Reverse Shoulder Arthroplasty Using an Implant With a Lateral Center of Rotation: Outcomes, Complications, and the Influence of Experience

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Abstract

Reverse shoulder arthroplasty (RSA) has revolutionized treatment of arthritis and rotator cuff insufficiency and is performed using implants with either a medial or a lateral center of rotation.

We conducted a study of the outcomes and the effect of surgeon learning after the first 60 consecutive lateral-center-of-rotation RSAs implanted by a single surgeon unaffiliated with the design team for this particular reverse shoulder prosthesis. At minimum 2-year follow-up, mean improvements in active forward elevation, abduction, and external rotation were 69°, 55°, and 23°, respectively; mean active internal rotation improved significantly as well ($P < .001$ for all). Mean Simple Shoulder Test (SST) scores improved from 1.8 (range, 0-6) to 6.9 (range, 0-12) ($P < .0001$), and mean final American Shoulder and Elbow Surgeons score was 72 (range, 27-100). Final radiographs showed scapular notching in 5 shoulders (11%). Gains in SST scores, active forward elevation, and active abduction were lower for the first 15 cases than for the next 45 cases, and 5 of the 8 reoperations were performed after the first 15 cases.

Overall improvements in active motion and self-assessed shoulder function in this series are comparable to those previously reported by the design team. Experience with RSA appears to influence efficacy, but the learning curve may not be as steep as previously reported.

Reverse shoulder arthroplasty (RSA) has revolutionized the treatment of patients with an irreparable rotator cuff tear with glenohumeral arthritis or pseudoparalysis; patients with failed rotator cuff surgery with anterosuperior escape or glenohumeral instability; and patients with failed shoulder arthroplasty with gross rotator cuff insufficiency.[1-10] Multiple RSA systems, each with its own features, including location of center of rotation (COR), are available. The original Grammont design used a glenosphere with medial COR to confer protection against baseplate failure,[11-13] but this design has been associated with increased risk of scapular notching.[10,14-16]

The RSP (DjO Global, Inc., Austin, Texas), a reverse shoulder prosthesis, is characterized by lateral COR[5] that improves the deltoid moment arm and tensions the remaining rotator cuff. Multiple studies by its design team have found excellent short- and intermediate-term outcomes and low revision rates in various patient populations.[5,7-9,17,18] However, only limited published data on the clinical performance of the RSP have been obtained independent of its design team.

We conducted a study of the clinical and self-assessed outcomes, complications, and influence of surgeon learning after the first 60 consecutive RSAs implanted by a single surgeon using the RSP. Our principal hypothesis was that this RSA would significantly improve clinical and self-assessed outcomes and that results would be comparable to those previously reported by its design team. Our secondary hypothesis was that there would be a learning curve for this RSA, with outcomes improving with experience.

Materials and Methods

As this was a retrospective study, we did not submit our study protocol to an outside institutional review board for approval. The protocol was reviewed and approved by the review committee of the Cincinnati Sports Medicine Research and Education Foundation.

We retrospectively reviewed the initial 60 RSAs (57 patients)

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Table I. **Reverse Shoulder Arthroplasty (RSA) Indications**

RSA	Indication	n
Primary	Cuff tear arthropathy	36
	Failed rotator cuff repair with pseudoparalysis	3
	Osteoarthritis with large rotator cuff tear	1
	Rheumatoid arthritis with irreparable rotator cuff tear	1
	Resection arthroplasty	1
Revision	Failed hemiarthroplasty for cuff tear arthropathy	7
	Failed hemiarthroplasty for fracture	6
	Failed total shoulder arthroplasty	3
	Failed humeral head resurfacing with chronic rotator cuff tear	2

performed by Dr. Hasan between June 2004 and May 2010. The RSP was used for all RSAs. Mean age at RSA was 75 years (range, 54-92 years), and 44 patients (47 shoulders) were women. Forty-two primary and 18 revision RSAs were performed. Revisions were typically performed because of instability or pseudoparalysis with or without glenoid or humeral bone deficiency. Indications for primary and revision RSAs are summarized in **Table I**.

