

REVERSE SHOULDER ARTHROPLASTY IN THE UNITED STATES: A COMPARISON OF NATIONAL VOLUME, PATIENT DEMOGRAPHICS, COMPLICATIONS, AND SURGICAL INDICATIONS

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ABSTRACT

Background: Shoulder arthroplasty is increasing in the United States. Reverse shoulder arthroplasty (RSA) has emerged as an alternative treatment for end-stage glenohumeral pathology. Until recently, administrative coding practices have not differentiated RSA from traditional total shoulder arthroplasty (TSA), and thus national procedural volume has been unknown. The purpose of this study was to define the utilization, patient characteristics, indications and complications for RSA, and contrast these to TSA and hemiarthroplasty (HA).

Methods: The 2011 Nationwide Inpatient Sample (HCUP-NIS) dataset was queried using ICD-9-CM codes to identify patients undergoing RSA, TSA, or HA. We used weighted estimates of national procedure volume, per-capita utilization, patient comorbidities, and inpatient complications defined by the Agency for Healthcare Research and Quality (AHRQ) and identified them using standard methods described by Elixhauser. ANOVA statistical analysis was used and significance was defined as p value <0.05 .

Results: In 2011, 66,485 patients underwent shoulder arthroplasty; there were 21,692 cases of RSA, 29,359 of TSA, and 15,434 of HA. Utilization of RSA and TSA increased between 2002-2011,

and decreased for HA. RSA patients were older (72.7 years vs 67.4 TSA vs 66.8 HA) and more commonly female. Comorbidity burden was highest in patients undergoing HA. Inpatient complications were highest after RSA ($p < 0.001$). When compared to TSA, RSA was more commonly used in the setting of rotator cuff disease, and post-traumatic sequelae ($p < 0.001$).

Conclusions: Our findings represent the first national estimates of RSA within the United States. RSA is a significant contributor to increasing shoulder arthroplasty utilization nationally representing one-third of arthroplasty cases. Conditions traditionally managed with HA in older populations appear to now be more commonly managed with RSA. RSA is performed on older patients with expanded indications.

INTRODUCTION

For decades, total shoulder arthroplasty (TSA) has been the gold-standard treatment for end stage arthritis of the glenohumeral joint. In appropriate patients, the efficacy of TSA provides long-term survival and satisfaction rates exceeding 86-95%^{1,2}. However, TSA in patients with concomitant rotator cuff pathology has been associated with early failure due to high rates of glenoid loosening. Thus, these patients were traditionally offered hemiarthroplasty or humeral head resurfacing³. Recently, however, reverse shoulder arthroplasty (RSA) has emerged as an alternative surgical option.

RSA provides a mechanical advantage for shoulder elevation in patients with rotator cuff disease⁴. Early RSA designs suffered catastrophic failures from glenoid loosening⁵. Modern designs, however, have shown improved results⁶, and RSA survival rates have exceeded 85% at 10 years^{7,8}. In November of 2003, the Food and Drug Administration (FDA) approved RSA arthroplasty in the United States. Since that time, RSA has been popularized for addressing a wide variety of shoulder conditions; these include glenohumeral arthritis, rotator cuff arthropathy, failed conventional total shoulder arthroplasty, fracture sequelae, rheumatoid arthritis with irreparable rotator cuff tears, proximal humerus tumors and proximal humerus fractures⁹⁻¹⁶.

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Ethical Review Statement: This article is IRB exempt and was HIPAA compliant

Disclaimer: The study examined inpatient admissions using the National Inpatient Sample (NIS), Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality. The HCUP and the hospitals participating in the NIS Program are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

The volume of shoulder arthroplasty has been increasing since the early 1990's^{9,18,20}. From 1990 to 2004 previous studies describe steadily increasing rates of TSA^{18,19}, outpaced only by the sharply increasing rates of hip and knee arthroplasty²⁰. However, since FDA approval, the overall volume of shoulder arthroplasty has accelerated^{18,20}. An aging population, improved implant designs, and broader indications have all been implicated for increasing volume and utilization¹⁸. Some postulate that RSA has also been the driver of these volume increases¹⁸. Until 2011, TSA and RSA were coded identically in administrative claims databases; both shared the International Classification of Disease, Ninth Revision (ICD-9) code, 81.80. Delineating United States (US) national volume of each has not been previously possible, and only small, single-institution, case series exist^{11,21}.

Given the paucity of epidemiological data, the purpose of this study was to define the national utilization, patient characteristics and indications, and inpatient complications of patients undergoing RSA in the US using the well-established Nationwide Inpatient Sample (NIS) database. A secondary goal was to compare these findings to patients undergoing TSA and hemiarthroplasty.

