J Shoulder Elbow Surg (2011) 20, 146-157

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Problems, complications, reoperations, and revisions in reverse total shoulder arthroplasty: A systematic review

Matthias A. Zumstein, MD[a,b], Miguel Pinedo, MD[a,d], Jason Old, MD, FRCSC[a,c], Pascal Boileau, MD[a,*]

[a]*Department of Orthopaedic Surgery and Sports Traumatology, Hôpital de L'Archet II, University of Nice Sophia-Antipolis, Nice, France*
[b]*Department of Orthopaedic Surgery and Traumatology, University of Bern, Inselspital, Bern, Switzerland*
[c]*Shoulder and Elbow Service, Section of Orthopaedic Surgery, University of Manitoba, Pan Am Clinic, Winnipeg, MB, Canada*
[d]*Department of Orthopaedic Surgery, Clinica Las Condes, Santiago, Chile*

The use of hemiarthroplasty in patients with an arthritic rotator cuff deficient shoulder has been shown to provide limited function and inconsistent pain relief.[1,2,35,47,72,76,99] The semiconstrained reverse shoulder prosthesis, designed by Grammont in the late 1980s,[39] was invented based on 2 biomechanical concepts: lowering the humerus and medialization of the center of rotation at the glenoid component. This design has the dual advantage of tensioning the deltoid muscle to increase its functional strength, and decreasing mechanical torque at the glenoid component, thus avoiding glenoid loosening.

The first series of reverse shoulder arthroplasty (RSA) with at least 2 years of follow-up confirmed the preliminary results, with excellent functional outcome and stable glenoid fixation.[3-5,10,12,73,82,89,98] However, these series had a small numbers of patients and reported variable complication and revision rates of 15% to 50% and reoperation rates of 4% to 40%. One reason for the high variability was unclear definitions of complications and revisions, which varied markedly between the series. Furthermore, it is difficult to draw conclusions from small numbers of patients.

The purpose of the present study was to determine the incidence and functional significance of adverse events after RSA, including problems, complications, reoperations, and revisions. We established a study design and specific objectives before commencing the literature research. These objectives were (1) to perform a systematic review of the published literature to determine the overall rates of problems, complications, reoperations, and revisions after RSA; (2) to compare their influence on the final functional outcome; and, (3) to analyze the different problems, complications, reoperations, and revisions based on the etiology of the RSA.

Definitions

We defined a problem as an intraoperative or postoperative event that was not likely to affect the patient's final outcome, including radiographic scapular notching, hematomas, heterotopic ossification, algodystrophy, phlebitis, intraoperative dislocations, intraoperative cement extravasation, or radiographic lucent lines of the glenoid.

A complication was defined as any intraoperative or postoperative event that was likely to have a negative influence on the patient's final outcome, including fractures, infections, dislocations, nerve palsies, aseptic loosening of humeral or glenoid components, modular stem or polyethylene disassociations, or glenoid screw problems.

*Reprint requests: Pascal Boileau, MD, University of Nice Sophia-Antipolis, Department of Orthpaedic and Sports Traumatology, Hôpital de l'Archet, 06200, Nice, France.

E-mail address: boileau.p@chu-nice.fr (P. Boileau).

1058-2746/$ - see front matter
doi:10.1016/j.jse.2010.08.001

Problems and complications were subcategorized as orthopedic complications of the patient's shoulder (fracture, infection, hematoma, etc) or of the prosthesis (component disassembly or loosening, polyethylene disassociation, etc.).

Reinterventions were subcategorized into reoperations and revisions. Reoperations were defined as interventions requiring any return to the operating room for any reason relating to the shoulder, without altering or replacing any of the components. Revisions were defined as surgeries with total or partial exchange or removal of the components. Liner exchanges and additions of humeral spacers were considered revisions.

Literature search

The systematic review was performed by following the relatively standard form according to Wright et al.[101] We selected articles in Medline, EMBASE, and the Cochrane Central Register of Controlled trials, which were published between 1985 and December 2008, using the keywords *shoulder*, *reverse*, *inverse*, *arthroplasty*, *prosthesis*, *delta*, *Grammont*, *fracture*, *problems*, *complications*, *reoperations*, and *revisions*. Our MEDLINE and EMBASE search used a combination of terms derived from its thesaurus, including the exploded index terms *shoulder*, *reverse*, or *inverse*. All further facets were searched in combination with one of the terms or with Boolean operators. General search terms were used to prevent missing studies. The references of all relevant articles were manually cross-referenced to ensure that all possible articles were considered. The final analysis did not include studies that did not report complication rates or studies that were only cited as abstracts, case reports, or reviews.[55] Two reviewers (M.P. and M.A.Z.) performed first- and second-stage screening.

Data extraction

The same 2 independent reviewers (M.P. and M.A.Z.) used a quality appraisal checklist to abstract the data from each of the studies that met the inclusion criteria.[101] Demographic data included the study design, level of evidence, the number of cases and patients enrolled and their age and gender, and the duration and range of follow-up. The diagnosis leading to RSA was classified as irreparable massive rotator cuff tears (MRCT), cuff tear arthropathy (CTA), primary osteoarthritis (OA), rheumatoid arthritis (RA), acute fracture (FX), posttraumatic fracture sequela (FS), tumor (T), or revision of a previous hemi or total shoulder arthroplasty (REV). Previous nonprosthetic shoulder surgery was also noted. Intraoperative data were recorded, including the prosthetic implant used, the surgical approach, the reattachment of the subscapularis in deltopectoral approaches, and concomitant procedures such as acromioplasty and bone grafts.

Preoperative and postoperative outcome data were extracted, including the range of motion, strength, percentage of very satisfied/satisfied and unsatisfied patients, subjective shoulder value (SSV), Constant-Murley scores[19,20] and its subscores for activities of daily living and functional use of the arm, American Shoulder and Elbow Surgeons (ASES) scores,[64] and all problems, complications, reoperations, and revisions. Also included in the study was appropriate additional relevant information such as specific postoperative course or information obtained from the postoperative radiographic images.

Selection bias

Because the studies were case series, we set out strict inclusion and exclusion criteria to provide as much homogeneity as possible and to limit the potential for selection bias. The inclusion criteria were the performance of an implantation of an RSA with a minimum mean clinical and radiographic follow-up of 24 months. There was no randomization in any of the trials, but the studies that were included in the final analysis had similar mean ages and percentages of female patients. Studies reporting previously published data, or earlier data on a cohort of patients that was later reported again with longer follow-up, were excluded to avoid duplication.

Exclusion bias

All studies in the final analysis had more than 80% follow-up and a mean duration of follow-up of 24 months. Thus, there is only minor potential for exclusion bias in this review.

Results

Literature search

We identified 84 articles in English, French, German, and Spanish involving human subjects. The abstracts of these 84 studies were reviewed to determine the applicability to the present study as determined by the inclusion and exclusion criteria, including a worksheet adapted from evidence-based guides.[84,101] We rejected 63 articles because of follow-up of less than 24 months,[14,28,36] absence of complication data in the study,[56,80,81] publication in another language than the reported 4,[71,97] and a second longer follow-up study of the same cohort by the same group.[25,26] Also excluded were abstracts[24,31] case reports,[86,87] and articles and reviews without original patient data.* The studies by Baulot and Grammont,[4,39,40] Middernacht et al,[65] Walch et al,[94] Boileau et al[7,8] Mottier et al,[66] Neyton et al,[67] and Wall and Walch,[96] were not included in the analysis because parts of them

* References 6, 11, 13, 16, 18, 30, 32, 36, 42-46, 48-50, 52-54, 59-63, 68-70, 74, 75, 78, 85, 90, 91, 93.