Before surgery, all patients underwent clinical examination, which included measurement of active range of motion (ROM): forward elevation (aFE), abduction (aAB), external rotation at the side (aER), and internal rotation to the back (aIR). Standardized Grashey and axillary-lateral radiographs were also obtained. In addition, the 12-item Simple Shoulder Test (SST)[19] was used to evaluate self-assessed shoulder function.

All RSAs were performed using a deltopectoral approach, incorporating previous incisions whenever practical. The proximal humerus and glenoid were prepared sequentially to accommodate the RSP components, with attention given to inferior glenoid baseplate position and tilt.[20-22] All glenoid baseplates were inserted with 3 or 4 locking screws for adjunctive baseplate fixation, and all humeral stems were inserted with antibiotics-impregnated cement. The subscapularis remnant was repaired to the lesser tuberosity using braided sutures through transosseous drill holes, and all shoulders were drained for 24 to 48 hours. Tendon transfers were not performed in any shoulder. Revision surgeries were performed using the same principles, but incisions were extended as needed. At time of revision surgery, 1 shoulder with an uncontained glenoid defect required superior glenoid augmentation using bulk allograft, and 3 shoulders with proximal humeral bone loss required reconstruction using bulk proximal humeral allograft prepared with a step cut[23] and affixed to the host bone using suture cerclage.

After surgery, all patients were admitted for intravenous antibiotics, pain control, and medical management. Then they were discharged home or to an inpatient facility with instructions to immobilize the arm in a padded soft brace for 3 weeks and to refrain from weight-bearing for 8 weeks. Supervised physical therapy was offered to select patients at Dr. Hasan's discretion, but most patients performed patient-directed exercises and then gradually returned to normal activities 8 to 12 weeks after surgery.

At most recent follow-up, 10 patients (11 shoulders) were deceased, and 2 patients (2 shoulders) with follow-up of less than 2 years could not be located and were excluded. However, 4 of the 11 shoulders in deceased patients had the minimum 2-year follow-up, and therefore their data were included in the analysis, for a total of 51 shoulders.

Self-assessed outcome scores—SST scores and American Shoulder and Elbow Surgeons (ASES) scores—were available for the 51 shoulders at minimum 2-year follow-up (mean, 36 months; range, 23-74 months). Radiographs and shoulder ROM data were available for 45 shoulders at minimum 2-year follow-up (mean, 33 months; range, 23-69 months). Complications and reoperations for the 60 RSAs included those of patients who subsequently died or who were lost to follow-up. Outcomes and complications for the first 15 shoulders (initial group) were compared with those for the next 45 shoulders (second group). Radiographs were evaluated by Dr. Hasan for dislocation, component dissociation or failure, scapular and humeral stress fractures, and scapular notching, which was evaluated using the method of Nerot,[16,24] as illustrated in the **Figure**.

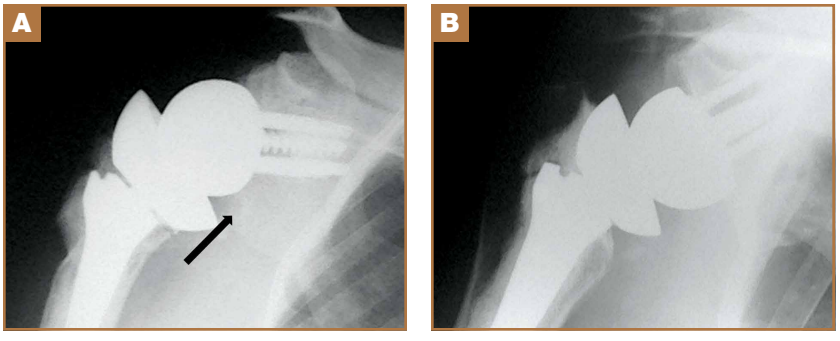

Figure. Grashey (true anteroposterior) radiographs show RSP (DjO Global, Inc., Austin, Texas) implants (A) with and (B) without scapular notching.

Dependent variables included preoperative and final aFE, aAB, aER, and aIR; preoperative and final SST scores; final ASES score; and change in aFE, aAB, aER, aIR, and SST scores. Initial and final outcome measures were compared using the paired *t* test. Analysis of variance (ANOVA) was performed using the main effects of sex, experience (initial vs second group), and surgery (primary vs revision), followed by paired *t* tests as appropriate. Significance levels for

the comparisons were computed from the ANOVA. Complication and reoperation rates for the groups (initial, second) were compared using the Fisher exact test. All statistical analysis was done at the $P < .05$ significance level using SAS software (SAS Institute, Cary, North Carolina).