PATIENTS AND METHODS

This is a multicenter observational epidemiologic study of prospectively collected data of primary total shoulder arthroplasties conducted in the United States in 2011. This study was exempt from IRB approval.

Data Source

The Nationwide Inpatient Sample (NIS) NIS is the largest national all payer database for inpatient hospital stays²². First published in 1988, it has subsequently been updated annually, up to 2011. As of 2011, the NIS captured data from 46 states, covering 97% of the U.S. population. All non-Federal, short-term, general, and specialty hospitals in the U.S. are eligible for inclusion, including long-term care facilities. Participating hospitals are stratified according to size and geographic location. Within each strata, the NIS approximates a randomly generated 20% sample of all discharges. A multiplier unique to each strata is then applied in order to provide national estimates for a given data point. In 2011, the NIS captured over 8 million discharges, and the multipliers were used to provide weighted averages for an estimated 38.5 million inpatient stays. The estimated data points include over 100 variables, encompassing patient demographic, medical comorbidities, and morbidity outcomes, as well as hospital characteristics and financial information. Notably, the database includes only in-hospital events. Events that occur after a patient's discharge or during subsequent admissions are not linked.

Participants, Sample Size & Interventions

We included all patients from the 2011 NIS database with an ICD-9-CM procedure code (International Classification of Diseases, Ninth Revision, Clinical Modification) for primary shoulder arthroplasty (either HA: 81.81; TSA: 81.80; or RSA: 81.88). Patients younger than 40 years or older than 95 years were excluded. Revision shoulder arthroplasty cases were excluded (ICD-9 codes 996.4x, 996.66, and 996.77). Prior to 2011, RSA and TSA shared a common code (81.80), but for the first time in 2011 RSA was given a unique identifier (81.88). Thus, 2011 is the first year in which these procedures could be distinguished. Ultimately, 66,485 procedures were identified. The FDA did not approve RSA for use in the United States until 2003¹⁸. Thus, in order to provide a comparison with procedure volume and patient characteristics prior to the introduction of RSA, we included a mirrored cohort from the 2002 NIS database, consisting of 24,677 patients, using the same selection criteria. US census data of population estimates by age was used to estimate the number of persons in the US age 40-95 in 2002 and 2011^{23,24}.

Indications and Comorbidities

Indications were identified by querying the primary ICD-9-CM code for incidences of osteoarthritis (715.xx), proximal humerus fracture (812.0x), proximal humerus nonunion/malunion (733.8x), aseptic necrosis (733.41), rotator cuff tear arthropathy (716.91), disorders of shoulder bursae and tendons (726.10), rheumatoid arthritis (714.0x), partial (726.1x) or massive (727.6x) rotator cuff tears. Patient comorbidities were identified from a query of the secondary ICD-9-CM codes, and included chronic respiratory insufficiency (518.83), anemia (280.x, 281.x, 282.x, 283.x, 284.x), asthma (493.x), diabetes mellitus (250.x, 249.x), obstructive sleep apnea (327.23), obesity (278.01), overweight (278.02), coagulopathy (286.x), atrial fibrillation (427.31) or tobacco use disorder (305.1).

In-Hospital Complications

We identified in-hospital procedure related complications by searching for any ICD-9 code specifying a complication of surgical care (ICD-9-CM: 996.x to 999.x). In addition, we evaluated several specific adverse diagnoses, including in hospital mortality from surgical causes (995.4, 968.4, 348.8, 798.2, 798.1, 798.9), spinal cord or nerve injury (952-956), venous thrombosis (453.4), respiratory distress following surgery (518.5), and acute post hemorrhagic anemia (285.1). All indications, comorbidities and complications within the dataset are reliant on medical documentation and in-hospital coding practices.

Table I: Demographics and Comorbidities of patients undergoing RSA (Reverse Shoulder Arthroplasty), TSA (Total Shoulder Arthroplasty), and HA (Hemiarthroplasty) within the US in 2011.

