RESEARCH ARTICLE

Reverse Shoulder Arthroplasty is Superior to Hemiarthroplasty for Cuff Tear Arthropathy with Preserved Motion

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Abstract

Background: It is unclear whether hemiarthroplasty (HA) or reverse shoulder arthroplasty (RS) are superior for patients with cuff tear arthropathy (CTA) and preserved preoperative motion (elevation >90˚).

Methods: This was a retrospective, single institution study. Patients who underwent RSA or HA for CTA were included if they had preserved preoperative motion with a minimum of 2 years of follow-up, or until complication/revision. Shoulder ROM and functional outcomes scores were obtained.

Results: Twenty-six HAs and 21 RSAs were evaluated at mean of 38.6 months (HA) and 36.3 months (RSA). Patients in the RSA group were significantly older at surgery (73.9 versus 65.1 years; *P=0.003*). Postoperatively, the mean change in active elevation was -15° for HA versus 26° for RSA, with RSA having significantly greater active elevation (153° versus 123°; *P=0.01*). There were no significant differences in final internal or external rotation between groups. Superior outcomes were seen for RSA versus HA for ASES score (84 vs. 66, P=0.003), Simple Shoulder Test (8.8 vs. 7.3, *P=0.3*), Single Assessment Numeric Evaluation (85 vs. 70, *P=0.017*), and 100mm VAS pain (7 vs. 33, *P<0.001*).

Conclusion: In patients with CTA and preserved preoperative forward elevation, RSA provided greater pain relief, superior functional outcomes, and better ROM compared with HA.

Level of evidence: IV

Keywords: Hemiarthroplasty, Reverse shoulder arthroplasty, Rotator cuff tear arthropathy

Introduction

Following the introduction of reverse shoulder arthroplasty for treatment of cuff tear arthropathy (CTA) in the United States, implant usage has risen at a rapid rate (1). Results have been encouraging in this patient population, demonstrating reliable improvements in mobility and pain relief (2-4). Outcomes of reverse, however, continue to lag behind those of anatomic arthroplasty in terms of range of motion and functional outcomes (5). In addition, complication rates (instability, infection, scapular notching) have been consistently higher than anatomic shoulder arthroplasty, and higher than would be desired (6-8). Therefore, the indications for reverse shoulder arthroplasty deserve ongoing investigation.

Patients with irreparable rotator cuff tears, and preserved range of motion present a unique treatment question for the operating surgeon. While reverse shoulder arthroplasty can provide overhead function

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to many patients with pseudoparalysis, average final range of motion in most series with reverse shoulder arthroplasty is from 110-140 degrees (3, 4, 9, 10). In addition, many patients lose some internal and external rotation following reverse total shoulder arthroplasty, which can have functional implications. This has led some surgeons to consider use of hemiarthroplasty (HA) rather than reverse shoulder arthroplasty (RSA) in this select patient population. Furthermore, HA has the most historical success in CTA patients with preserved range of motion (ROM) preoperatively (11). Head-to-head comparison of RSA and HA without discriminating preoperative motion, however, has consistently favored RSA (9, 10). No study has directly compared HA to RSA for CTA with preserved ROM.

The purpose of this non-randomized cohort study was to examine intermediate term clinical outcomes in patients with rotator cuff tear arthropathy (CTA) and preserved preoperative ROM (>90˚ forward elevation), who underwent hemiarthroplasty or reverse shoulder arthroplasty. We hypothesized that (1) hemiarthroplasty may be performed in this patient population with less surgical/postoperative morbidity than reverse shoulder arthroplasty, as measured by intraoperative and postoperative complications; (2) revision rate will be higher following HA than RSA; (3) RSA will result in better shoulder elevation, while HA will result in better internal and external rotation based on clinical examinations; and (4) hemiarthroplasty and reverse shoulder arthroplasty will have equivalent functional outcomes, as documented by functional outcome measurements and visual analog pain scores at final follow up.

