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Volume, indications, and number of surgeons performing reverse total shoulder arthroplasty continue to expand: a nationwide cohort analysis from 2016-2020

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Background: Since its approval, reverse total shoulder arthroplasty (rTSA) has continued to increase in usage, with expanding indications beyond rotator cuff arthropathy. Existing literature has captured further increased utilization over the last decade through 2017. However, this data has not been updated to include a contemporary cohort of patients. This study sought to determine the trends of anatomic total shoulder arthroplasty (aTSA), rTSA, and hemiarthroplasty (HA) usage based on primary diagnosis and total number of surgeons performing each procedure annually from 2016-2020.

Methods: Patients who underwent primary rTSA, aTSA, and HA from 2016-2020 were identified in the Premier Healthcare Database. Primary indication diagnoses for procedures were identified using International Classification of Diseases 10th edition codes. Temporal trends in patient and hospital demographics, primary indication, and procedure utilization were captured on an annualized basis. The number of surgeons performing each procedure annually was noted. Descriptive statistics were employed with significance set at $P < .05$.

Results: From 2016 to 2020, 154,499 patients undergoing primary shoulder arthroplasty were identified: 48,890 aTSA, 95,808 rTSA, and 9801 HA. In 2016, rTSA comprised a slight majority (55%) of all arthroplasty cases but increased to nearly 70% of all arthroplasty cases in 2020. The absolute numbers of aTSA and HA cases decreased over time, while rTSA volume increased from 14,781 in 2016 to a high of 23,644 cases in 2019. There was a corresponding 12% increase in the number of surgeons performing rTSA across the same time period, contrasted with a 42.1% decrease in surgeons performing HA and a 14.3% decrease for aTSA. Glenohumeral osteoarthritis remains the most common indication for rTSA and aTSA, while HA is used primarily for proximal humerus fractures or hardware complications.

Conclusion: The volume of primary rTSA in the United States has continued to increase from 2016 to 2020 with concurrent decreases in the number of primary aTSA and HA cases performed. Primary rTSA accounts for nearly 70% of all primary shoulder arthroplasty cases. The number of surgeons performing rTSA continues to increase, while there has been a decrease in the number of surgeons performing aTSA and HA.

Since its introduction in 1993,[10] the reverse total shoulder arthroplasty (rTSA) has been used for rotator cuff arthropathy. rTSA has continued to gain popularity since Food and Drug Administration (FDA) approval in 2004,[8] and reportedly accounts for more than 50% of all shoulder arthroplasties performed.[23] The indications for rTSA have expanded to include revision, fracture, glenoid insufficiencies, and primary osteoarthritis in the elderly without rotator cuff insufficiency.[1,3,4,14,16-18,21]

Over the last two decades, literatures investigating the usage of both anatomic total shoulder arthroplasty (aTSA) and rTSA have noted concomitant increases in both procedures in the United States.[5-7,13,20,24] Studies in the 2000s had difficulty quantifying the impact of the rTSA on that increase, as both the aTSA and rTSA were logged under the same International Classification of Diseases-9 (ICD-9) procedure code before 2010.[13] The addition of a separate

This study was exempted by the institutional review board as all patient information was deidentified in accordance with the Health Insurance Portability and Accountability Act.

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rTSA code in 2010 allowed subsequent studies to trend the utilization of rTSA specifically. Several of these studies demonstrated a significant increase in utilization of rTSA over a period of just a few years, with similar trends noted in several European countries.[2,15,19,23] Few studies have analyzed the utilization of shoulder arthroplasty by primary diagnosis with a modern cohort through the year 2020.

The purpose of this study was to determine the trends of aTSA, rTSA, and hemiarthroplasty (HA) usage over a period of 5 years based on primary diagnosis. A secondary aim was to analyze patient comorbidities and hospital characteristics within these groups and to assess the number of surgeons performing each shoulder arthroplasty procedure. We hypothesized that both rTSA utilization would increase and indications would broaden relative to aTSA and HA over the 5-year period.

Methods

Data source and study population

The Premier Healthcare Database (PHD) was queried to identify all patients who underwent aTSA, rTSA, and HA from January 1, 2016 to December 31, 2020. The PHD is a nationally representative database of approximately 25% of the population that samples from over 1000 hospitals across the United States. It contains inpatient data regarding patient demographics, hospital factors, ICD codes, Current Procedural Terminology codes, and billing data. ICD-Tenth Revision (ICD-10) codes were utilized to identify these procedures within the PHD (rTSA: 0RRK00Z, 0RRJ00Z; aTSA: 0RRK0JZ, 0RRJ0JZ; HA: 0RRK0J6, 0RRJ0J6). All patients under 18 years old and those who underwent revision aTSA, rTSA, or HA were excluded.