	RSA	TSA	HA	p
Mean Patient Age (years)	72.71	67.44	66.84	<0.0001
Female Sex (%)	63.86	50.65	62.48	<0.0001
Race (%)				0.001
Black	4.75	4.73	4.77	
White	89.36	89.66	87.28	
Other	5.9	5.6	7.95	
Type of Insurance (%)				<0.0001
Private	14.96	31.28	28.42	
Medicaid	1.45	1.79	4.25	
Other	83.59	66.94	67.33	
Comorbidities				
Chronic Respiratory Insufficiency (%)	0.13	0.07	0.4	0.0005
Chronic Anemia (%)	2.77	2.35	4.36	<0.0001
Asthma (%)	8.95	9.11	8.72	0.8215
Diabetes Mellitus (%)	21.32	19.39	22.16	0.0033
Obstructive Sleep Apnea (%)	7.27	9.32	6.66	<0.0001
Obesity (%)	11.69	14.97	13.09	<0.0001
Overweight (%)	0.22	0.26	0.47	0.1253
Coagulopathy (%)	0.27	0.25	0.36	0.6668
Atrial fibrillation (%)	8.81	5.15	7.07	<0.0001
Tobacco use disorder (%)	6.32	7.24	10.33	<0.0001
Any Comorbidity (%)	47.52	47.13	51.20	<0.0001

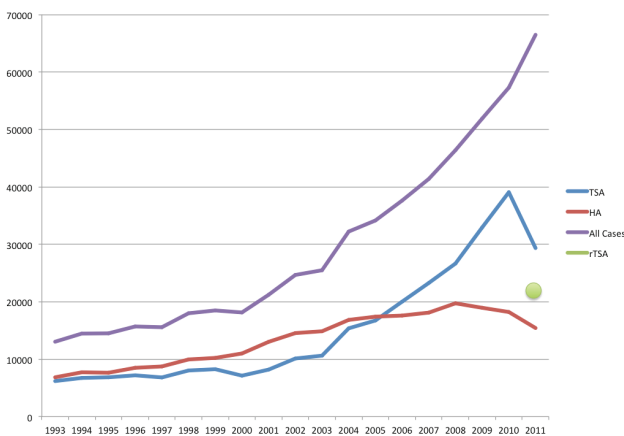


Figure I: Trends in shoulder arthroplasty within the US 1993-2011. This data was obtained from the NIS-HCUP database for HA: 81.81; TSA: 81.80; or RSA: 81.88.

Statistical Analysis

All data was analyzed with SAS (Version 9.3; SAS Institute, Cary, NC). Analysis of variance (ANOVA) statistical analysis was used to identify differences across groups and significance was defined as p value <0.05.

Source of Funding

There was no external source of funding for this study.

RESULTS

Volume & Utilization

In 2002, 24,677 patients underwent primary shoulder arthroplasty, of which 10,125 (41%) were TSA and 14,552 (59%) were HA. In 2011, 66,485 patients underwent shoulder arthroplasty procedures, of which 21,692 (32.6%) were RSA, 29,359 (44%) were TSA, and 15,434 (23%) were HA [Figures 1 & 2]. Between 2002 and 2011, the US population between the ages of 40-95 increased by 21.37% (100,637,078 in 2002 versus 122,142,979 in 2011)^{23,24}. The per-capita utilization of shoulder arthroplasty increased from 24.5 arthroplasties per 100,000 population in 2002 to 54.4 arthroplasties per 100,000 population in 2011. The utilization of HA during this same period decreased from 14.5 arthroplasties per 100,000 population in 2002 to 12.6 arthroplasties per 100,000 population in 2011. The utilization of TSA increased from 14.5 per 100,000 population in 2002 to 24.0 arthroplasties per 100,000 population in 2011. The utilization of RSA for patients between the ages of 40-95 in 2011 was 17.8 arthroplasties per 100,000 population.

Demographics

The mean age of patients undergoing RSA in 2011 was 72.71 years. This is significantly higher than that of patients undergoing TSA (67.44 years) or HA (66.84

Table II: In-hospital morbidity and mortality in patients undergoing shoulder arthroplasty in 2011 for RSA (Reverse Shoulder Arthroplasty), TSA (Total Shoulder Arthroplasty), and HA (Hemiarthroplasty).

	RSA	TSA	HA	p
Incidence of Any Morbidity or Mortality (%)	27.38	16.64	23.96	<0.0001
Mortality (%)	0.2	0.04	0.26	0.0137
Neurologic Injury (%)	0.17	0.11	0.4	0.012
Venous Thrombosis (%)	0.19	0.05	0.15	0.0797
Acute Respiratory Distress (%)	1.19	0.43	1.07	<0.0001
Post-hemorrhagic Anemia (%)	16.73	9.75	15.77	<0.0001
General Complications of Surgical Care (%)	7.54	3.56	6.11	<0.0001
Paralytic Ileus (%)	0.24	0.23	0.31	0.7586
Post-Operative Hypotension (%)	2.17	1.18	0.96	<0.0001
Hypovolemia (%)	0.37	0.21	0.26	0.3358

Table III: Indications for patients undergoing shoulder arthroplasty in 2011; RSA (Reverse Shoulder Arthroplasty), TSA (Total Shoulder Arthroplasty), and HA (Hemiarthroplasty).