Table I Details of demographic data, including study design and level of evidence of the analyzed studies

First author	Year	Etiologies	Level of evidence	Total cases (No.)	Patients (No.)	Follow-up (mon)	Range	Age (y)	Range (y)	Gender, No. (%)	
										F	M
Baulot[3]	1995	CTA + osteonecrosis	IV	16	16	27	17-48	67	46-79	11	5
DeWilde[25]	2001	CTA, FS, FX	IV	5	4	30	23-39	54	34-73	1	3
Jacobs[51]	2001	CTA	IV	7	7	26	16-37	72	54-80	7	0
Rittmeister[74]	2001	RA	IV	8	7	54.3	48-73	60	34-86	5	2
Valenti[90]	2001	CTA	IV	39	39	84	60-108	70	55-87	29	10
Boulahia[12]	2002	CTA, MRCT, FS	IV	16	16	35	24-65	72	66-80	14	2
Delloye[29]	2002	CTA, REV	IV	5	5	81	66-96	73	67-79	N/S	N/S
Woodruff[103]	2003	RA	IV	13	11	87	60-110	64.5	44-72	11	0
Sirveaux[83]	2004	CTA	IV	80	77	44.5	24-97	72.8	60-86	63	14
Vanhoeve[94]	2004	CTA	IV	14	14	29.5	11-50	72	55-85	12	2
De Wilde[27]	2005	T	IV	4	4	38	24-60	42	23-51	N/S	N/S
Frankle[34]	2005	CTA, FS, RA	IV	60	60	33	24-68	71	34-86	41	19
Werner[101]	2005	CTA, REV	IV	58	58	38	min 24	68	44-84	43	15
Boileau[10]	2006	CTA, FS, REV	II	45	45	40	24-72	72	50-87	36	9
Cazeneuve[15]	2006	FX	IV	16	16	86	60-132	75.5	56-90	N/S	N/S
Gohlke[37]	2007	REV	II	34	34	31.5	12-59	68	N/S	29	5
Levy [58]	2007	REV	IV	29	29	35	min 24	69	42-80	25	4
Levy[59]	2007	REV	IV	19	18	44	24-89	72	56-83	11	7
Wall[97]	2007	CTA, MRCT, FS, FX, REV, T	II	196	186	39.9	24-118	75.3	26-89	145	41
Cuff[22]	2008	MRCT, FS, REV	IV	96	94	27.5	24-38	72	52-88	64	32
Cuff[23]	2008	REV	IV	22	21	43	25-66	67	43-83	11	10
Total (%)	…	…	…	782	761	42	…	68	…	558 (77)	178 (23)

CTA, cuff tear arthropathy; *F,* female; *FS,* posttraumatic fracture sequela; *FX,* acute fracture; *M,* male; *MRCT,* massive rotator cuff tear; *N/S,* not stated; *RA,* rheumatoid arthritis; *REV,* revision of a previous hemi or total shoulder arthroplasty; *T,* tumor.

were the same cohort as in other published studies.[3,10,40,41,95] Twenty-one cohort studies were appropriate for the analysis.[†]

Demographic data

Study design, level of evidence, total number of patients, follow-up, and age and gender of the patients were included in the analysis and are reported in Table I. The review included 782 RSAs in 761 patients with a minimum average follow-up of 24 months. The indications are summarized in Table II. No randomized controlled trials (level I), 3 prospective cohort studies (level II),[10,37,95] and 18 therapeutic studies (level IV) were included.[‡]

Surgical technique and concomitant procedures

The reverse prosthesis was implanted with a delta-pectoral approach in 15 studies containing 617 cases (79%), with a superolateral approach in 8 studies containing 137 cases (17.5%), with a transacromial approach in 4 studies containing 23 cases (2.9%), and in 1 study containing 5 cases (0.6%) with an osteotomy of the clavicle. A Delta prosthesis (De Puy, France) was used in 525 cases (67.1%), an Aequalis Reversed prosthesis (Tornier, France) in 31 (4%), and an Encore Reversed Shoulder Prosthesis (Encore Medical Corporation, Austin, TX) in 226 (28.9%). The subscapularis was reattached in 42.1% of the studies. Additional concomitant procedures in 13.5% of the cases in 7 studies included acromioplasty in 29 cases,[82] a humeral window during revision arthroplasty in 34,[37] a bone graft at the humeral or glenoid side in 19 (8 glenoid, 11 humerus),[22,23,27,57,58,82] and a spacer removal in 18.[22,57]

Rehabilitation protocol

If indicated, the arm was placed in a sling in internal rotation in 10 studies (63%), in a brace in abduction and neutral rotation in 4 studies (25%), especially in revisions cases, and without any sling or brace in 2 studies (13%). Sling or brace use was discontinued between 3 and 6 weeks. All postoperative rehabilitation protocols started with unrestricted passive motion between the first and third postoperative week, without any bracing. The patients began active shoulder range of motion exercises as early as 2 weeks and as late as 6 weeks after surgery. Strengthening was initiated between 3 and 12 weeks.

[†] References 3, 10, 12, 15, 22, 23, 25, 27, 29, 34, 37, 51, 57, 58, 73, 82, 88, 92, 95, 98, 100.

[‡] References 3, 12, 15, 22, 23, 25, 27, 29, 34, 51, 57, 58, 73, 82, 88, 92, 98, 100.

Table II Summarized indications of the reverse shoulder arthroplasties

Authors	Year	Total cases (No.)	CTA (No.)	REV (No.)	MRCT (No.)	FS (No.)	OA (No.)	RA (No.)	FX (No.)	T (No.)
Baulot[3]	1995	16	16	…	…	…	…	…	…	…
DeWilde[25]	2001	5	…	5	…	…	…	…	…	…
Jacobs[51]	2001	7	7	…	…	…	…	…	…	…
Rittmeister[74]	2001	8	…	…	…	…	…	8	…	…
Valenti[90]	2001	39	39	…	…	…	…	…	…	…
Boulahia[12]	2002	16	6		7	3				…
Delloye[29]	2002	5	1	4	…	…	…	…	…	…
Woodruff[103]	2003	13	…	…	…	…	…	13		…
Sirveaux[83]	2004	80	80	…	…	…	…	…	…	…
Vanhoeve[94]	2004	14	14	…	…	…	…	…	…	…
De Wilde[27]	2005	4		…	…	…	…	…	…	4
Frankle[34]	2005	60	58	…	…	1	…	1	…	…
Werner[101]	2005	58	17	21	19	1	…		…	…
Boileau[10]	2006	45	21	19	…	5	…		…	…
Cazeneuve[15]	2006	16	…	…	…	…	…	…	16	…
Gohlke[37]	2007	34	…	34	…	…	…	…	…	…
Levy [58]	2007	29	…	29	…	…	…	…	…	…
Levy[59]	2007	19	…	19	…	…	…	…	…	…
Wall[97]	2007	196	59	45	34	28	25	…	2	2
Cuff [22]	2008	96	…	23	70	3	…	…	…	…
Cuff[23]	2008	22	…	17	5	…	…	…	…	…
Total, No. (%) *		782	318 (40.7)	216 (27.6)	135 (17.3)	41 (5.2)	25 (3.2)	23 (2.9)	18 (2.3)	6 (0.8)

CTA, cuff tear arthropathy; *FS,* posttraumatic fracture sequela; *FX,* acute fracture; *MRCT,* massive rotator cuff tear; *OA,* osteoarthritis; osteoarthris; *RA,* rheumatoid arthritis; *REV,* revision of a previous hemi or total shoulder arthroplasty; *T,* tumor.