This study was exempted by the institutional review board as all patient information was deidentified in accordance with the Health Insurance Portability and Accountability Act.

Patient demographics and comorbidities

Patient characteristics were extracted from PHD including age, sex, length of stay (LOS), and inpatient hospital charges. Hospital factors including geographic region, urban/rural setting, size, and teaching designation (academic/nonacademic) were collected. Rates of comorbidities were collected and compared between aTSA, rTSA, and HA patients. Lastly, the number of total operating surgeons within the PHD performing aTSA, rTSA, and HA were collected. These temporal trends were reported on an aggregated and annualized basis from 2016 to 2020.

Statistical analysis

Descriptive statistics were performed to report all patient demographics, hospital factors, and rates of comorbidities. Independent t-tests and chi-squared analyses for continuous and categorical variables, respectively, were performed to assess for differences in these factors between cohorts. Statistical significance was defined as $P < .050$. All statistical analyses were performed using STATA (version 16.1; StataCorp, College Station, TX, USA).

Results

Overall trends in arthroplasty and surgeon volume

In total, from 2016 to 2020, 154,499 patients were identified: 48,890 aTSA, 95,808 rTSA, and 9801 HA. The year with the highest volume of arthroplasty cases was 2019, with a 5-year high of 35,845 cases. The total number of annual arthroplasty cases has remained relatively stable since 2016, with an average of 30,860 cases per year. The number of surgeons performing shoulder arthroplasties in that timeframe has also remained steady, with an average aggregate of 2124 surgeons per year. However, within the total number of cases and surgeons performing them, there have been significant shifts in the proportion of each arthroplasty type.

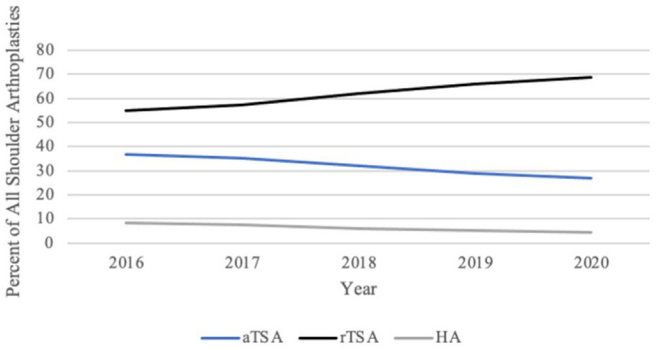

Figure 1 Proportion of annual shoulder arthroplasties by arthroplasty type (aTSA, rTSA, and HA). *aTSA*, anatomic total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty; *HA*, hemiarthroplasty.

In the United States, rTSA has come to account for the vast majority of shoulder arthroplasty cases. In 2016, rTSA comprised a slight majority (55%) of all arthroplasty cases. By 2020, that figure had risen to nearly 70% of all arthroplasty cases, as illustrated in Figure 1. There was a corresponding 112% increase in the number of surgeons performing rTSA across the same time period, contrasted with a 42.1% decrease in surgeons performing HA and a 14.3% decrease for aTSA. Additional data on arthroplasty and surgeon volume are given in Tables I and II.

Patient and hospital characteristics

Our three arthroplasty groups differed significantly in all demographic respects. These differences included age, sex, race, LOS, cost of care, insurance status, primary diagnoses, and comorbidities ($P < .0001$ in all). The rTSA group had the greatest mean age at 71.3 years. In terms of sex, there was a higher proportion of females in the rTSA group. Racial distribution was also significantly different across arthroplasty groups. Medicare users accounted for the greatest proportion of patients in all three arthroplasty groups, but this was the highest in the rTSA group at approximately 73%, relative to 56% and 50% in the aTSA and HA groups, respectively. HA patients had the longest mean hospital stay, at 2.12 days; however, costs of care were highest in the rTSA group. Each type of arthroplasty was most likely to have been performed at urban, nonacademic centers of size >500 beds. Tables III and IV provide a detailed illustration of patient and hospital characteristics. The three groups differed significantly in terms of comorbidities as well, with the three most prevalent being hypertension, obesity, and chronic pulmonary disease. Table V illustrates comorbidities in detail.