(ICD-9-CM) Primary Diagnosis	RSA	TSA	HA	p
(715.xx) Osteoarthritis and allied disorders	43.67	88.63	40.51	<0.0001
(812.0x) Fracture of proximal end of humerus, closed	9.36	0.99	35.19	<0.0001
(73341) Aseptic necrosis of head of humerus	0.98	1.9	6.46	<0.0001
(716.91) Unspecified arthropathy shoulder (cuff tear arthropathy)	11.83	3.58	2.37	<0.0001
(726.10) Disorders of bursae and tendons in shoulder	14.03	0.54	1.86	<0.0001
(733.8x) Nonunion or Malunion	3.27	0.39	3.17	<0.0001
(714.0) Rheumatoid arthritis	1	0.95	0.48	0.0311
(726.1x) Partial RTC Tear	0.12	0.06	0	na
(727.6x) Massive RTC Tear	2.55	0.16	0.23	<0.0001

years) ($p < 0.001$) [Table I]. Patients of white race were less likely to undergo HA ($p = 0.001$) [Table I]. Patients with Medicaid insurance were more likely to undergo HA ($p < 0.001$) [Table I]. The presence of certain patient comorbidities varied between the three procedures. Patients undergoing RSA were more likely to carry a diagnosis of atrial fibrillation ($p < 0.001$) and chronic respiratory insufficiency ($p < 0.001$). Chronic anemia, diabetes mellitus, and tobacco use disorder were more common in HA cases ($p < 0.001$). Patients undergoing TSA were more commonly diagnosed with obstructive sleep apnea or obesity ($p < 0.001$) [Table I]. When comorbid conditions were pooled, patients undergoing HA were significantly more comorbid ($p < 0.001$).

Indications

Osteoarthritis (OA) was the primary indication for 88.63% of TSA cases in 2011. This was significantly higher than the percentage of patients who underwent RSA (43.67%) or HA (40.51%) ($p < 0.001$) [Table III]. 35.19% of HA cases were performed for proximal humerus fractures compared to 9.36% of RSA and 0.99% of TSA cases

($p < 0.001$). Similarly, posttraumatic sequelae including nonunion or malunion were more commonly indicated in RSA and HA ($p < 0.001$). RSA was performed more often for rotator cuff arthropathy, or shoulder bursa and tendon disorders ($p < 0.001$) [Table III]. The mean age of patients who underwent RSA was significantly higher than TSA or HA for the indications of osteoarthritis, proximal humerus fractures, aseptic necrosis and rotator cuff tear arthropathy ($p < 0.001$).

In-Hospital Complications

The incidence of any in-hospital morbidity or mortality was higher in RSA (27.38%) compared to TSA (16.64%) or HA (23.96%) ($p < 0.001$) [Table II]. The incidence of in-hospital mortality was higher in RSA (0.2%) and HA (0.26%) when compared to TSA (0.04%) ($p = 0.014$). Acute respiratory distress ($p < 0.001$), post-hemorrhagic anemia ($p < 0.001$), general complications of surgical care ($p < 0.001$), post-operative hypotension ($p < 0.001$) and pulmonary embolism ($p = 0.019$) were more common in RSA [Table II].

DISCUSSION

Reverse total shoulder arthroplasty has emerged as an alternative to TSA and HA with rapid acceptance in the United States over the past decade. Previously, the national volume of RSA in the United States has been largely unknown. Changes in administrative coding practices in 2011 have allowed for separation of RSA and TSA procedures. In this study, we have analyzed patient data from 66,485 total shoulder arthroplasties queried from a national discharge database. Relative to the growth of TSA over the last decade, RSA volume represents a significant portion. The patient demographics, inpatient complications, and indications of patients undergoing RSA and TSA also differ significantly. Several of these findings merit further discussion.

This study has several limitations. First, indications and comorbidities within the dataset are reliant on medical documentation and in-hospital coding practices. Secondly, short term and long-term patient outcomes after discharge are not available in the NIS-HCUP database as all data is collected prior to discharge; we are therefore unable to address differences in certain complications including infections and dislocations that more commonly occur after discharge. Third, the data presented represents hospital discharged from a single year; only one year of complete data (2011) presently exists that distinguishes RSA and conventional TSA. Also, due to the size of data collection the NIS-HCUP database, availability of comprehensive data is generally delayed two years. Last, this study is limited to the population in the United States.