* Percentage of all cases

Problems, complications, reoperations, and revisions

Problems and complications

There were 347 problems and 188 complications, representing a global problem rate of 44% and a complication rate of 24% (Table III). Two intraoperative and 345 postoperative problems were reported. The complications occurred in 24 cases intraoperatively and in 164 cases postoperatively. The most common problem was radiographic scapular notching in 277 cases, followed by radiographic glenoid lucent lines in 29 and hematomas in 20. The most common complication was instability, which occurred in 37 cases (4.7%), followed by infection in 30 cases (4%).

The problem and complication rates differed among the different etiologies (Table IV) and were both twice as frequent in the REV patients as in the combined primary arthroplasty group (CTA, MRCT, FS, OA, RA, FX, and T), at 12.5% vs 6.0%, and 33.3% vs 13.4%. A detailed analysis showed the REV group had average higher rates than the primary arthroplasty groups for intraoperative (7.4% vs 1.4%) and postoperative complications (23.6% vs 13.3%). Although problems and complications in the RA and the FX groups could be as high as in the REV group, both groups had only small numbers of patients and their adverse effects were mainly related to the transacromial approach.[73]

The highest incidence of problems and complications directly related to the surgical approach was in the group with an osteotomy of the clavicle, with 6 problems and complications in 3 of the 5 patients,[25] followed by the transacromial approach, with 5 problems and complications in 23 patients.[3,40,73,82] The deltopectoral approach group had higher mean rates than in the superolateral approach group for problems (9.8% vs 7.1%), complications (23.5% vs 18.7%), reoperations (3.6% vs 0.6%), and revisions (9.5% vs 5.8%).

Intraoperative problems and complications (26 cases)

The 2 intraoperative problems reported were a cement extravasation[57] and an intraoperative dislocation during wound closure, which was immediately reduced. All intraoperative complications were fractures, comprising 16 humeral fractures, 7 glenoid fractures, and 1 fracture of the acromion. Intraoperative humeral fractures[10,29,40,51,95] occurred mainly during removal of the primary humeral stem or cement mantle in revision surgery in up to 24.1% of all revisions.[97] These events influenced the final outcome.[10]

Intraoperative glenoid fractures[10,88,95,100] were rare and related to the initial reaming or fixation technique. However, they may have a pejorative effect on the functional outcome.[10] Therefore, everything should be done to improve the initial fixation of the meta-glenoid on the remaining bone stock. The intraoperative fracture of the

Table III Incidences of problems and complications

Variable	Cases (No.)	% of all problems and complications (n = 535)	% of all cases (n = 782)
Intraoperative problems			
Miscellaneous	2	0.4	0.3
Intraoperative complications, total	24		
Humeral fractures	16	3.0	2.0
Glenoid fractures	7	1.3	0.9
Miscellaneous	1	0.2	0.1
Postoperative problems, total	345		
Scapular notching	277	51.8	35.4
Lucent lines around the glenoid	23	4.3	2.9
Hematomas	20	3.7	2.6
Problems with acromion osteosynthesis	7	1.3	0.9
Heterotopic ossifications	6	1.1	0.8
Algodystrophic + phlebitis	4	0.7	0.5
Miscellaneous	8	1.5	1.0
Postoperative complications, total	164		
Instability	37	6.9	4.7
Infection	30	5.6	3.8
Aseptic glenoid loosening	27	5.0	3.5
Acromion and scapular spine fractures	12	2.2	1.5
Glenoid disassembly	12	2.2	1.5
Humeral disassembly, polyethylene dislocation	12	2.2	1.5
Humeral fracture	11	2.1	1.4
Humeral loosening	10	1.9	1.3
Neurologic complications (axillary, radial)	9	1.7	1.2
Miscellaneous	4	0.7	0.5

acromion was associated with the transacromial approach.[3,40]

Postoperative problems and complications (230 cases)

The 345 postoperative problems and 164 postoperative complications represented an overall problem and complication rate of 44% and 20.7%.

The most common postoperative problem was radiographic scapular notching, which was present in 277 cases (35%). Notching was present in almost half of the cases using the Grammont reverse shoulder system (49.8%), but no cases of notching were reported using the Encore shoulder system. The Sirveaux classification of scapular notching[82] was available for 172 cases (62%); of these, 116 were stage 1 or 2 (67%) and 56 were stage 3 or 4 (33%). According to approach, 77% (66 of 86 shoulders) were in the anterosuperior group and 49% (168 of 342 shoulders) were in the deltopectoral group. However, there was no precise information of the notching incidences in the subgroups of the etiologies in the studies.

The next most frequent postoperative problems were lucent lines around the glenoid component without clinical effect (23 cases) and hematomas (20 cases). Lucent lines around the glenoid were rare in the Grammont reverse shoulder system (14 of 556 cases, mean incidence of 2.5%),[29,82,88,95,100] and were almost twice as frequent in the Encore shoulder system (9 of 226 cases, mean incidence of 4%),[22,23,33,57,58] in which they were up to 11.1%.[58] Postoperative hematomas occurred in 20 cases and were reported with a wide range (1% to 21%) and necessitated a surgical intervention in 9 cases and an aspiration in 5.[10,12,22,23,25,58,98] No subsequent infections or adverse clinical outcomes were reported in the patients who had hematomas.

Instability (37 cases)[10,15,22,23,25,37,57,95,98] was the most common postoperative complication, with a mean incidence of 4.7%. The deltopectoral approach was used in 97.3% of the shoulders with subsequent instability. Instability was more frequent in the REV group (9.4%) than in the primary arthroplasty group (4.1%).[10,22,25,37,57,95,98] A reoperation was necessary in 87.5%,[10,37,57,98] consisting of open reduction and exchange of the polyethylene liner alone, or combined with the addition of a metallic humeral spacer to improve tension of the deltoid.[98] If the patient's general health allowed a reoperation, there was no negative effect on the final functional outcome.[10,57,98]

Infections (30 cases) were reported in 14 studies.[§] The incidence of deep infection after RSA was 3.8%, which was comparable with anatomic arthroplasties but higher than in other shoulder surgeries.[21] A revision with debridement, polyethylene, or component exchange, or both, with

[§] References 4, 10, 15, 22, 25, 34, 37, 40, 57, 58, 73, 82, 88, 98

Table IV Summarized and detailed incidences of problems, complications, reoperations, and revisions in patients treated with reverse shoulder arthroplasty

Etiology	No.	Problems (n = 70)	Complications (n = 188)	Reinterventions (n = 105)	
				Reoperations (n = 26)	Revisions (n = 79)
Total	782	44%	24%	3.3%	10.1%
Primary arthroplasty group	566	6.0%	13.4%	3.0%	6.3%
Cuff tear arthropathy	318	6.9%	19.5%	11.9%	…
Fracture sequela	41	N/S	5%	4.9%	…
Rheumatoid arthritis	23	21.7%*	45%*	26.1%	…
Acute fracture	18	(11.1%)†	(36%)†	(6.3%)†	(12.5%)†
Tumor	6	N/S	N/S	N/S	…
N/S	160	N/S	N/S	N/S	…
Revision	216	12.5%	33.3%	4.2%	15.7%

N/S, No clear statement among the different etiologies reported.
* Only cited in 2 studies with problems related to the approach[74]
† Only cited in 1 study[94]

postoperative antibiotics, was performed in 29 of the 30 infected RSAs. There was an increased rate of infection in the revision group compared with the primary group (5.8% vs 2.9%).[10,25,37,57,58,98] As in other shoulder surgeries,[79,83] low-virulence organisms, such as *Propionibacterium acnes* and *Staphylococcus epidermidis,* were frequently implicated in RSA infections.[10,95,98]

Aseptic glenoid loosening (27 cases) was not reported as being related to a progression of inferior scapular notching. Like postoperative glenoid lucent lines, aseptic glenoid loosening is twice as frequent in the studies using the Encore shoulder system[22,23,33,57,58] than in the studies using the Grammont reverse shoulder arthroplasty system[10,12,29,73,82,92,95,98] (5.8% vs 2.5%; $P = .025$). In one study,[34] there was no osseous ingrowth in any of the 7 revised shoulders. However, when 5 shoulders with loose glenoid components were revised with another RSA, the clinical outcome was excellent in 4 and good in 1.