Materials and Methods

Patients and Data Collection

This study was approved by our institutional review board. All patients who had undergone HA or RSA for rotator cuff tear arthropathy at our institution from January 1, 2007 to December 31, 2013 were considered for inclusion. Charts were reviewed, and patients were included only if they had preoperative range of motion (active forward shoulder elevation) greater than or equal to 90˚. Patients were excluded if they had: previous arthroplasty, history of infection, or history of fracture, or neurologic dysfunction. All patient charts were reviewed for patient history, preoperative range of motion, operative technique and notes, complications, revision procedures, and functional outcomes

Surgical Technique

Implant choice (HA vs. RSA) was at the discretion of the attending physician. For both HA and RSA, a deltopectoral approach was completed for all patients. In both HA and RSA, if the subscapularis was intact, it was taken down with a lesser tuberosity osteotomy. If there was significant subscapularis deficiency, a subscapularis peel of the intact portion was completed. The subscapularis was repaired when possible in both groups. Uncemented humeral components were used unless there was concern about fixation. A deep drain was used in all cases and removed following 48 hours.

Postoperative protocol

All patients were placed in a sling postoperatively. Hemiarthroplasty patients began passive external rotation (ER) and elevation exercises on their own at home. Limits were set based on surgical factors, but most commonly, an elevation limit of 140° and external rotation limit of 40° was set. Patients were seen in clinic at 2 weeks. At that point, restrictions on passive elevation were removed, and below shoulder level activities of daily living were allowed. If they had significant stiffness (<90° elevation or <0° ER), they were sent to formal physical therapy (PT) for assistance with passive stretching. At 6 weeks postoperatively, active assisted ROM and strengthening was added, with formal PT. At 3 months, patients were released from restrictions.

RSA patients remained immobilized in a sling until their 2 week visit. Elbow, wrist, and hand ROM were encouraged. When the patients were seen back at their 2 week visit, table glides and pendulum exercises were initiated, and patients were instructed to perform below shoulder level activities of daily living as tolerated. At 6 weeks, external rotation, elevation, and pulley exercises were initiated. At 3 months patients were released from restrictions.

Follow-up Assessment

All eligible patients were followed up with radiographs and a clinical exam. Outcome measures included the ASES (American Shoulder and Elbow Surgeons) Shoulder Score, (12) Simple Shoulder Test (SST), (13) Single Assessment Numeric Evaluation (SANE), (14) and a 100mm visual analog scale (VAS) for pain. Patient who were unable to schedule follow-up appointments were mailed the same survey with an additional self-assessed range of motion (ROM) component, consisting of pictorial depictions of forward elevation, external rotation at 0° abduction, and internal rotation behind the back. Records of eligible patients who did not respond to follow-up requests or mailed questionnaires were reviewed to assess their postoperative course; if these non-responding patients had over two years of documented clinical follow-up, suffered a complication or underwent a revision procedure, the most recent ROM and outcomes scores (or in the case of revision, the most recent prior to revision) were included in the final analysis.

Statistical Analysis

A two-sample t-test was used to compare baseline range of motion and demographic characteristics between the two groups, as well preoperative versus postoperative changes in elevation, external rotation, and internal rotation. Fisher's Exact test was used to compare categorical data. The α level for statistical significance was set at .05.

Results

Study Subjects

Four hundred and seventy-six patients who underwent HA and 455 patients had undergone RSA during this six-year time frame. Of these, 43 (HA) and 51 (RSA) had preserved preoperative forward elevation >90°.

33 HA patients (36 shoulders) and 32 RSA patients (32 shoulders) were over two years from surgery and were contacted for clinical follow-up. In the HA group, 4 patients (5 shoulders) had deceased, 6 patients (7 shoulders) were evaluated in clinic, 10 patients (11 shoulders) responded to the mailed questionnaire and 13 patients were lost to follow-up. Data from an additional 8 non-responding HA patients were included from the chart review. In the RSA cohort, 7 patients were evaluated in clinic, 9 patients responded to the mailed questionnaires, and 17 were lost to follow-up. Data from an additional 5 non-responding RSA patients were included from the chart review. There was no difference in overall response rate (50% vs. 47%; *P=0.81*) or type of follow-up (i.e. clinic vs. mail; *P=1.0*) between groups. In total, 26 (18 full outcomes) HA and 21 (15 full outcomes) RSA shoulders were included in the final analysis.

