



Reverse shoulder arthroplasty has higher perioperative implant complications and transfusion rates than total shoulder arthroplasty

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Background: Indications for reverse total shoulder arthroplasty (RTSA) have expanded. The purpose of this retrospective cohort study was to evaluate national trends in shoulder arthroplasty utilization and to compare national perioperative complication rates for hemiarthroplasty (HA), total shoulder arthroplasty (TSA), and RTSA in a matched cohort.

Methods: The National Inpatient Sample was queried from 2011–2013 to identify patients who underwent HA, TSA, or RTSA. Age, sex, race, insurance type, Elixhauser comorbidity index, and perioperative complications were identified. A coarsened exact matching algorithm was used to match RTSA patients with TSA and HA patients to compare medical and implant-related perioperative in-hospital complications. Multivariable logistic regression analysis was performed on unmatched data to identify risk factors for development of perioperative complications.

Results: Overall, 42,832 shoulder arthroplasties were identified (44% TSAs, 34% RTSAs, 19% HAs). After matching, RTSAs had 6.2 times the odds of a perioperative implant-related complication ($P < .001$) and 2 times the odds of a red blood cell transfusion compared with TSAs ($P < .001$). The logistic regression model showed that prior shoulder arthroplasty (odds ratio [OR], 15.1; $P < .001$), younger age (OR, 0.98; $P = .006$), earlier year of index surgery (OR, 0.83; $P = .002$), history of illicit drug use (OR, 6.2; $P = .008$), and depression (OR, 2.3; $P = .003$) were risk factors for development of in-hospital implant-related complications after RTSA.

Conclusion: The perioperative implant-related complication rate and postoperative transfusion rate of RTSAs were significantly higher than those of TSAs. In addition, prior shoulder surgery, younger age, earlier year of index surgery, history of illicit drug use, and depression were risk factors for implant-related complications after RTSA. However, the perioperative RTSA implant-related complications did decline each year, suggesting a growing national proficiency with performing RTSA.

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The concept of reverse total shoulder arthroplasty (RTSA) was first explained by Grammont et al³² >25 years ago. During the past 2 decades, the RTSA has been used to treat a range of complex shoulder diseases, including total shoulder arthroplasty (TSA) and hemiarthroplasty (HA) implant failures, complex proximal humeral fractures, asymmetric glenoid wear, posterior humeral head subluxation in patients with intact rotator cuffs, and irreparable rotator cuff tears in the absence of arthritis.³⁶ However, several studies

The Boston University Medical Center Institutional Review Board reviewed and deemed this study not human subjects research.

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documented a steep learning curve with RTSA, reflecting the relative difficulty of the procedure because of its technically demanding nature, prosthesis design limitations, and iatrogenic morbidity.^{28,36} Compared with TSA, which has a complication rate of roughly 10%, there is a significant variation in the complication rates for RTSA ranging from 14% to 75%.^{5,26,29} The reported variation in the complication rates is concerning because of the expanding indications and substantial increase in RTSA utilization.²⁵ Prior reports of increased rates of complications in RTSA compared with TSA may not accurately reflect current complication rates for reasons such as the rapidly evolving RTSA surgical technique and implant design. The Grammont prosthesis underwent a complete evolution and now has an increased head-neck offset of 135° in certain manufacturers vs. the original 155° system that was

developed in 1987.²⁴ Patients undergoing RTSA also reportedly experience significantly longer hospital admissions and increased hospital costs independent of higher RTSA implant costs compared with TSA and HA patients.¹⁶

Understanding shoulder prosthesis utilization rates and associated complications is important for both surgeons and patients. No reports or published papers are available that use national data to compare the complication rates between the 3 types of shoulder arthroplasty over time. The goal of this study was to evaluate recent national trends in shoulder arthroplasty utilization and to compare national perioperative complication rates for HA, TSA, and RTSA in a matched cohort.

Methods

The National Inpatient Sample (NIS) was queried from 2011 through 2013 to identify patients who underwent HA, TSA, or RTSA. Before 2011, the reverse shoulder arthroplasty was coded the same as the TSA. However, after 2011, separate coding was established for RTSA, which has enabled direct comparisons of the 3 implant types. The NIS is the largest national database of all-payer inpatient discharge information, sampling approximately 20% of all nonfederal U.S. hospitals, and is composed of 9 million hospital admissions annually. Each NIS entry includes *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* diagnosis and procedure codes of activity during the patient's hospitalization at the time of discharge as well as patients' demographics, hospital characteristics, and duration of stay.