Results

Mean (SD) preoperative aFE was 43° (34°), aAB was 42° (28°), aER was 9° (14°), and aIR was to the buttock. By most recent follow-up, mean (SD) aFE had improved to 112° (31°) ($P < .0001$), aAB to 98° (26°) ($P < .0001$), aER to 29° (21°) ($P < .0001$), and aIR to the L3 spinous process ($P < .001$). Mean number of SST *yes* responses improved from 1.8 (range, 0-6) to 6.9 (range, 0-12) ($P < .0001$). Mean final ASES score was 72 (range, 27-100).

Compared with the women, the men demonstrated significantly more final mean (SD) aFE, 128° (21°) versus 106° (33°) ($P < .05$), and aAB, 116° (20°) versus 92° (25°) ($P < .01$). Mean (SD) SST scores were higher for the men as well, but the differences only approached statistical significance with the numbers available: 8.7 (2.8) versus 6.4 (3.5) ($P = .08$). Patients who had revision RSA had comparable outcomes but larger gains in active ROM than patients who had primary RSA: change in mean (SD) aFE, 95° (27°) versus 56° (45°) ($P < .01$); change in mean (SD) aAB, 73° (31°) versus 47° (34°) ($P < .05$). Mean (SD) ASES scores for patients who had revision RSA and primary RSA were 64 (24) and 76 (20), respectively ($P = .08$). **Table II** summarizes the ROM and outcome scores by sex and by status (primary, revision).

Mean preoperative aFE and aAB were much lower in the second group (35.5°, 33.5°) than in the initial group (66.2°, 66.7°), and, though the groups' mean postoperative aFE and aAB were similar, the second group showed substantially more improvement (change in aFE, 77° vs 34°, $P = .08$; change in aAB, 62° vs 21°, $P < .05$) (**Table III**). Larger gains in SST scores were also found for the second group, but these were not statistically significant because of the effects of the other confounders.

Sixteen complications (14 patients, 24.6%) were identified (**Table IV**). Six patients (11%) underwent 8 reoperations, including 4 closed reductions for dislocation (3 patients), 2 open revisions for instability and a dissociated liner (1 patient), 1 evacuation of a hematoma, and 1 fixation of a symptomatic scapular spine nonunion. Five reoperations were performed in the initial group of 15 RSAs, and 3 reoperations (closed reductions) were performed in the second group of 45 RSAs ($P < .05$). Radiographs at minimum 2-year follow-up showed mild scapular notching in 5 (11%) of 45 shoulders, and only 1 additional shoulder demonstrated any scapular notching

Table II. Mean Range of Motion, Outcome Scores, and Improvement for All Patients and by Sex and Status (Primary, Revision)

	Preoperative[a]		Postoperative		Improvement	
	Mean	SD	Mean	SD	Mean	SD
Active Forward Elevation, °						
Overall	43	34	112	31	69	45
Women	44	32	106	33	63	44
Men	43	41	128	21	85	44
Primary	50	37	108	31	56	45
Revision	29	19	119	33	95	27
Active Abduction, °						
Overall	42	28	98	26	55	35
Women	43	29	92	25	49	35
Men	38	29	116	20	75	27
Primary	46	31	96	26	47	34
Revision	33	21	100	27	73	31
Active External Rotation at Side, °						
Overall	9	14	29	21	23	22
Women	10	12	28	21	21	21
Men	6	21	32	22	29	25
Primary	10	16	28	20	23	22
Revision	8	11	31	24	24	25
Active Internal Rotation to Back						
Overall	Buttock		L3 spinous process		—	—
Women	Buttock		L3 spinous process		—	—
Men	Buttock		L3 spinous process		—	—
Primary	Buttock		L3 spinous process		—	—
Revision	Buttock		L3 spinous process		—	—
Simple Shoulder Test Score						
Overall	1.8	1.6	6.9	3.5	5.1	3.4
Women	1.5	1.4	6.4	3.5	4.8	3.6
Men	2.5	2.1	8.7	2.8	6.4	2.4
Primary	2.0	1.7	7.2	3.4	5.0	3.4
Revision	1.2	1.5	6.1	3.6	5.6	3.7
ASES Score						
Overall	—	—	72	22	—	—
Women	—	—	71	22	—	—
Men	—	—	77	22	—	—
Primary	—	—	76	20	—	—
Revision	—	—	64	24	—	—

Abbreviation: ASES, American Shoulder and Elbow Surgeons.
[a]N = 51 patients.