RSA patients were significantly older at the time of surgery (73.9 versus 65.1 years; *P=0.003*) [Table 1]. The groups were otherwise similar in terms of sex, body mass index, number of previous surgeries on the operative shoulder, and duration of follow-up. Previous ipsilateral surgeries in the HA group included arthroscopic debridement (2), acromioplasty (2), and rotator cuff repair (8). There were eight prior ipsilateral rotator cuff repairs in the RSA group. Intraoperative rotator cuff (RTC) assessment revealed irreparable RTC tears in all patients who underwent RSA. Partial RTC repair was completed in ten HA shoulders, with sixteen cases deemed irreparable.

Shoulder Range of Motion

The mean preoperative forward shoulder elevation (and standard deviation) was 138° ± 22° (range, 100° to 180°) for patients who underwent HA and 127° ± 21° (range, 100° to 160°) for the reverse cohort [Table 2]. The mean preoperative external rotation was 39° ± 18° (range, 0° to 70°) for patients who underwent HA and 30° ± 13° (range, 5° to 45°) for the reverse cohort. The mean preoperative internal rotation behind the back was L5 ± 2 vertebral levels (range, buttock to T8) for patients who underwent HA and L5 ± 1.5 vertebral levels (range, buttock to T12) for the reverse cohort. There were no significant differences in preoperative elevation, external rotation, or internal rotation between the two groups (*P=0.09*, *P=0.06*, *P=0.51*, respectively).

The mean postoperative forward shoulder elevation was 123° ± 47° (range, 30° to 180°) for patients who underwent HA and 153° ± 24° (range, 90° to 180°) for the reverse cohort. RSA patients made greater gains in elevation (*P<0.001*) and had greater postoperative elevation compared with HA (*P=0.01*). There were no statistically significant changes in external rotation or

Table 1. Characteristics of Included Patients

Characteristic	HA (N = 26)	RSA (N = 21)	*P-value*
Age at surgery *(yr)*			
Mean ± SD	65.1 ± 10	73.9 ± 9	0.003*
(Range)	(42 - 85)	(50 - 84)	
Male/female (*no. [%female]*)†	14/12 (46%)	9/12 (57%)	0.56
BMI	30.2	28.0	0.30
Prior Surgery†	12 (46%)	8 (38%)	0.76
Mean FW duration *(mo)*	38.60	36.3	0.68

*A significant value; BMI, body mass index; †Fisher's Exact Test

Table 2. Range of Motion

		HA	RSA	HA vs. RSA
Elevation	Preop	138° ± 22°	127° ± 21°	*P = 0.08*
	Postop	123° ± 47°	153° ± 24°	*P = 0.01**
	Preop vs. postop	*P = 0.17*	*P = 0.0006**	
External Rotation	Preop	39° ± 17°	30° ± 13°	*P = 0.06*
	Postop	48° ± 21°	38° ± 24°	*P = 0.098*
	Preop vs. postop	*P = 0.1*	*P = 0.31*	
Internal Rotation	Preop	L5 ± 2 levels	L5 ± 1.5 levels	*P = 0.5*
	Postop	L4 ± 1.8 levels	L5 ± 1.5 levels	*P = 0.6*
	Preop vs. postop	*P = 0.6*	*P = 0.5*	

internal rotation from preoperative to postoperative for either HA or RSA. There were no significant differences between HA and RSA in final postoperative external rotation (48° ± 21° vs. 38° ± 24°; *P=0.1*) or internal rotation (L4 ± 1.8 levels vs. L5 ± 1.5 levels; *P=0.58*).