Analysis included patients undergoing shoulder arthroplasty procedures (ICD-9 procedural coding: 81.80, TSA; 81.81, partial shoulder arthroplasty; and 81.88, reverse shoulder arthroplasty). Procedure type, patient age, sex, race, insurance type, Elixhauser comorbidity index, and complications were identified. The primary outcome was medical and surgical complications occurring during the same hospitalization, with secondary analyses of mortality, discharge destination, and hospital charges. Perioperative medical complications included acute cardiac event, pulmonary edema, venous thromboembolic event, cerebrovascular event, acute kidney injury, pneumonia, sepsis, and urinary tract infection. Perioperative surgical complications included mechanical complications, wound disruption, hematoma formation, implant failure, fractures, blood transfusions, and any reported adverse surgical event. Adjusted odds ratios were calculated to assess the risk of medical and surgical complications and mortality comparing the 3 groups of shoulder arthroplasty (HA, TSA, and RTSA).

A secondary analysis was performed using the coarsened exact matching algorithm to match RTSA patients with TSA and HA patients on the basis of age, sex, race, insurance type, Elixhauser comorbidity index score, history of prior shoulder arthroplasty, procedure year, and hospital characteristics. Both perioperative and in-hospital complications of primary RTSAs were compared with those of TSAs and HAs, excluding proximal humerus fractures, malunions, and nonunions. Multivariable logistic regression analysis was performed to identify risk factors for perioperative complications.

Results

A total of 42,832 shoulder arthroplasties were identified in the NIS database (44% TSAs, 34% RTSAs, and 19% HAs). Patients who received RTSAs were significantly older than patients who received TSAs or HAs (72.6 years vs. 67.4 years and 66.4 years, respectively; $P < .001$) and significantly more likely to be female (63.6% RTSA vs. 50.7% TSA; $P < .001$).

After matching based on patient and hospital characteristics (Table I), RTSAs were found to have a perioperative implant-related complication rate 6.2 times that of anatomic TSAs²⁸ (95% confidence interval [CI], 4.23–9.21; $P < .001$) and 2 times the odds of a red blood cell transfusion compared with TSAs (odds ratio [OR], 2.0; CI, 1.7–2.3; $P < .001$; Table II). No significant differences were found in type of arthroplasty for perioperative medical complications, including cardiac, respiratory, and central nervous system. Furthermore, there were no significant differences found in terms of perioperative complications between RTSA and HA.

The logistic regression model found that prior shoulder arthroplasty (OR, 15.1; CI, 12.1–19.0; $P < .001$), younger age (OR, 0.98; CI, 0.97–0.99; $P = .006$), earlier year of surgery (OR, 0.83; CI, 0.74–0.93; $P = .002$), history of illicit drug use (OR, 6.2; CI, 1.6–24.3; $P = .008$), and depression (OR, 2.3; CI, 1.3–3.9; $P = .003$) were significant risk factors in predicting increased in-hospital implant-related complications after RTSA.

Discussion

RTSA was first described as a solution to treat older patients with rotator cuff tear arthropathy for which nonsurgical therapies had failed.³² The U.S. Food and Drug Administration approved the RTSA implant for use in December 2003 for elderly patients with a rotator cuff arthropathy indication. However, today it has gained further prominence for its use in the treatment of numerous shoulder conditions, which include but are not limited to complex proximal humerus fracture fixation, failed arthroplasty, irreparable rotator cuff tears in the absence of arthritis, Walch B2 glenoid morphology or significant posterior humeral head subluxation in the setting of intact rotator cuff and arthritis, and reconstruction of the proximal humerus after tumor resection.^{2,9} Even though RTSA has been performed in Europe for >20 years and in the United States for 14 years, substantial discrepancies exist in the literature on the reported complication rates after primary RTSA.^{3,9,14,33} RTSA complications include scapular notching, nerve compromise, prosthetic instability, acromial fractures, glenoid component loosening, and infection.¹¹ Nonetheless, the number of RTSAs performed each year is increasing. In the United States, according to the American Association of Orthopaedic Surgeons, >55,000–80,000 shoulder replacements are performed each year, and more than half of these are RTSA.¹⁶ An NIS database study found that RTSA represented 44% of all shoulder arthroplasties in 2011.³⁵ Kim et al²¹ argued that the increase in the number of shoulder arthroplasties performed in the United States has been driven by the Food and Drug Administration approval of the RTSA implant in 2003. Despite the higher rate of complications described in the implant's infancy during the early 2000s, recent studies have found that RTSA and TSA have similarly low complication rates, and patients report successful pain relief and regain of function postoperatively, with the exception of limited external range of motion among RTSA patients.²