Postoperative fractures of the acromion and scapular spine[10,22,23,34,98] (12 shoulders) are rare (1.5% incidence). In the case of conservative treatment of an acromion fracture with immobilization, there was no influence on the final outcome reported. However, fractures of the scapular spine may require osteosynthesis and compromise the final outcome.

Glenoid disassembly (12 cases)[3,29,82,88] occurred only in the first series of the Grammont shoulder system and decreased after introducing a modified Morse taper fixation system for the glenosphere on the metaglene.[82]

Humeral stem disassembly (4 cases) and polyethylene disassociations (8 cases)[12,34,37,98] was also a rare complication in different studies. Humeral stem disassembly did not always need reintervention,[12] and disassociated polyethylene components were revised without clinical impact.[34,37,58,98]

All postoperative humeral fractures[10,22,37,40,57,58,92] (11 cases) were associated with a traumatic event. One fracture was treated conservatively with an excellent result at follow up.[23] The remaining shoulders were revised with a long stem and open reduction and internal fixation with plates or cerclages. Postoperative humeral fractures had a negative impact on the clinical outcome.

Humeral subsidence (loosening)[10,23,57,58,73,82,98] (10 cases) was reported in 7 different studies. They were only revised in case of clinical impact.[10,57,82]

Neurologic complications were reported in 9 cases[10,23,57,98] and included axillary (2 cases), radial (6 cases) and musculocutaneous (1 case) nerve palsies. Whereas axillary nerve palsies were immediate postoperative complications,[10,98] radial nerve palsies were often subsequent to a humeral shaft fracture during follow-up.[23,37,57] In 1 shoulder, the axillary lesion resolved completely without any effect on the functional outcome and the other shoulder had only partial recovery, with inferior outcome.

Glenoid screw problems (2 cases) were rarely reported and occurred with the inferior screws, which were too long and penetrated the lateral scapular border.[3]

Reoperations and revisions

Eighty-four patients underwent 26 reoperations and 79 revisions, representing rates of 3.3% and 10.1%, respectively. A detailed analysis of the revisions showed there were 23 less ‘‘aggressive’’ cases in which the glenosphere was rescrewed, the polyethylene was exchanged, or a metallic humeral spacer was implanted.[10,15,22,23,34,38,57,58,73,98] The remaining 56 cases were removals or exchanges of the baseplate, the humeral stem or both.** Although the incidence of reoperation was nearly equal in the REV and the primary arthroplasty groups (4.2% vs 3.0%), revisions were more than twice as

** References 3, 10, 12, 15, 22, 23, 29, 34, 38, 57, 58, 73, 82, 88, 98.

frequent in the REV group (15.7% vs 6.3%; Table IV). Prosthesis removals were necessary in 5 cases and all were treated with resection arthroplasty.[10,40,73,88,98] No removal treated with an arthrodesis was reported. Nine prostheses were converted to hemiarthroplasty.[10,34,98]

In contrast to problems and reoperations,[10,34,98] most complications and revisions had an effect on the final outcome. In 7 studies, a more inferior average Constant-Murley or ASES score was reported with complications than without (32 vs 68 points, and 60 vs 69 points, respectively).[22,23,27,29,51,73,92] Because complications were not separated into problems and complications in the study of Werner et al,[98] a complication had an effect on the final outcome only in 18.2% of the cases. In 3 studies in which the effect of a revision on the clinical result was reported, the clinical outcome measured by the Constant-Murley score was also inferior after revision compared with without (54 vs 62 points).[51,95,98]

Discussion

Treatment of the rotator cuff deficient shoulder has evolved during the last 2 decades, and today RSA is a commonly performed procedure in Europe and all over the world. There has been growing interest in using RSA and indications continue to expand. However, high rates of problems, complications, reoperations, and revisions have been reported with the procedure.

On the basis of the present study, the global rates for problems, complications, reoperations, and revisions after RSA were 44%, 24%, 3.5%, and 10%, respectively. However, wide variations were noted among the studies and occurred for several possible reasons. The definition of a problem or complication differs significantly among the studies. Whereas some authors included and reported all intraoperative or postoperative problems and complications during revisions, others did not because they were related to the revision procedure itself and not to the RSA implantation.[95] Also, some series included radiographic changes around the humeral or glenoid components as complications, whereas others considered these separately as radiographic findings.

The complication and reoperation rates were much higher after revision RSA than after primary RSA. Although the values in the RA and in the FX groups are as high as in the REV group, they may be overestimated because of the problem and complication rates of the transacromial approach in 1 study.[73] However, surgeons should be aware of the possible problems and complications in RA or FX situations. The results of this review are comparable with a previous French multicenter study[94] that found a similar overall complication rate and an almost 4-fold increase in complications in the revision RSA group. The initial pathology in shoulders that are subsequently revised has a significant influence on subsequent complications.[10,95,98] Several series have reported lower complication rates; however, these series excluded revision cases.[33,34] The higher complication rate in revision shoulder arthroplasty was mainly related to the revision surgery and not to the reverse prosthesis itself.

Scapular notching was by far the most frequently reported problem after RSA. It was present in almost half of all the Grammont prostheses in our series, which is similar to the published rates in the literature on scapular notching using this reverse shoulder design.[56] The relative medialization of the center of rotation in the Grammont design is thought to predispose to impingement of the humeral component against the scapular neck in adduction.[56,69] A biomechanical study by Nyffeler et al[69] showed that the most important factor in preventing notching is inferior placement of the glenosphere. In contrast to the Grammont design, the Encore prosthesis features a lateralized center of rotation. This design seems to be effective in preventing notching, because no notching was observed in the Encore prostheses in our study. The approach seems to influence the incidence of notching in the studies. Simovitch et al[80,81] reported the importance of the prosthetic scapular neck angle and the inferior positioning of the glenoid component in avoiding notching. In their report, notching can be prevented by optimal positioning of the glenoid component, with a sensitivity and specificity of 90% using the notching index calculation. The inferior positioning of the glenoid component is assumed to be more difficult through a superior approach because the clear exposure of the inferior glenoid rim is difficult to achieve.

The clinical significance of scapular notching is a matter of some controversy. Although some studies have implicated scapular notching as a cause of glenoid component loosening[7,12,25,82,88] and negative impact on clinical outcome scores,[81,82] the largest and most comprehensive study on the subject found no clinical effect and only 1 case of progressive notching leading to loosening at 114 months postoperatively.[56]

Lucent lines around the glenoid component, which was the most frequently documented postoperative problem, did not have any clinical effect reported. To prevent lucent lines of the glenoid, the consensus in other studies is that that the central peg of the base plate is thought to be the critical point for glenoid component stability and should be fixed in native bone stock.[70,94] The lateralization of the center of rotation in the Encore shoulder system, compared with the Grammont shoulder system, theoretically increases the torque forces at the glenosphere-baseplate interface. This could be the reason for the more frequently reported lucent lines and glenoid loosening (5.8% vs 2.5%; $P = .025$) in this reverse shoulder system.