Shoulder Outcome Measures

RSA patients reported better postoperative outcome scores with each assessment tool at final follow-up [Figure 1]. While SST scores were not significantly different between the two groups (*P=0.309*), significantly superior VAS pain, ASES, and SANE scores were seen with RSA compared with HA (*P<0.001*, *P=0.003*, *P=0.017*, respectively).

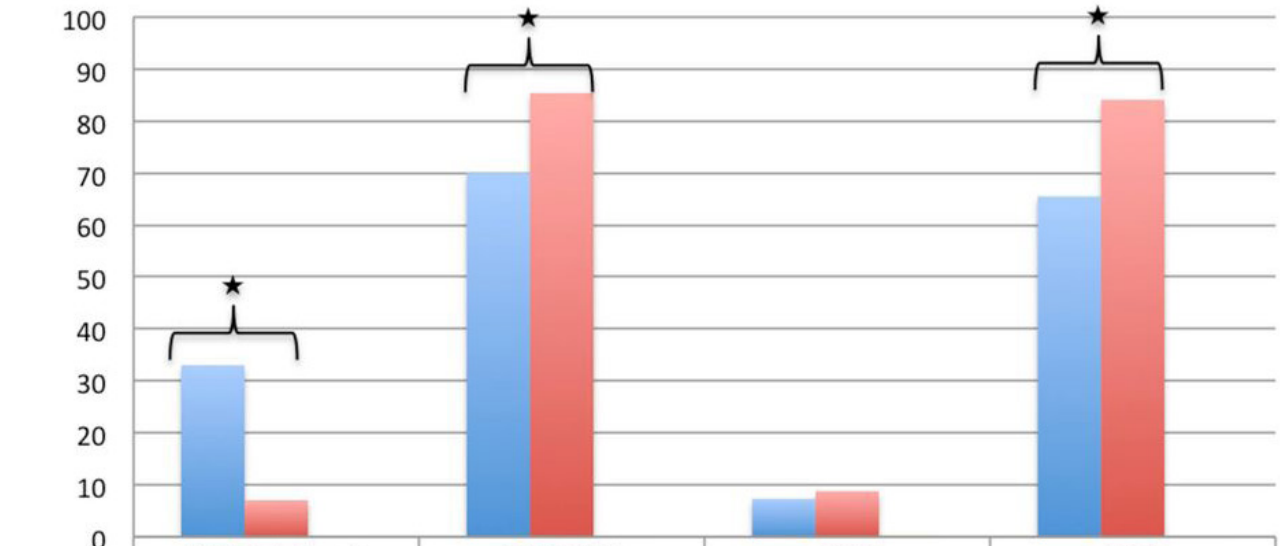
Surgical Complications and Revision Procedures

Eleven HA patients (11/36 = 31%) and four RSA patients (4/32 = 13%) experienced a complication (*P=0.087*) [Table 3]. In the HA group, five patients (5/36 = 14%) required conversion to RSA at an average of 6.9 months for recurrent RTC tear with or without instability, lesser tuberosity osteotomy failure, or continued pain. The most common complication in this group was failure of the lesser tuberosity osteotomy, which occurred in 7 patients (19%) [Figure 2].One RSA patient presented to clinic four weeks postoperatively with a fever and a swollen red arm. His prosthesis was found to be dislocated, and he received an open reduction, irrigation, and revision RSA. This was the only revision in the RSA group. The number of revision procedures was not significantly different between groups (*P=0.2*).

Discussion

While soft tissue and bony deficiency present unique challenges to surgical reconstruction, numerous procedures have been used to treat CTA with mixed results. Early experience with total shoulder arthroplasty was unsatisfactory, with a high prevalence of glenoid component loosening and failure due to eccentric loading (15-17). Several studies have reported generally favorable results with hemiarthroplasty (HA) for CTA (11, 18-22). Most patients in these series experienced significant pain relief, improved functional outcomes, modest gains in ROM, and a satisfactory outcome in 67-89% of cases (11, 14, 18-20, 22). However, competency of the coracoacromial arch was found to be crucial in maintaining stability of the prosthesis, and concerns regarding bony erosion of both the glenoid and acromion persisted (15, 18, 19).