Table III. **Mean Range of Motion, Outcome Scores, and Improvement for Patients by Group (Initial, Second)**

	Preoperative[a]		Postoperative		Improvement	
	Mean	SD	Mean	SD	Mean	SD
Active Forward Elevation, °						
Initial group	66	32	106	38	34	45
Second group	36	31	113	30	77	41
Active Abduction, °						
Initial group	67	27	99	33	21	29
Second group	34	24	97	24	62	32
Active External Rotation at Side, °						
Initial group	10	14	24	25	15	24
Second group	9	15	30	21	22	22
Active Internal Rotation to Back						
Initial group	Buttock		L3 spinous process		—	—
Second group	Buttock		L3 spinous process		—	—
Simple Shoulder Test Score						
Initial group	1.8	1.8	6.3	3.8	3.4	4.0
Second group	1.8	1.6	7.1	3.4	5.6	3.2
ASES Score						
Initial group	—	—	70	21	—	—
Second group	—	—	73	22	—	—

Abbreviation: ASES, American Shoulder and Elbow Surgeons.
[a]N = 51 patients.

Table IV. **Complications**

Complication	n
Orthopedic	
Dislocation	4
Dissociation of humeral socket	1
Scapular spine fracture	3
Acromion fracture	1
Humeral stress fracture	1
Postoperative hematoma	1
Deltoid strain	1
Cervical radiculopathy	1
Medical	
Altered mental status	2
Bowel obstruction	1

on most recent radiographs. To date, no deep infections have been identified, and none of the baseplates or humeral stems have been revised.

Discussion

Our results confirmed those reported by the design team in other studies,[3,5,8,9,17,18,25] which demonstrated a low incidence of scapular notching and improved active ER with the RSP compared with systems having a more medial COR. Frankle and colleagues[5] initially reported a mean final ASES score of 68.2, mean FE improvement of 50.1°, and mean ER improvement of 29.1°. In a minimum 24-month follow-up study, Cuff and colleagues[3] reported an overall complication rate of 6% without baseplate failure or scapular notching. They also reported a mean final ASES score of 78, an increase in SST scores from 1.8 to 6.8, and mean aFE and aER gains of 55° and 15°, respectively. Their findings are nearly identical to ours with respect to mean SST scores (improved from 1.8 to 6.9) and mean aFE and aER gains (69°, 23°).

In contrast, most studies of Grammont-type implants have not found substantial gains in ER.[10,11,14] Boileau and colleagues[14] reported a mean aFE gain of 66° but only a mean 4° gain in aER. Simovitch and colleagues[26] found a mean 9° improvement in ER among patients with minimal external rotator muscle atrophy but a mean 7° loss among patients with substantial atrophy. More recent reports have documented ER gains with Grammont-type implants and a surgical technique using either adjunctive modified L'Episcopo transfer of the latissimus dorsi[27,28] or a bony increased-offset technique that interposes cancellous autograft between baseplate and glenoid to lateralize the prosthetic COR.[29]

RSP clinical studies independent of the design team are scarce. Levy and Blum[30] reported on a single-surgeon experience immediately after fellowship training. Although they identified complications in 10 (25%) of the first 40 consecutive patients who received the RSP, revision surgery was needed in only 2 cases (5%). However, initial and final clinical and self-assessed outcomes were not provided. Clark and colleagues[31]

found that subscapularis repair did not influence ROM, dislocation rate, or overall complication rate after RSA using the RSP. At a mean follow-up of about 12 months, active forward flexion was increased 56° in the nonrepair group and 54° in the repair group—improvements comparable to those found in the present study.