In our study, we found 6.2 times the odds of perioperative mechanical complications and 2 times the odds of receiving red blood cell transfusions in patients undergoing RTSA compared with TSA. However, by comparison, we found no difference in perioperative medical complications between TSA, RSA, and HA after matching based on patient demographics, comorbidities, and hospital characteristics (Table I). In contrast, Westermann et al³⁵ reported that RTSA (27.4%) had a higher in-hospital morbidity and mortality compared with TSA (16.6%), with posthemorrhagic anemia and general surgical complications being the most common major complications. A major difference between this study and the study of Westermann et al³⁵ was that the latter did not control for patient comorbidities and hospital-related factors. Given that

Table I
Baseline patient and hospital characteristics after coarsened exact matching RTSA to TSA and RTSA to HA

Baseline characteristics	RTSA vs. TSA			RTSA vs. HA		
	RTSA (n = 7197)	TSA (n = 9000)	P value	RTSA (n = 5269)	HA (n = 2149)	P value
Age (yr)	72.9 (32-95)	72.9 (33-93)	.54*	73.4 (45-91)	73.4 (46-90)	.95*
Female	62.7	62.7	1	66.1	66.1	1
Race						
White	88.0	88.0	1	92.8	92.8	1
Black	2.0	2.0	1	0.8	0.8	1
Hispanic	1.4	1.4	1	0.6	0.6	1
Other/missing	8.5	8.5	1	5.9	5.9	1
Insurance type						
Medicare	85.2	85.2	1	88.0	88.0	1
Medicaid	0.3	0.3	1	0.2	0.2	1
Private insurance	12.5	12.5	1	10.4	10.4	1
Other/missing	1.9	1.9	1	1.4	1.4	1
Elixhauser comorbidity index score	1.0 (-9 to 20)	1.0 (-9 to 20)	.35*	0.9 (-8 to 20)	0.9 (-7 to 19)	.60*
Prior history of shoulder arthroplasty	2.6	2.6	1	0.5	0.5	1
Type of hospital						
Rural	9.4	9.4	1	8.4	8.4	1
Urban nonteaching	44.3	44.3	1	47.0	47.0	1
Urban teaching	46.4	46.4	1	44.6	44.6	1
Hospital region						
Northeast	11.8	11.8	1	11.3	11.3	1
Midwest	27.6	27.6	1	26.9	26.9	1
South	43.7	43.7	1	45.5	45.5	1
West	16.8	16.8	1	16.2	16.2	1

RTSA, reverse total shoulder arthroplasty; TSA, total shoulder arthroplasty; HA, hemiarthroplasty. Categorical variables are presented as percentage. Continuous variables are presented as mean (range). * Student *t*-test. All others with Pearson χ^2 test.

RTSA is performed in older patients, matching based on preoperative patient factors is necessary because older patients are likely to have more cardiovascular and respiratory comorbidities.

The perioperative implant-related complication rate of RTSAs was significantly higher than that of TSAs, even after excluding humeral shaft fractures and controlling for prior shoulder arthroplasty. Wierks et al³⁶ also determined that there was a higher rate and greater range of complications along with greater potential for technical pitfalls in RTSA compared with TSA. The majority of the perioperative implant-related complications are likely to be attributed to instability or dislocations after RTSA. Chalmers et al⁴ reported the dislocation rate at the Mayo Clinic from 2006 to 2013 as 1.1% (12/1081) in primary RTSA and 4.4% (15/342) in revision RTSA. The majority of the patients (69%) had the dislocation within 3 months of the index surgery. Treatment consisted of both closed reduction and operative management (open reduction with or without liner exchange), with higher success rates reported in

the operative group. Closed reduction in dislocated revision RTSA is rarely successful, and preoperative prosthetic instability was the main risk factor for chronic instability. Kohan et al²² also reported 22 dislocations after RTSA in their institution, with most occurring during the early postoperative period. They found two distinct causes: instability due to inadequate soft tissue tensioning or axillary nerve palsy and instability due to impingement or liner failure. Implant-related complications can be attributed to both implant design and the surgeon's learning curve. There is an inverse correlation between the number of RTSA procedures performed and perioperative complications, with reports identifying that the complication-based learning curve decreases after 10-40 cases.^{18,26,27} Given that the surgeon's experience is an independent risk factor for complications, we expect to see complications, especially dislocations and other perioperative implant-related complications, to decline on a national level over time as RTSA proficiency increases.²⁶