More recently, reverse total shoulder arthroplasty (RSA) has been increasingly used to treat patients with CTA (15, 19, 23). The semi-constrained prosthesis medializes the center of rotation and increases the moment arm of the deltoid, bypassing the deficient rotator cuff (24). Many authors have reported significant pain relief, considerable increases in forward elevation, and improved functional outcomes with RSA for CTA (3, 4, 25-31). However, complication rates of up to 50% have



	VAS Pain (mm)	SANE (%)	SST	ASES
HA	33	70.1	7.3	65.5
RSA	7	85.4	8.8	84.1
p value	0.0004	0.017	0.309	0.003

Figure 1. Final postoperative functional outcome scores. *A significant value.

been reported along with inconsistent gains in external and internal rotation (4, 25, 31).

Few studies have directly compared HA and RSA for the treatment of CTA. Three retrospective comparisons reported significantly higher functional outcome scores in patients receiving RSA compared with HA (3, 9, 10). Both Favard et al. and Leung et. al reported significantly greater active forward elevation with RSA; improvement in external rotation was mixed, as one group noted better external rotation with RSA at 44 months and the other found an initial superiority of RSA with ER to diminish after two years (3, 9). Age was implicated as a potential confounding factor, with poorer functional scores reported in younger patients (9, 10). While RSA is significantly more expensive that HA, a Markov decision model examining health utility and cost of the two prostheses found RSA to be a cost-effective treatment option (32).

Despite these reports, it remains unclear whether RSA provides superior clinical results compared to HA in all situations. Goldberg et al. found preoperative motion to be a predictor of clinical outcomes of hemiarthroplasty (11). They reported significantly better functional outcomes and pain relief with HA in patients with preoperative elevation greater than 90° as compared

Table 3. Complications After HA or RSA for Cuff Tear Arthropathy

Patient No.	Index Procedure	Age at Surgery (yr)	Complication	Revision	Final FW (mos)	ROM (FE/ER/IR)	VAS Pain (of 100)	SANE (%)	SST (of 100)	ASES (of 100)
1	HA	57.8	Subscapularis rupture, Anterosuperior escape	RSA @ 8.9 months	42.8	85/0/buttock*	ø	ø	ø	ø
5	HA	54.9	Subscapularis rupture	No	7.8	140/45/buttock	-	-	-	-
6	HA	74.9	Anterosuperior escape	No	72.9	60/10/sacrum	30	50	16.7	48.3
8	HA	42	Subscapularis rupture, recurrent subluxation	No	12.2	75/55/L3	-	-	-	-
12	HA	68.6	Continued pain	RSA @ 7.4 months	60.1	90/40/T10*	10†	50†	58.3†	76.7†
18	HA	62.5	Recurrent supraspinatus tear, pain	RSA @ 5.5 months	7.7	120/40/buttock*	60†	60†	50†	40†
21	HA	74.9	LTO failure	No	3.5	40/70/0	-	-	-	-
24	HA	68.2	LTO failure	LTO ORIF @ 3.9 months; RSA @ 6.8 months	17.7	30/45/buttock*	50	-	-	-
31	HA	48.3	Anterosuperior escape, instability	No	39.6	90/40/L3	40	50	16.7	45
34	HA	74.3	LTO failure	RSA @ 5.9 months	7.3	-	-	-	-	-
36	HA	71.9	Anterosuperior escape	No	20.4	90/30/L5	50	50	8.3	41.7
Total	HA		11 Complications (31%)	5 Revisions (14%)						
37	RSA	78.2	Stress fracture of acromion, scapular spine	No	68.2	110/40/L2	0	-	41.7	-
48	RSA	82.5	Glenosphere displacement after fall	No	40.8	90/10/buttock	10	-	-	-
56	RSA	76.8	Infection, dislocation	Revision RSA @ 1 month	3.7	-	0	-	-	-
68	RSA	62.7	Painful os acromiale malunion	No	25.5	125/30/buttock	30	61	33.3	62.5
Total	RSA		4 Complications (13%)	1 Revision (3%)						