Since the FDA approval of RSA in 2003, overall shoulder arthroplasty volume has been sharply increasing^{18,20}. Between 2002 and 2011, the utilization of shoulder arthroplasty more than doubled. The utilization of conventional TSA increased by 66% between 2002 and 2011. While use of RSA was limited prior to 2003, RSA comprised one-third of all shoulder arthroplasty cases in 2011. RSA, therefore, may be a principle factor driving the increased utilization of shoulder arthroplasty. Our study is the first to report decreasing rates of hemiarthroplasty on a national level. Rates of hemiarthroplasty had been previously reported to be steadily increasing between 1990 and 2004^{18,20}. Between 2002 and 2011, the utilization of hemiarthroplasty decreased by 12.5%. We believe the growing acceptance of RSA may be contributing to coincidentally declining HA volumes. Patient populations, especially the elderly, who were previously HA candidates may now be better treated with RSA²⁵.

Our findings also demonstrate significant differences in patient characteristics between patients undergoing RSA, TSA, and HA. Previous reports suggest RSA should be reserved for elderly patient (>70 years old)

with low functional demands^{8,17}. The mean age of patients undergoing RSA in the US in 2011 was 72.71 years. This was significantly higher than patients undergoing TSA or HA. Then mean ages of patients who underwent shoulder arthroplasty in our cohort are comparable to previous reports^{18,26,27}. The United States has an aging population²⁸. The RSA is ideal for low demand, elderly patients who previously may not have been candidates for HA or TSA. In our series, RSA was more commonly performed in females (63.86%), however this was not true for TSA (50.65%) $p < 0.001$ and this is consistent with previous reports¹¹.

Our findings demonstrate varying indications between RSA, TSA, and HA. In general, RSA carried a wider array of indications when compared to TSA and HA. RSA's are more commonly performed in the setting of rotator cuff associated conditions due to mechanical advantages of implant design^{29,30}. Our data suggests 28.5% of patients underwent RSA with a primary diagnosis of rotator cuff disease. In 2007, Wall et al. reported good outcomes for patients undergoing RSA for massive rotator cuff tears, primary rotator cuff arthropathy, and osteoarthritis¹¹. These indications represent of approximately 72.2% of the volume of RSA observed in the 2011. In addition, RSA has been described for treatment of proximal humerus fractures^{4,15,31}. Prosthetic replacement of the proximal humerus may be appealing in certain fracture patterns where the incidence of avascular necrosis of the humeral head is high with open reduction and internal fixation; also, tuberosity resorption is common in hemiarthroplasty. In 2011, surgeons in the US were 7-times more likely to choose RSA over a conventional TSA for prosthetic treatment of a proximal humerus fractures. HA remains the most common shoulder arthroplasty option for management of proximal humerus fractures (5,402 cases). Furthermore, surgeons were more likely to choose RSA or HA to address posttraumatic sequelae after proximal humerus fractures (malunion or nonunion). Therefore broad indications for RSA in the 2011 cohort may be due in part to an aging population, and relatively increased utilization in the setting of rotator cuff disease, fracture and post-traumatic sequelae.

Reports of complications after reverse total shoulder arthroplasty vary greatly^{8,11,17,21,27}. According to our findings, RSA was associated with higher rates of in-hospital complications overall. Approximately half of these complications were post-operative anemia. In-patient peri-operative mortality was nearly five times higher after RSA and HA compared with TSA (0.2%, 0.26% versus 0.04%, $p = 0.014$). Previous reports indicate that in-hospital morbidity and mortality is highly dependent on patient comorbidities in arthroplasty populations³². Also, patient age has been well established as an independent risk fac-

tor for complications in the acute perioperative period³³. Patients undergoing RSA were found to be significantly older than those undergoing TSA or HA (72.71 versus 67.44 and 66.84 years, $p < 0.001$). As we did not control for patient factors, we are unable to tell if the true incidence of complications differs between groups.

Our findings represent the first national estimates of RSA within the United States. The national volume of RSA was 21,692 cases in 2011. Overall, the volume of shoulder arthroplasty in the US continues to rise; a phenomenon driven, likely in part, by the expanding use of RSA. Conditions traditionally managed with HA in older populations appear to now be more commonly managed with RSA. Importantly, patients undergoing RSA and TSA differ significantly in their demographics, comorbidities, surgical indications and inpatient complications. Given the burden of shoulder disease within the United States, this data will help define a baseline for studying the role of RSA. Future epidemiological studies should continue analyzing the temporal trends of shoulder arthroplasty.

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