Table II
Comparison of in-hospital perioperative complications for matched RTSA vs. TSA and for matched RTSA vs. HA

Perioperative outcomes	RTSA vs. TSA			RTSA vs. HA		
	RTSA (n = 7197), %	TSA (n = 9000), %	OR (95% CI)	RTSA (n = 5269), %	HA (n = 2149), %	OR (95% CI)
Cardiac	0.38	0.43	0.87 (0.53-1.42)	0.42	0.42	1.00 (0.46-2.18)
Respiratory	0.53	0.56	0.95 (0.62-1.44)	0.55	0.31	1.79 (0.77-4.17)
Central nervous system	0.28	0.17	1.65 (0.85-3.23)	0.28	0.37	0.77 (0.33-1.82)
Gastrointestinal	0.21	0.15	0.74 (0.35-1.55)	0.09	0.15	0.61 (0.15-2.45)
Genitourinary	0.51	0.63	0.82 (0.54-1.24)	0.44	0.66	0.66 (0.34-1.27)
Wound dehiscence	0.06	0.02	3.16 (0.50-19.9)	0.06	0.08	0.72 (0.11-4.77)
Hematoma/seroma	0.29	0.22	1.30 (0.71-2.41)	0.27	0.59	0.45 (0.21-0.97)
Surgical site infection	0.03	0.02	1.16 (0.17-7.92)	0.02	0.03	0.64 (0.03-14.6)
Mechanical complication	2.10	0.34	6.24 (4.23-9.21)*	1.44	1.66	0.86 (0.58-1.29)
Blood transfusion	6.78	3.48	2.01 (1.74-2.33)*	6.60	7.15	0.92 (0.75-1.11)
Deep venous thrombosis	0.11	0.11	1.00 (0.39-2.54)	0.13	0.30	0.41 (0.08-2.03)
Pulmonary embolism	0.14	0.08	1.84 (0.69-4.86)	0.15	0.38	0.40 (0.15-1.06)
Mortality	0.06	0.11	0.51 (0.16-1.64)	0	0	1.00 (1.00-1.00)

RTSA, reverse total shoulder arthroplasty; TSA, total shoulder arthroplasty; HA, hemiarthroplasty; OR, odds ratio; CI, confidence interval. * *P* < .001.

Nerve injury is one of the implant design-related complications. This is due to the relative proximity of major nerves to the working space for RTSA implant placement.¹⁷ Using a cadaveric model, Leschinger et al²³ found that the axillary nerve was only 13.6 mm from the inferior glenoid rim on average, whereas the suprascapular nerve was only 10.8 mm from the glenoid center in the anteroposterior direction. Nerve injury, either transient or permanent, can also be related to stretching in retractor placement during glenoid exposure for glenosphere placement. Screw length and screw positioning, especially for the superior and posterior screws, are also related to an increased risk of suprascapular nerve injury.²³ Injury to the axillary nerve can result in deltoid atony with soft tissue tensioning issues that may lead to dislocations and contribute to the increased perioperative implant-related complications seen with RTSA.

Fracture is another technical pitfall that may be due to RTSA biomechanical design and poor bone quality. Implant-related fractures during the perioperative period can be due to the stress from the superior screw placement on the top of the metaglene, which may cause a type III scapular spine fracture.^{6,19,23,31} The incidence of scapular fractures due to RTSA ranges from 0.8% to 10.2%.^{6,19,31} Post-RTSA scapular fracture can also be related to minor upper extremity trauma, such as falling onto an outstretched hand or acromial stress fracture.¹⁸ A cohort study by Frankle et al¹² that observed 60 RTSA patients during a span of 2 years found that in spite of overall improvements in average American Shoulder and Elbow Surgeons score, pain score, and function, 13 patients (17%) developed non-surgery-related acromial fractures. Aseptic loosening is another mechanical complication that mostly occurs on the humeral side but can occur on the glenoid side as well.² Humeral loosening has been reported among modular components and can be related to inadequate fixation from proximal humeral bone loss.^{3,7} Glenoid loosening is a rare complication that is typically related to technical errors, such as glenoid placement with excessive superior inclination.^{2,15}

In our logistic regression model, we found that prior shoulder arthroplasty, younger age, earlier year of index surgery, history of illicit drug use, and depression were significant factors in predicting increased in-hospital implant-related complications after RTSA. Given the complexities of revision arthroplasty in patients with RTSA, it is expected that this cohort will have higher risk for complications. In addition, younger age or earlier year of surgery may be related to traumatic injuries or fractures as indications for the reverse, which can also lead to higher perioperative risks. There is a paucity of data in the literature regarding history of illicit drug use and complications after shoulder arthroplasty. Werner et al³⁴ reported that a preoperative diagnosis of depression is an independent predictor of less overall improvement in the American Shoulder and Elbow Surgeons score after TSA, but the difference did not reach clinical significance, and perioperative complications were similar to those of patients without depression.