The wide variation in rates of postoperative hematoma between studies could be because some authors only included hematomas as a complication if there was a need for a reoperation,[10] whereas others included all hematomas, even if no reintervention was needed.[98] The lack of tamponade effect of the rotator cuff results in a large dead

space; therefore, we think the space should be drained with at least 1 drain for 48 hours. Werner et al[98] suggested a delayed start of the rehabilitation program that might favor hematoma formation in the first days postoperatively.

Postoperative instability subsequent to RSA was the most frequent complication, but it is difficult to analyze the causes because of the variability among the studies. Some have reported that the deltopectoral approach seems to negatively influence the incidence of instability.[94] Factors such as altered version of the humeral and glenoid components, ruptured, and fatty infiltrated subscapular muscle are present in different approaches, so they cannot be the main reason for increased instability in studies using the deltopectoral approach. However, the complete release of the subscapularis, including the inferior and middle glenohumeral ligaments at the glenoid insertion site, may predispose to weakened anterior restraints in deltopectoral approaches. Therefore, the subscapularis seems to be of tremendous importance and should be repaired and protected whenever possible.[10,95,98]

Another potential cause of instability is a loss of tension of the deltoid. This could be because of preexisting atrophy or insufficiency of the anterior part of the deltoid, or because of relative humeral shortening compared with the contralateral side. Preoperative deltoid insufficiencies in revision arthroplasty are probably underestimated and were reported to be present in 71% in the Gohlke and Rolf study.[37] In cases of revision or fracture sequelae, intraoperative assessment of deltoid tension can be difficult (eg, general anesthesia, fibrosis, scar, and retraction of soft tissue), and preoperative templating of the humeral length is essential. In recurrent instability, additional humeral spacers can be implanted with success.[10,98]

Postoperative infection rates were high both in primary and revision surgery. As in the French multicenter study,[96] there was a trend toward higher infection rates in revision surgery compared with primary arthroplasty groups. As previously mentioned, the large subacromial dead space, the compromised general health of some patients, and the large surgical dissection, especially in revision cases, may predispose to later infection.

Although the rate of aseptic glenoid loosening is not reported to be a major problem in the Grammont system (2.5%),[††] it has been reported in up to 11.7%[34] in the first-generation Encore system, which is comparable to the loosening rate of anatomic shoulder prostheses. Changes in design to the Encore system, including the addition of locking screws and hydroxyapatite coating of the baseplate, seem to have decreased the risk of loosening: a subsequent study using only the updated system had only 1 case of loosening in 96 RSAs.[22] To avoid loosening, every effort should be made to optimally fix the glenoid component onto good bone stock at the inferior border of the glenoid.[70,94] Because initial fixation is dependent on the central peg, scapular notching does not seem to predispose to aseptic loosening of the glenoid.[70] Preoperative assessment of glenoid bone stock and careful planning for optimal positioning of the meta-glenoid may be important in preventing loosening.[69,81] Lateralization of the baseplate using a glenoid bone graft taken from the osteotomized humeral head may theoretically increase range of motion and lessen impingement of the humerus on the scapula.[9]

Postoperative fractures of the acromion often occur spontaneously. They can be treated with skilful neglect and are not a contraindication to a reverse prosthesis. Conversely, postoperative fractures of the scapular spine lead to poor functional outcome and may require osteosynthesis, as reported by of Mottier et al.[66]

Postoperative glenoid disassembly was rare and was a problem related to the design of the Grammont prosthesis used before 1995.[10] Modification of the Grammont design with a Morse taper central fixation and a new central screw fixation improved the fixation and avoided dissociation of the glenosphere thereafter.

Similarly to study by Chuinard et al,[17] humeral disassembly, loosening, and polyethylene disassociations were minor problems subsequent to the design changes to the Delta III prosthesis, which had had problems with disassembly. These complications may require revision in cases of unstable components. However, in shoulders with thin cortical bone in the proximal humerus and tuberosities, extensive cementing around the prosthesis in the area of the tuberosities to prevent component rotation may be preferable to revision.

Postoperative humeral fractures occurred mainly at the distal tip of the stem and were generally treated conservatively.[77] However, they can have a negative effect on the functional outcome.[10,37,57,58] Proper cementing technique at the distal tip with correct sizing of the component can decrease stress forces to the bone and may prevent fractures. Neurologic injury is fortunately very rare and had an effect only in case of incomplete recovery.[10]

Reoperations were mainly related to hematomas[10,23,34,98] and the transacromial approach[73] and did not influence the final outcome in most of the cases.[10,34,98] However, because complications and subsequent reoperations are directly associated with the transacromial approach[3,40,73] and the osteotomy of the clavicle,[25] there has been a trend in the last decade to use the deltopectoral or the superolateral approach. Revision procedures and revisions subsequent to RSA have a major impact on the final outcome, so every attempt should be made to avoid complications and revision.

Performance bias

Performance bias may occur if high numbers of concomitant procedures are performed. One study reported 29

[††] References 3, 10, 12, 15, 25, 27, 29, 37, 51, 73, 82, 88, 92, 95, 100.

acromioplasties (36.3% of all cases in that study);[82] however, we do not believe that this results in a substantive difference leading to performance bias. The 34 patients who had a surgical approach with a humeral window had slightly inferior clinical results.[37] Although these patients represented only 15.7% of all revision cases, their inclusion in the revision group may predispose to underestimation of the clinical outcome in revision procedures.

Detection bias

The Constant-Murley score was used in 16 of the 22 studies, and the ASES score was the primary outcome measure in 5 of the remaining 6 studies. Both scores are well established and validated. There was no appreciable difference between the series in scores and pain. Inferior function was documented in 3 of the 22 studies, with an active forward flexion below 90°.[23,57,58] All 3 studies included only or mainly revision cases subsequent to failed hemiarthroplasty. This supports the observation that revision of RSAs predisposes to inferior outcomes.

The present review has weaknesses related to the homogeneity among the groups. After reviewing the literature, no level I studies met the criteria at the time of the literature research. Three studies were prospective cohort studies. This indicates the need for studies of improved quality on the problems, complications, reoperations, and revisions after RSA. A meta-analysis could not be performed because of the lack of homogeneity, and a systematic review was performed instead. However, systematic reviews are qualitatively and quantitatively limited by the quality of the published studies. We therefore analyzed in detail the differences between the different etiologies and attempted to exclude any study with a potential confounding factor, such as less than 24 months of follow-up, absence of complication data, or subsequent longer follow-up of the same cohort.

Complication rates may have been influenced by potential confounding factors that were not extractable from the published data. RSA is a complex procedure with a considerable learning curve; however, none of the studies reported the operating surgeon's experience with the procedure. Similarly, updates have been made in the design of both the Grammont and Encore reverse shoulder systems to address problems with the original design, but it was not always possible to determine whether an original or updated design was used. We were therefore unable to determine whether design changes had an effect on the problem and complication rates.

Conclusions

Problems, complications, reoperations, and revisions after RSA are frequent (44%, 24%, 3.5%, and 10% respectively). Scapular notching is a common problem but is rarely clinically significant. Although reoperations were equal in the REV and primary arthroplasty group, REV arthroplasty as an etiology has an effect, with a higher average problem, complication, and revision rate of 12.5%, 33.3%, and 15.7%, respectively. Instability and infection were the 2 most frequent complications leading to revision.