ASES, American Shoulder and Elbow Society score; HA, hemiarthroplasty; RSA, reverse shoulder arthroplasty; VAS, visual analog scale; SST, Simple Shoulder Test; SANE, Single Assessment Numeric Evaluation; ROM, range of motion; LTO, lesser tuberosity osteotomy; *ROM measurements of failed arthroplasty before revision; ø patient deceased; †Outcome scores from revision arthroplasty (RSA) at long-term follow-up.

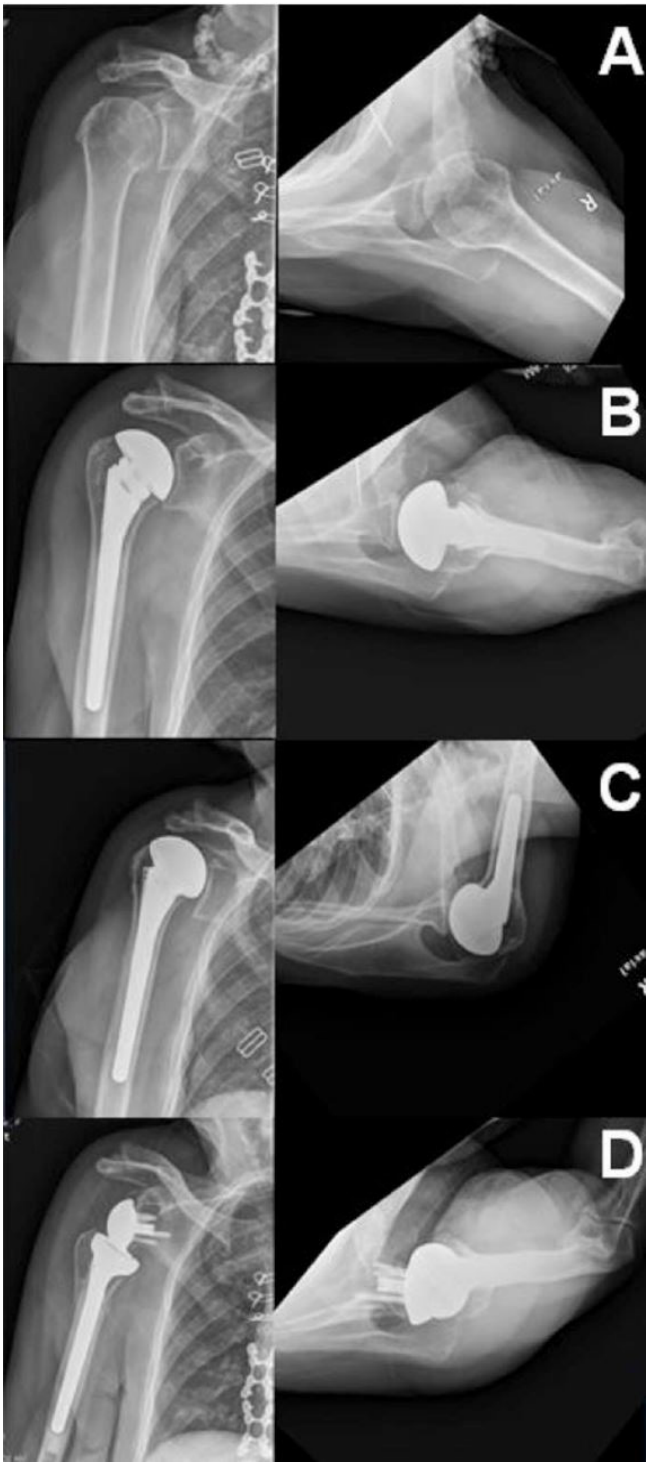


Figure 2. A – 74 F with CTA and preserved ROM (elevation: 150°, ER: 45° with 5° lag) who failed non-operative management. B – Postoperative radiographs after hemiarthroplasty with excellent pain relief at 2 weeks. C – Return at 6 weeks with clinical and radiographic failure of lesser tuberosity osteotomy. D – Radiographs following revision to reverse TSA, now pain free at early follow up.