Another complication identified in this study is that patients undergoing RTSA had 2 times the odds of needing a red blood cell transfusion than those undergoing TSA with a matched cohort. Prior studies have found that the need for red blood cell transfusion after shoulder replacement is associated with increased age, low preoperative hemoglobin level, and postoperative anemia. Gruson et al¹³ found that for every 5-year age increase, the risk of transfusion after shoulder arthroplasty increased by 32%. Furthermore, they found that patients older than 65 years had a 3-fold increase in transfusion risk, and those undergoing reverse shoulder replacement were at a higher risk of transfusion compared with the standard HA or TSA.¹³ Similarly, Slover et al³⁰ found that patients ≥ 80 years of age had 3 times the odds of needing a blood transfusion compared with younger patients after total joint

arthroplasty. It is thought that elderly patients are at a greater risk for red blood cell transfusions because of baseline preoperative anemia due to numerous causes more commonly occurring in the elderly, such as nutritional deficiencies, inflammatory diseases, renal failure, and myelodysplastic syndromes.^{1,8} Where possible, it is important to manage these risk factors for anemia preoperatively to reduce risk of blood transfusion and complications in the post-operative period.

Although we matched on the basis of age in our study, the increased need for blood transfusions could be due to closed suction drainage, which is commonly used in RTSA procedures to decrease swelling, hematoma formation, and the number of dressing changes. The use of drains in total joint arthroplasty has been heavily examined in hip and knee replacements; however, there is a paucity of literature examining effects of drains in shoulder arthroplasty. A study by Erickson et al¹⁰ compared patients who underwent TSA and RTSA with and without a closed suction drain, finding that patients who received closed suction had a greater hemoglobin loss. However, the authors did not compare the extent of blood loss between TSA and RTSA. Because of the increased risk of blood transfusion and possible infection within the perioperative period, closed suction drainage recently has fallen out of favor at many academic institutions.

After controlling for patient demographics, comorbidities, and hospital characteristics, we found no difference in perioperative medical complications, such as cardiac, respiratory, and central nervous system complications (Table II), between the 3 arthroplasty groups. This is the only study that has evaluated perioperative complications within 30 days, and we found that the rate of medical perioperative complications was similar across RTSA, TSA, and HA with no significant difference. A previous study found that after 2-years of follow-up, RTSA and TSA have similar medical complication rates.²⁰ We found no difference in perioperative medical complications for RTSA and TSA, which signifies that the same surgical care applies to both procedures.

There are several limitations in this study. Like other NIS database studies, there is a lack of postdischarge data. Nonetheless, these data are significant because they include information collected from >7 million hospital visits across 44 states, which creates a snapshot of shoulder arthroplasty performed on a national scale. However, like other database studies, data from numerous clinical sites may lead to differences in data quality. Furthermore, this database does not consider differences in surgical experience or technique, implant design, or perioperative protocols, all of which can affect the results of this study. Information such as the operative time and the amount of blood loss and details of the operative procedure, such as use of a drain, are not available through this database. We also cannot infer causation to the high rate of red blood cell transfusion in RTSA procedures, which could be a consequence of fracture or multitrauma. Also, a specific ICD-9 procedural code differentiating between RTSA and TSA was not created until October 2010; therefore, data before this coding separation were not included in this study and analysis. This study is unique because we were able to differentiate between primary and revision arthroplasty compared with previously published database studies.

Conclusion

According to our results, RTSA patients showed 6.2 times the odds of perioperative implant-related complications and 2 times the odds of needing a red blood cell transfusion compared with TSA patients. Prior shoulder arthroplasty, younger age, earlier year of surgery, history of illicit drug use, and depression were significant factors in predicting increased in-hospital implant-related

complications after RTSA. Even though the complication rates decreased over time, it is essential to identify the underlying reasons for the increased perioperative mechanical complications and blood transfusion rate between RTSA and TSA to better optimize patients before surgery. It is also necessary to counsel patients in the preoperative setting about the possibility of RTSA implant-related complications that might occur in the postoperative period.

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