Disclaimer

This is a systematic review of the literature concerning problems and complications encountered with all types of RSA (Depuy, Tornier, Encore). Any royalties and/or consultant payments received are not related directly to the subject matter or content of this article. The 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. Arntz CT, Jackins S, Matsen FA 3rd. Prosthetic replacement of the shoulder for the treatment of defects in the rotator cuff and the surface of the glenohumeral joint. J Bone Joint Surg Am 1993;75:485-91.
2. Barrett WP, Franklin JL, Jackins SE, Wyss CR, Matsen FA 3rd. Total shoulder arthroplasty. J Bone Joint Surg Am 1987;69:865-72.
3. Baulot E, Chabernaud D, Grammont PM. [Results of Grammont's inverted prosthesis in omarthritis associated with major cuff destruction. Apropos of 16 cases]. Acta Orthop Belg 1995;61(suppl 1):112-9.
4. Baulot E, Garron E, Grammont PM. [Grammont prosthesis in humeral head osteonecrosis. Indications—results]. Acta Orthop Belg 1999;65(suppl 1):109-15.
5. Baulot E, Valenti P, Garaud P, Boileau P, Neyton L, Sirveaux F, et al. [Results of Inverse Shoulder Prosthesis]. Rev Chir Orthop Reparatrice Appar Mot 2007;93:63-92. doi:10.1016/S0035-1040(07)92712-9
6. Boileau P, Chuinard C, Le Huec JC, Walch G, Trojani C. Proximal humerus fracture sequelae: impact of a new radiographic classification on arthroplasty. Clin Orthop Relat Res 2006;442:121-30. doi:10.1097/01.blo.0000195679.87258.6e
7. Boileau P, Chuinard C, Roussanne Y, Bicknell R, Rochet N, Trojani C. Reverse shoulder arthroplasty combined with a modified latissimus dorsi and teres major tendon transfer for shoulder pseudoparalysis associated with dropping arm. Clin Orthop Relat Res 2008;466:584-93. doi:10.1007/s11999-008-0114-x
8. Boileau P, Chuinard C, Roussanne Y, Neyton L, Trojani C. Modified latissimus dorsi and teres major transfer through a single delto-pectoral approach for external rotation deficit of the shoulder: as an isolated procedure or with a reverse arthroplasty. J Shoulder Elbow Surg 2007;16:671-82. doi:10.1016/j.jse.2007.02.127
9. Boileau P, Roussanne Y, Brassart N. Bony increased offset reverse shoulder arthroplasty (BIO-RSA): a biologic solution to scapular notching, prosthetic instability and limited shoulder rotation. Presented at: Society of European Shoulder and Elbow Surgeons, 21st Annual Meeting. Brugge, Belgium; 2008. p. 69.

10. 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. doi:10.1016/j.jse.2006.01.003
11. Boudreau S, Boudreau ED, Higgins LD, Wilcox RB 3rd. Rehabilitation following reverse total shoulder arthroplasty. J Orthop Sports Phys Ther 2007;37:734-43. doi:10.2519/jospt.2007.2562
12. Boulahia A, Edwards TB, Walch G, Baratta RV. Early results of a reverse design prosthesis in the treatment of arthritis of the shoulder in elderly patients with a large rotator cuff tear. Orthopedics 2002;25: 129-33.
13. Brunner U, Kohler S. [Shoulder arthroplasty for treatment of the sequelae of proximal humerus fractures]. Orthopade 2007;36:1037-49. doi:10.1007/s00132-007-1157-5
14. Bufquin T, Hersan A, Hubert L, Massin P. Reverse shoulder arthroplasty for the treatment of three- and four-part fractures of the proximal humerus in the elderly: a prospective review of 43 cases with a short-term follow-up. J Bone Joint Surg Br 2007;89:516-20. doi:10.1302/0301-620X.89B4.18435
15. Cazeneuve JF, Cristofari DJ. [Grammont reversed prosthesis for acute complex fracture of the proximal humerus in an elderly population with 5 to 12 years follow-up]. Rev Chir Orthop Reparatrice Appar Mot 2006; 92:543-8. doi:RCO-10-2006-92-6-0035-1040-101019-200519199
16. Chebli C, Huber P, Watling J, Bertelsen A, Bicknell RT, Matsen F 3rd. Factors affecting fixation of the glenoid component of a reverse total shoulder prothesis. J Shoulder Elbow Surg 2008;17: 323-7. doi:10.1016/j.jse.2007.07.015
17. Chuinard C, Trojani C, brassart N, Boileau P. Humeral problems in reverse total shoulder arthroplasty. In: Boileau P, editor. Reverse shoulder arthroplasty. Nice: Sauramps; 2006. p. 275-88.
18. Codsi MJ, Iannotti JP. The effect of screw position on the initial fixation of a reverse total shoulder prosthesis in a glenoid with a cavitary bone defect. J Shoulder Elbow Surg 2008;17:479-86. doi: 10.1016/j.jse.2007.09.002
19. Constant CR. Age related recovery of shoulder function after injury. Cork, Ireland: University College; 1986.
20. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. Clin Orthop 1987:160-4.
21. Coste JS, Reig S, Trojani C, Berg M, Walch G, Boileau P. The management of infection in arthroplasty of the shoulder. J Bone Joint Surg Br 2004;86:65-9. doi:10.1302/0301-620X.86B1.14089
22. 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. doi:10.2106/JBJS.G.00775
23. Cuff DJ, Virani NA, Levy J, Frankle MA, Derasari A, Hines B, et al. The treatment of deep shoulder infection and glenohumeral instability with debridement, reverse shoulder arthroplasty and postoperative antibiotics. J Bone Joint Surg Br 2008;90:336-42. doi:10. 1302/0301-620X.90B3
24. De Buttet A, Bouchon Y, Capon D, Delfosse J. Grammont shoulder arthroplasty for osteoarthritis with massive rotator cuff tears—report of 71 cases. J Shoulder Elbow Surg 1997;6:197.
25. De Wilde L, Mombert M, Van Petegem P, Verdonk R. Revision of shoulder replacement with a reversed shoulder prosthesis (Delta III): report of five cases. Acta Orthop Belg 2001;67:348-53.
26. De Wilde L, Sys G, Julien Y, Van Ovost E, Poffyn B, Trouilloud P. The reversed Delta shoulder prosthesis in reconstruction of the proximal humerus after tumour resection. Acta Orthop Belg 2003;69: 495-500.
27. De Wilde LF, Plasschaert FS, Audenaert EA, Verdonk RC. Functional recovery after a reverse prosthesis for reconstruction of the proximal humerus in tumor surgery. Clin Orthop Relat Res 2005;430: 156-62. doi:10.1097/01.blo.0000146741.83183.18
28. 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. doi:RCO-06-2002-88-4-0035-1040-101019-ART8
29. Delloye C, Joris D, Colette A, Eudier A, Dubuc JE. [Mechanical complications of total shoulder inverted prosthesis]. Rev Chir Orthop Reparatrice Appar Mot 2002;88:410-4. doi:RCO-06-2002-88-4-0035-1040-101019-ART13
30. Ecklund KJ, Lee TQ, Tibone J, Gupta R. Rotator cuff tear arthropathy. J Am Acad Orthop Surg 2007;15:340-9.
31. Favard L, Sirveaux F, Oudet D, Huguet D, Mole D. Hemiarthroplasty versus reverse arthroplasty in treatment of arthropathy with massive rotator cuff tear. Proceeding of the European Federation of National Associations of Orthopaedics and Traumatology (EFORT). J Bone Joint Surg Br 2004;86(suppl III):230ff.
32. Favre P, Loeb MD, Helmy N, Gerber C. Latissimus dorsi transfer to restore external rotation with reverse shoulder arthroplasty: a biomechanical study. J Shoulder Elbow Surg 2008;17:650-8. doi: 10.1016/j.jse.2007.12.010
33. Frankle M, Levy JC, Pupello D, Siegal S, Saleem A, Mighell M, et al. The reverse shoulder prosthesis for glenohumeral arthritis associated with severe rotator cuff deficiency. A minimum two-year follow-up study of sixty patients surgical technique. J Bone Joint Surg Am 2006;88(suppl 1 Pt 2):178-90. doi:10.2106/JBJS.F.00123
34. 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. doi: 10.2106/JBJS.D.02813
35. Franklin JL, Barrett WP, Jackins SE, Matsen FA 3rd. Glenoid loosening in total shoulder arthroplasty. Association with rotator cuff deficiency. J Arthroplasty 1988;3:39-46.
36. Gerber C, Pennington SD, Lingenfelter EJ, Sukthankar A. Reverse Delta-III total shoulder replacement combined with latissimus dorsi transfer. A preliminary report. J Bone Joint Surg Am 2007;89:940-7. doi:10.2106/JBJS.F.00955
37. Gohlke F, Rolf O. [Revision of failed fracture hemiarthroplasties to reverse total shoulder prosthesis through the transhumeral approach: method incorporating a pectoralis-major-pedicled bone window]. Oper Orthop Traumatol 2007;19:185-208.
38. Gohlke F, Rolf O, Werner Ch. Results of reverse arthroplasty in revision of failed hemiarthroplasties. In: Reverse shoulder arthroplasty: clinical results, complications, revision - Nice Shoulder Course editor. Montpellier: Sauramps Médical; 2006. p. 209-15. ISBN: 9782840234678.
39. Grammont P, Trouilloud P, Laffay J, Deries X. Etude de réalisation d'une nouvelle prothèse d'épaule. Rhumatologie 1987;39:407-18.
40. Grammont PM, Baulot E. Delta shoulder prosthesis for rotator cuff rupture. Orthopedics 1993;16:65-8.
41. 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. doi:10.2106/JBJS.E.00851
42. Gutierrez S, Greiwe RM, Frankle MA, Siegal S, Lee WE 3rd. Biomechanical comparison of component position and hardware failure in the reverse shoulder prosthesis. J Shoulder Elbow Surg 2007;16:S9-12. doi:10.1016/j.jse.2005.11.008
43. Gutierrez S, Keller TS, Levy JC, Lee WE 3rd, Luo ZP. Hierarchy of stability factors in reverse shoulder arthroplasty. Clin Orthop Relat Res 2008;466:670-6. doi:10.1007/s11999-007-0096-0
44. Gutierrez S, Levy JC, Lee WE 3rd, Keller TS, Maitland ME. Center of rotation affects abduction range of motion of reverse shoulder arthroplasty. Clin Orthop Relat Res 2007;458:78-82. doi:10.1097/ BLO.0b013e31803d0f57
45. Habermeyer P, Ebert T. [Current status and perspectives of shoulder replacement]. Unfallchirurg 1999;102:668-83.
46. Harman M, Frankle M, Vasey M, Banks S. Initial glenoid component fixation in "reverse" total shoulder arthroplasty: a biomechanical evaluation. J Shoulder Elbow Surg 2005;14:162S-7. doi:10.1016/j. jse.2004.09.030
47. Hawkins RJ, Bell RH, Jallay B. Total shoulder arthroplasty. Clin Orthop Relat Res 1989:188-94.

