate 36% =1xacromion fracture, 5x infection, 4xhaematoma needing surgery, 1xneuropraxia, 3 luxations, 2 disconnection of components	19.1% including 8 revisions, 15 dislocations, 8 infections, nerve palsy, loosening and fractures Note not specific to fracture sequelae	Overall complication rate of 41% =11 dislocations, 2 infections	Overall complication rate of 25% =1 deep infection, 2 transient brachial plexopathies, 2 dislocations	Overall complication rate of 27.7% =1 axillary neuropathy, 2 dislocation, 2 infections	Overall complication rate of 20% =6 dislocations, 1 axillary nerve palsy	Overall complication rate of 26%-2x humeral loosening, 4x periprosthetic fracture, 1 x intra-op fracture, 1x radial nerve palsy	Overall complication rate of 9.5%-1x humeral shaft fracture, 1x infection, 1x dislocation, 1x aseptic loosening

ASES, American shoulder and elbow surgeons score; VAS, visual analogue score; SST, simple shoulder test.

degrees with only the results from Wall *et al.* not being statistically significant (Figure 3).[15] Internal rotation was recorded in five of the seven studies and had variable success post operatively. Constant score was used as a scoring system in six of the nine studies and showed a statistically significant improvement following surgery with RSA with a mean change in score ranging from 29-42.5. The American Shoulder and Elbow surgeons Shoulder score (ASES) was used in the remaining three studies although the study by Hattrup *et al.* had incomplete pre and post operative ASES.[17] The studies by Hussey *et al.* and Willis *et al.* had post operative changes (mean) in ASES of 22.3 and 35 respectively.[11,20]

The most frequently observed complication was dislocation at 16.7% (39/234) and infection 6.8% (16/234). There was an overall 3% (7/234) risk of fracture. Nerve injury, ranging from neuropraxia to a plexopathy, occurred in 2.6% (6/234).

Forest plots and tests of heterogenicity were not produced due to the retrospective nature of the studies and only the studies by Raiss *et al.* and Zafra *et al.* provided information regarding the mean and standard deviation.[14,16] Without this information and the standard error or confidence intervals could not be calculated.

Discussion

Our literature review identified nine eligible studies reporting the management of fracture sequelae of the proximal humerus with RSA. All studies were retrospective with the exception of Zafra *et al*. which was prospective.[16] We reviewed baseline demographics, surgical procedure and outcomes for each study.

All papers reported statistically significant improvement of forward flexion resulting from the anterior deltoid function. Also, all studies showed statistically significant improvement in abduction with reverse geometry prosthesis. Willis *et al.* attributed this to the use of a lateral-offset prosthesis whereby lateralization of the glenosphere improves deltoid action and working length.[11] This lateralization also allows for increased retroversion of the humeral stem without impingement and facilitates external rotation.[11] Our review of the literature found improvement in external rotation in all studies with only the study by Wall *et al.* not reaching statistical significance.[15]

Internal rotation improved in six of the seven studies that reported post-operative internal rotation. The varied measurement of degrees and associated improvement in spinal level made comparison difficult. After reviewing the operative methodology for the selected studies it was apparent that in some cases repair of the subscapularis and indeed the tuberosities was not always possible. This clearly would affect rotator cuff function and in particular external and internal rotation. The approaches used may also affect post-operative function. In our reviewed cases the delto-pectoral approach was used. This approach places the anterior deltoid fibres at risk from devascularisation thereby affecting its ability to act as an internal rotator once the glenosphere has been lateralized. An alternative approach would be to use the antero-superior Neviaser-MacKenzie or a modified delto-pectoral approach as described by Levy *et al.* to try and preserve anterior deltoid function by reducing the risk of devascularisation.[21] The Constant score is a validated shoulder score as was used by six studies all reporting a statistically significant improvement from pre-operative scores. This tool has been shown to be reliable for detecting improvement after intervention in a variety of shoulder pathologies.[22] The American Shoulder and Elbow Surgeons Score (ASES) is a functional score that was used by Willis *et al.*, Hattrup *et al.* and Hussey *et al.*.[11,17,20] This has been shown to be a reliable, valid and responsive outcome tool in patients with shoulder dysfunction. Unfortunately, the study by Hattrup *et al.* only provided post-operative results although the Willis *et al.* and Hussey *et al.* studies both showed statistically significant improvements in the ASES.[11,17,20]

Of the 234 patients reviewed across 9 studies the most frequently reported complications were dislocation 16.7% (39/234) and infection 6.8% (16/234). There was an overall risk of fracture of 3% (7/234) and nerve injury, ranging from neuropraxia to a plexopathy of 2.6% (6/234).