Enthusiasm for RSA has been dampened by reports of high complication and reoperation rates and a steep learning curve, though the definition of complication has varied widely. Our 24.6% complication rate and 11% reoperation rate are comparable to the 20% and 14% rates reported by Clark and colleagues,[31] the 17% complication rate reported initially by Frankle and colleagues,[5] and the 28% to 32% complication rate reported by Levy and colleagues[8,9] for RSA for failed hemiarthroplasty. Our study identified 1 case of component dissociation, which occurred after the first RSA, performed as a revision, and no cases of component loosening or baseplate failure.

In their early reports, the design team did not identify any cases of scapular notching.[3,5,8,9] In addition, Bries and colleagues[22] did not identify scapular notching in their retrospective review of 138 RSAs. Absence of notching may be related to a larger impingement-free arc of motion afforded by the lateral COR and enhanced by inferior baseplate positioning and tilt.[32,33] Length of follow-up may influence the incidence of scapular notching, though most cases occur within the first year after implantation.[15]

More recently, the design team reported a 13.5% incidence of scapular notching,[18] which is comparable to the 11% in the present study and considerably lower than the 44% to 96% reported in multiple studies of Grammont-type implants.[14-16,34,35] Although its long-term clinical consequences remain incompletely understood, scapular notching has been shown to predict an inferior clinical outcome.[34,35]

Our study findings support the hypothesis that there is an RSA learning curve. With experience, the reoperation rate declined, and the clinical outcome improved (with the numbers available, however, some of these improvements did not reach statistical significance). Specifically, the initial group in our study demonstrated smaller increases in aAB, a trend toward smaller increases in SST scores and aFE, and a higher incidence of reoperation.

Several other studies have aimed to define the RSA learning curve[30,36-39]; their conclusions have varied. Wierks and colleagues[38] reported an overall complication rate of 75% during the first 3 months after their initial 20 RSAs, but this rate was overstated because intraoperative pitfalls were included that did not affect outcome. According to the investigators, intraoperative complications were 10% as likely in their second group (10 RSAs).

In a series of 192 RSAs, Kempton and colleagues[36] analyzed complications to compute a threshold of 40 cases and reported surgical complication rates of 23.1% for the first 40 cases and 6.5% for the next 152 cases. Riedel and colleagues[37] studied the influence of learning in a series of 62 RSAs, comparable in size to the series in the present study. They plotted operative time across their experience to determine that 18 cases were needed for a flat slope or proficiency point. Last, Levy and Blum[30] found no difference in complication rates between the first and second 20 patients. However, during fellowship training the surgeon had experience with 131 RSAs using the same implant system, so the learning curve may have already leveled off.

Our results suggest a learning curve similar to the curves reported by Kempton and colleagues[36] and Riedel and colleagues.[37] With experience, our complication rate decreased, and clinical outcomes appeared to improve, though these results were confounded by patient sex, frequency of revision surgery, and other factors. Our minimum 2-year follow-up was longer than the 3-month follow-up in the study by Wierks and colleagues[38] and the 6-month follow-up in the study by Kempton and colleagues.[36] Furthermore, our cohort represents the first 60 RSAs of any type performed by Dr. Hasan, so the data truly represent the influence of learning a new surgery. Last, our study of the initial RSA learning curve is different because it evaluated outcomes, including shoulder mobility and self-assessed shoulder function. Nevertheless, we could not identify any specific factors that might explain the improvements with experience given the heterogeneous patient population and various indications for surgery.

RSA learning curve studies, including this study, suggest that the learning curve spans 15 to 20 cases. As Dr. Hasan performed 36 RSAs in 2004 and 105 in 2010, for a mean of 63 per year during the study period, the learning curve may not generalize to low-volume surgeons. Furthermore, we agree with Rockwood[40] that RSA should be reserved for surgeons who perform 20 or more shoulder arthroplasties a year (given that typically only a portion of these are RSAs) to ensure that the learning curve does not extend past a few years.

This study's limitations include its retrospective nature and lack of preoperative ASES scores. In addition, radiographs and ROM measurements were not available for 15 of the 60 patients at the minimum 24-month follow-up. Therefore, this study may underestimate the incidence of scapular notching and other late sequelae.

Conclusion

The RSP improves active shoulder motion and function in carefully selected older patients with pseudoparalysis or a failed shoulder replacement. Our study replicates the clinical and radiographic outcomes of using the RSP for RSA reported by the design team. Scapular notching is infrequent, and, though reoperations and complications occur, the learning curve may not be as steep as previously reported.

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