48. Hedtmann A, Heers G. [Principles of shoulder prosthesis implantation]. Orthopade 2001;30:354-62.
49. Hedtmann A, Werner A. [Shoulder arthroplasty in rheumatoid arthritis]. Orthopade 2007;36:1050-61. doi:10.1007/s00132-007-1153-9
50. Humphrey CS, Kelly JD 2nd, Norris TR. Optimizing glenosphere position and fixation in reverse shoulder arthroplasty, Part two: the three-column concept. J Shoulder Elbow Surg 2008;17:595-601. doi:10.1016/j.jse.2008.05.038
51. Jacobs R, Debeer P, De Smet L. Treatment of rotator cuff arthropathy with a reversed Delta shoulder prosthesis. Acta Orthop Belg 2001;67:344-7.
52. Jerosch J, Schunck J, Morsy MG. [Shoulder resurfacing in patients with rotator cuff arthropathy and remaining subscapularis function]. Z Orthop Unfall 2008;146:206-10. doi:10.1055/s-2007-989313
53. Karelse AT, Bhatia DN, De Wilde LF. Prosthetic component relationship of the reverse Delta III total shoulder prosthesis in the transverse plane of the body. J Shoulder Elbow Surg 2008;17:602-7. doi:10.1016/j.jse.2008.02.005
54. Kelly JD 2nd, Humphrey CS, Norris TR. Optimizing glenosphere position and fixation in reverse shoulder arthroplasty, part one: The twelve-mm rule. J Shoulder Elbow Surg 2008;17:589-94. doi:10.1016/j.jse.2007.08.013
55. L'Abbe KA, Detsky AS, O'Rourke K. Meta-analysis in clinical research. Ann Intern Med 1987;107:224-33.
56. Levigne C, Boileau P, Favard L, Garaud P, Mole D, Sirveaux F, et al. Scapular notching in reverse shoulder arthroplasty. J Shoulder Elbow Surg 2008;. doi:10.1016/j.jse.2008.02.010
57. Levy J, Frankle M, Mighell M, Pupello D. The use of the reverse shoulder prosthesis for the treatment of failed hemiarthroplasty for proximal humeral fracture. J Bone Joint Surg Am 2007;89:292-300. doi:10.2106/JBJS.E.01310
58. Levy JC, Virani N, Pupello D, Frankle M. Use of the reverse shoulder prosthesis for the treatment of failed hemiarthroplasty in patients with glenohumeral arthritis and rotator cuff deficiency. J Bone Joint Surg Br 2007;89:189-95. doi:10.1302/0301-620X.89B2.18161
59. Liem D, Marquardt B, Witt KA, Steinbeck J. [Shoulder arthroplasty: biomechanics and design]. Orthopade 2007;36:1027-36. doi:10.1007/s00132-007-1156-6
60. Loew M, Raiss P, Kasten P, Rickert M. [Shoulder arthroplasty following rotator cuff tear: acquired arthropathy of the shoulder]. Orthopade 2007;36:988-95. doi:10.1007/s00132-007-1147-7
61. Matsen FA 3rd, Boileau P, Walch G, Gerber C, Bicknell RT. The reverse total shoulder arthroplasty. J Bone Joint Surg Am 2007;89:660-7.
62. Matsen FA, Boileau P, Walch G, Gerber C, Bicknell RT. The reverse total shoulder arthroplasty. Instr Course Lect 2008;57:167-74.
63. McFarland EG, Sanguanjit P, Tasaki A, Keyurapan E, Fishman EK, Fayad LM. The reverse shoulder prosthesis: a review of imaging features and complications. Skeletal Radiol 2006;35:488-96. doi:10.1007/s00256-006-0109-1
64. Michener LA, McClure PW, Sennett BJ. American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form, patient self-report section: reliability, validity, and responsiveness. J Shoulder Elbow Surg 2002;11:587-94. doi:10.1067/mse.2002.127096
65. Middernacht B, De Wilde L, Mole D, Favard L, Debeer P. Glenosphere disengagement: a potentially serious default in reverse shoulder surgery. Clin Orthop Relat Res 2008;466:892-8. doi:10.1007/s11999-007-0090-6
66. Mottier F, Wall B, Nove-Josserand L. Galoisy Guibal L, Walch G. [Reverse prosthesis and os acromiale or acromion stress fracture]. Rev Chir Orthop Reparatrice Appar Mot 2007;93:133-41. doi:RCO-04-2007-93-2-0035-1040-101019-200520005
67. Neyton L, Boileau P, Nove-Josserand L, Edwards TB, Walch G. Glenoid bone grafting with a reverse design prosthesis. J Shoulder Elbow Surg 2007;16:S71-8. doi:10.1016/j.jse.2006.02.002
68. Nicholson GP. Current concepts in reverse shoulder replacement. Curr Opin Orthop 2006;17:306-9. doi:10.1097/01.bco.0000233723.33763.ca.
69. Nyffeler RW, Werner CM, Gerber C. Biomechanical relevance of glenoid component positioning in the reverse Delta III total shoulder prosthesis. J Shoulder Elbow Surg 2005;14:524-8. doi:10.1016/j.jse.2004.09.010
70. Nyffeler RW, Werner CM, Simmen BR, Gerber C. Analysis of a retrieved delta III total shoulder prosthesis. J Bone Joint Surg Br 2004;86:1187-91. doi:10.1302/0301-620X.86B8.15228.
71. Paladini P, Collu A, Campi E, Porcellini G. The inverse prosthesis as a revision prosthesis in failures of shoulder hemiarthroplasty. Chir Organi Mov 2005;90:11-21.
72. Petroff E, Mestdagh H, Maynou C, Delobelle JM. [Arthroplasty with a mobile cup for shoulder arthrosis with irreparable rotator cuff rupture: preliminary results and cineradiographic study]. Rev Chir Orthop Reparatrice Appar Mot 1999;85:245-56.
73. Rittmeister M, Kerschbaumer F. Grammont reverse total shoulder arthroplasty in patients with rheumatoid arthritis and nonreconstructible rotator cuff lesions. J Shoulder Elbow Surg 2001;10:17-22.
74. Roberts CC, Ekelund AL, Renfree KJ, Liu PT, Chew FS. Radiologic assessment of reverse shoulder arthroplasty. Radiographics 2007;27:223-35. doi:10.1148/rg.271065076
75. Rockwood CA Jr. The reverse total shoulder prosthesis. The new kid on the block. J Bone Joint Surg Am 2007;89:233-5. doi:10.2106/JBJS.F.01394
76. Sanchez-Sotelo J, Cofield RH, Rowland CM. Shoulder hemiarthroplasty for glenohumeral arthritis associated with severe rotator cuff deficiency. J Bone Joint Surg Am 2001;83:1814-22.
77. Sarmiento A, Kinman PB, Galvin EG, Schmitt RH, Phillips JG. Functional bracing of fractures of the shaft of the humerus. J Bone Joint Surg Am 1977;59:596-601.
78. Seebauer L. Total reverse shoulder arthroplasty: European lessons and future trends. Am J Orthop 2007;36:22-8.
79. Settecerri JJ, Pitner MA, Rock MG, Hanssen AD, Cofield RH. Infection after rotator cuff repair. J Shoulder Elbow Surg 1999;8:1-5.
80. Simovitch R, Helmy N, Zumstein M, Gerber C. Impact of fatty infiltration of the teres minor muscle on the outcome of reverse total shoulder arthroplasty. J Bone Joint Surg Am 2007;89:934-9. doi:10.2106/JBJS.F.01075
81. Simovitch R, Zumstein M, Lohri E, Helmy N, Gerber C. Predictors of scapular notching in patients managed with the Delta III reverse total shoulder replacement. J Bone Joint Surg Am 2007;89:588-600. doi:10.2106/JBJS.F.00226
82. Sirveaux F, Favard L, Oudet D, Huquet D, Walch G, Mole 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. doi:10.1302/0301-620X.86B3
83. Sperling JW, Kozak TK, Hanssen AD, Cofield RH. Infection after shoulder arthroplasty. Clin Orthop Relat Res 2001:206-16.
84. Spindler KP, Kuhn JE, Dunn W, Matthews CE, Harrell FE Jr, Dittus RS. Reading and reviewing the orthopaedic literature: a systematic, evidence-based medicine approach. J Am Acad Orthop Surg 2005;13:220-9.
85. Terrier A, Reist A, Merlini F, Farron A. Simulated joint and muscle forces in reversed and anatomic shoulder prostheses. J Bone Joint Surg Br 2008;90:751-6. doi:10.1302/0301-620X.90B6.19708
86. Tischer T, Rose T, Imhoff AB. The reverse shoulder prosthesis for primary and secondary treatment of proximal humeral fractures: a case report. Arch Orthop Trauma Surg 2008;128:973-8. doi:10.1007/s00402-007-0519-0
87. Ueblacker P, Ansah P, Vogt S, Imhoff AB. Bilateral reverse shoulder prosthesis in a patient with severe syringomyelia. J Shoulder Elbow Surg 2007;16:e48-51. doi:10.1016/j.jse.2006.12.003
88. Valenti P, Boutens D, Nerot C. Delta 3 reversed prosthesis for arthritis with massive rotator cuff tear: long term results ($>$ 5 years).