This clearly raises concerns as an RSA for fracture sequelae provides opportunity of functional benefits with impressive outcomes but with risk of significant complications. In order to reduce dislocation rates patient education and counselling is important pre-operatively and post-operatively in order for them to understand the operation and the precautions needed to prevent dislocation. The development and recent publication of the PROFHER trial may influence the management of 3- and 4-part humeral fractures.[23] This multicenter randomized trial comparing surgical fixation *vs* conservative therapy found no significant difference in patient related outcome scores, complications or need for further surgical

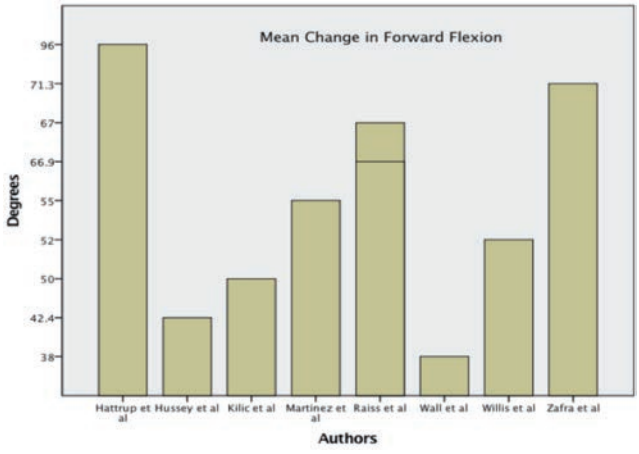

Figure 2. Mean change in forward flexion (in degrees) among the studies.

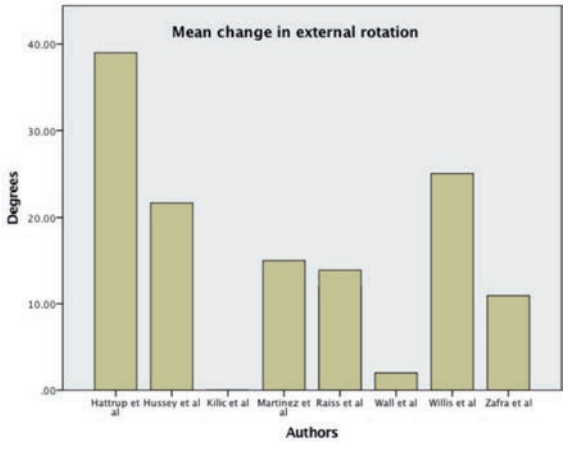

Figure 3. Mean change in external rotation (in degrees) among the studies.

intervention. The conclusion was that a more conservative approach should be favoured.[23]

There is conflicting evidence in the literature with Iyenger *et al.* that reported that 3- and 4-part humeral fractures had complication rates of 48% and malunion in 23%.[24] This is particularly interesting as the PROFHER trial was hailed as a landmark paper by the British Orthopaedic Trainees Association (BOTA). This may lead to a trend to conservative management and may lead to increased rates of fracture sequelae in proximal humerus fractures.

Conclusions

Despite the limitations and complications reported in the literature, RSA can improve the range of movement and function following proximal humerus fracture sequelae. This is a complex group of patients who pose a challenge to the surgeon. We recommend that surgery be provided in centers that provide a regular RSA service and encounter fracture sequelae of the proximal humerus on a regular basis. This study justifies investing in future prospective comparative studies and randomized trials to further test RSA in fracture sequelae patients. This will provide us with information regarding the life span of different prosthesis, outcomes and cost-effectiveness of treatment.

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