with those who were unable to actively elevate the arm past horizontal. To our knowledge, our report is the first to specifically compare the benefits of RSA and HA in patients with CTA with preserved preoperative elevation greater than 90°. Our results have demonstrated significantly better forward elevation, pain relief, and functional outcomes with RSA without impairment in rotation compared with HA.

This study has several limitations. As a retrospective study, the HA and RSA groups were not randomized, and the implant choice was at the surgeons' discretion. Thus, apart from clinical presentation (i.e. CTA with preserved preoperative elevation), the two groups were not matched (the RSA patients were significantly older than the HA patients). Additionally, preoperative shoulder outcome data were not consistently available for comparison. Patients were treated by several different surgeons, without standardized diagnostic criteria for CTA, and there may have been variations in diagnosis and surgical technique. Finally, while all attempts at follow up were made, there were still a significant number of patients not available for final follow-up. This introduces the possibility of selection bias.

In patients with CTA and preserved preoperative forward elevation (>90°), reverse total shoulder arthroplasty provided greater pain relief, superior functional outcomes, and increased active elevation compared with hemiarthroplasty. While not statistically significant, there was a lower rate of complications (31% vs. 13%) and revisions (14% vs. 3%) in the RSA group compared to the HA group. Subscapularis failure was a frequent complication in patients with HA in this series, occurring in 19% of patients.

***Patient Consent*:** Informed consent from study participants was not needed due to the nature of the study. All

PHI was stripped from study data once the initial query was completed. Subsequently, patients were strictly referred to by an identification number.