In: Walch G, Boileau P, Molé P, editors. 2000 shoulder prosthesis: two to ten years follow up. Montpellier: Sauramps Medical; 2001. p. 253-9.
89. Valenti P, Sauzieres P, Cogswell L, O'Toole G, Katz D. The reverse shoulder prosthesis—surgical technique. Tech Hand Up Extrem Surg 2008;12:46-55. doi:10.1097/BTH.0b013e3181572b14
90. Van Hoof T, Gomes GT, Audenaert E, Verstraete K, Kerckaert I, D'Herde K. 3D computerized model for measuring strain and displacement of the brachial plexus following placement of reverse shoulder prosthesis. Anat Rec (Hoboken) 2008;291:1173-85. doi: 10.1002/ar.20735
91. Van Seymortier P, Stoffelen D, Fortems Y, Reynders P. The reverse shoulder prosthesis (Delta III) in acute shoulder fractures: technical considerations with respect to stability. Acta Orthop Belg 2006;72: 474-7.
92. Vanhove B, Beugnies A. Grammont's reverse shoulder prosthesis for rotator cuff arthropathy. A retrospective study of 32 cases. Acta Orthop Belg 2004;70:219-25.
93. Virani NA, Harman M, Li K, Levy J, Pupello DR, Frankle MA. In vitro and finite element analysis of glenoid bone/baseplate interaction in the reverse shoulder design. J Shoulder Elbow Surg 2008;17:509-21. doi: 10.1016/j.jse.2007.11.003
94. Walch G, Wall B, Mottier F. Complications and revision of the reverse prothesis: a multicenter study of 457 cases. In: Boileau P, editor. Reverse shoulder arthroplasty. Nice: Sauramps; 2006. p. 335-52.
95. Wall B, Nove-Josserand L, O'Connor D, Edwards T, Walch G. Reverse total shoulder arthroplasty: A review of results according to etiology. J Bone Joint Surg Am 2007;89:1476-85. doi:10.2106/JBJS.F.00666
96. Wall B, Walch G. Reverse shoulder arthroplasty for the treatment of proximal humeral fractures. Hand Clin 2007;23:425-30, v-vi. doi:10.1016/j.hcl.2007.08.002.
97. Weissinger M, Helmreich C, Teumann E. Initial experience using the inverse prosthesis of the shoulder. Acta Chir Orthop Traumatol Cech 2008;75:21-7.
98. Werner CM, 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. doi:10.2106/JBJS.D.02342
99. Williams GR Jr, Rockwood CA Jr. Hemiarthroplasty in rotator cuff-deficient shoulders. J Shoulder Elbow Surg 1996;5:362-7.
100. Woodruff MJ, Cohen AP, Bradley JG. Arthroplasty of the shoulder in rheumatoid arthritis with rotator cuff dysfunction. Int Orthop 2003; 27:7-10. doi:10.1007/s00264-002-0406-9
101. Wright RW, Brand RA, Dunn W, Spindler KP. How to write a systematic review. Clin Orthop Relat Res 2007;455:23-9. doi: 10.1097/BLO.0b013e31802c9098