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References

1. Kim SH, Wise BL, Zhang Y, Szabo RM. Increasing incidence of shoulder arthroplasty in the United States. J Bone Joint Surg Am. 2011; 93(24):2249-54.
2. Drake GN, O'Connor DP, Edwards TB. Indications for reverse total shoulder arthroplasty in rotator cuff disease. Clin Orthop Relat Res. 2010; 468(6):1526-33.
3. Favard L, Lautmann S, Sirveaux F, Oudet D, Kerjean Y, Huguet D. Hemiarthroplasty versus reverse arthroplasty in the treatment of osteoarthritis with massive rotator cuff tear. In: Walch G, Boileau P, Mole D, editors. 2000 shoulder prostheses. Two to ten year follow-up. Montepellier, France: Sauramps Medical; 2001. P. 261-8.
4. Nolan BM, Ankerson E, Wiater JM. Reverse total shoulder arthroplasty improves function in cuff tear arthropathy. Clin Orthop Relat Res. 2011; 469(9):2476-82.
5. Flurin PH, Marczuk Y, Janout M, Wright TW, Zuckerman J, Roche CP. Comparison of outcomes using anatomic and reverse total shoulder arthroplasty. Bull Hosp Jt Dis. 2013; 71)Suppl 2(:101-7.
6. Chalmers PN, Rahman Z, Romeo AA, Nicholson GP. Early dislocation after reverse total shoulder arthroplasty. J Shoulder Elbow Surg. 2014; 23(5):737-44.
7. Groh GI, Groh GM. Complications rates, reoperation rates, and the learning curve in reverse shoulder arthroplasty. J Shoulder Elbow Surg. 2014; 23(3): 388-94.
8. Roche CP, Stroud NJ, Martin BL, Steiler CA, Flurin PH, Wright TW, et al. The impact of scapular notching on reverse shoulder glenoid fixation. J Shoulder Elbow Surg. 2013; 22(7):963-70.
9. Leung B, Horodyski M, Struk AM, Wright TW. Functional outcome of hemiarthroplasty compared with reverse total shoulder arthroplasty in the treatment of rotator cuff tear arthropathy. J Shoulder Elbow Surg. 2012; 21(3):319-23.
10. Young SW, Zhu M, Walker CG, Poon PC. Comparison of functional outcomes of reverse shoulder arthroplasty with those of hemiarthroplasty in the treatment of cuff-tear arthropathy: a matched-pair analysis. J Bone Joint Surg Am. 2013; 95(10):910-5.
11. Goldberg SS, Bell JE, Kim HJ, Bak SF, Levine WN, Bigliani LU. Hemiarthroplasty for the rotator cuff-deficient shoulder. J Bone Joint Surg Am. 2008; 90(3):554-9.
12. 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(6):587-94.
13. L'Insalata JC, Warren RF, Cohen SB, Altchek DW, Peterson MG. A self-administered questionnaire for assessment of symptoms and function of the shoulder. J Bone Joint Surg Am. 1997; 79(5):738-48.
14. Williams GN, Gangel TJ, Arciero RA, Uhorchak JM, Taylor DC. Comparison of the single assessment numeric evaluation method and two shoulder rating scales. Outcomes measures after shoulder surgery. Am J Sports Med. 1999; 27(2):214-21.
15. Feeley BT, Gallo RA, Craig EV. Cuff tear arthropathy: current trends in diagnosis and surgical management. J Shoulder Elbow Surg. 2009; 18(3):484-94.
16. Franklin JL, Barrett WP, Jackins SE, Matsen FA 3rd. Glenoid loosening in total shoulder arthroplasty. Association with rotator cuff deficiency. J Arthroplasty. 1988; 3(1):39-46.
17. Matsen FA 3rd, Clinton J, Lynch J, Bertelsen A, Richardson ML. Glenoid component failure in total shoulder arthroplasty. J Bone Joint Surg Am. 2008; 90(4):885-96.
18. Field LD, Dines DM, Zabinski SJ, Warren RF. Hemiarthroplasty of the shoulder for rotator cuff arthropathy. J Shoulder Elbow Surg. 1997; 6(1):18-23.
19. 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(12):1814-22.
20. Visotsky JL, Basamania C, Seebauer L, Rockwood CA, Jensen KL. Cuff tear arthropathy: pathogenesis, classification, and algorithm for treatment. J Bone Joint Surg Am. 2004; 86(Suppl 2):35-40.
21. Williams GR Jr, Rockwood CA Jr. Hemiarthroplasty in rotator cuff-deficient shoulders. J Shoulder Elbow Surg. 1996; 5(5):362-7.
22. Zuckerman JD, Scott AJ, Gallagher MA. Hemiarthroplasty for cuff tear arthropathy. J Shoulder Elbow Surg. 2000; 9(3):169-72.
23. Ecklund KJ, Lee TQ, Tibone J, Gupta R. Rotator cuff tear arthropathy. J Am Acad Orthop Surg. 2007; 15(6):340-9.
24. Wiater JM, Fabing MH. Shoulder arthroplasty: prosthetic options and indications. J Am Acad Orthop Surg. 2009; 17(7):415-25.
25. 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(5):527-40.
26. Cuff D, Clark R, Pupello D, Frankle M. Reverse shoulder arthroplasty for the treatment of rotator cuff deficiency: a concise follow-up, at a minimum of five years, of a previous report. J Bone Joint Surg Am. 2012; 94(21):1996-2000.
27. 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(6):1244-51.
28. 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(8):1697-705.
29. Seebauer L, Walter W, Keyl W. Reverse total shoulder arthroplasty for the treatment of defect arthropathy. Oper Orthop Traumatol. 2005; 17(1):1-24.
30. 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(3):388-95.
31. 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(7):1476-86.
32. Coe MP, Greiwe RM, Joshi R, Snyder BM, Simpson L, Tosteson AN, et al. The cost-effectiveness of reverse total shoulder arthroplasty compared with hemiarthroplasty for rotator cuff tear arthropathy. J Shoulder Elbow Surg. 2012; 21(10):1278-88.