Annualized trends in shoulder arthroplasty

In the period from 2016-2020, absolute number of aTSA cases decreased over time, from approximately 10,000 per year in 2016-2018 to 7987 in 2020. There was no significant change in the mean age or insurance status of aTSA patients over this period. However, there was a significant difference in other demographic respects, including sex ($P = .005$) and racial distribution (<0.0001). The mean LOS decreased steadily over time as well ($P < .0001$), with a 2020

Table I
Annual case volume by arthroplasty type.

	2016	2017	2018	2019	2020
	Annual volume (% of total annual volume)	Annual volume (% of total annual volume)	Annual volume (% of total annual volume)	Annual volume (% of total annual volume)	Annual volume (% of total annual volume)
aTSA	9810 (36.6)	10,700 (35.1)	10,017 (32.1)	10,376 (29.0)	7987 (26.7)
rTSA	14,781 (55.1)	17,435 (57.3)	19,358 (61.9)	23,644 (66.0)	20,590 (68.8)
Hemi	2232 (8.32)	2312 (7.59)	1878 (6.01)	1825 (5.09)	1354 (4.52)
Total annual volume	26,823	30,447	31,253	35,845	29,931

aTSA, anatomic total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty.

Table II
Annual surgeon volume by arthroplasty type.

	2016	2017	2018	2019	2020
	Annual volume	Annual volume	Annual volume	Annual volume	Annual volume
aTSA	1416	1515	1387	1400	1213
rTSA	1508	1673	1661	1782	1688
Hemi	900	844	718	706	521
Aggregated annual volume	2129	2244	2124	2142	1983

aTSA, anatomic total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty.

Table III
Patient characteristics.

	aTSA (n = 48,890)	rTSA (n = 95,808)	Hemiarthroplasty (n = 9801)	*P* value
Mean age ± SD	66.74 ± 9.21	71.32 ± 8.50	64.12 ± 13.45	<.0001
Sex (%)				<.0001
Female	24,294 (49.8)	56,273 (61.0)	5181 (52.9)	
Male	24,521 (50.2)	37,424 (39.1)	4618 (47.13)	
Race (%)				<.0001
White	43,317 (88.6)	85,242 (89.0)	8451 (87.3)	
Black	2438 (5.0)	4711 (4.9)	557 (5.8)	
Asian	2553 (5.2)	4320 (4.5)	534 (6.7)	
Other	582 (1.2)	1072 (1.1)	140 (1.5)	
Payer category (%)				<.0001
Private	14,916 (36.9)	14,955 (20.2)	2868 (35.4)	
Medicare	22,585 (55.9)	53,886 (72.7)	4022 (49.6)	
Medicaid	1924 (4.8)	2702 (3.6)	774 (9.5)	
Workers' Compensation	868 (2.2)	2329 (3.1)	325 (4.0)	
Other	148 (0.4)	282 (0.4)	123 (1.5)	
Mean length of stay ± SD	1.45 ± 1.19	1.87 ± 2.03	2.14 ± 3.89	<.0001
Mean cost ± SD	65,657 ± 35,334	78,622 ± 42,265	69,527 ± 53,941	<.0001
Primary diagnoses (%)				<.0001
Osteoarthritis	42,389 (86.9)	51,150 (54.0)	3459 (36.7)	
Proximal humerus hardware failure	1812 (3.7)	6268 (6.6)	1857 (19.7)	
Inflammatory arthritis	1545 (3.2)	4140 (4.4)	200 (2.1)	
Avascular necrosis	1110 (2.3)	1158 (1.2)	757 (8.0)	
Posttraumatic arthritis	633 (1.3)	1393 (1.5)	108 (1.2)	
Unspecified arthropathy	488 (1.0)	4760 (5.0)	330 (3.5)	
Proximal humerus fracture	383 (0.8)	11,394 (12.0)	2294 (24.3)	
Rotator cuff tear	224 (0.5)	12,120 (12.8)	210 (2.2)	
Proximal humerus malunion / nonunion	170 (0.4)	2293 (2.4)	213 (2.3)	

aTSA, anatomic total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty; *SD*, standard deviation.

mean LOS of approximately 1.3 days compared to the overall mean of 1.5 days. Mean cost increased over time as well ($P < .0001$), with a 2020 mean of $70,954 compared to the overall mean of $65,657. Primary diagnoses differed significantly across the five-year period ($P < .0001$). Osteoarthritis remained the leading diagnosis in each year, accounting for approximately 86%-87% of all aTSA cases. Table VI provides a detailed report of trends in aTSA over the 5-year period from 2016-2020.

Absolute numbers of rTSA cases have generally increased over time. While in 2016 there were approximately 3000 more rTSA cases compared with aTSA cases, rTSAs saw a high of 23,644 cases in 2019 compared to 14,781 in 2016. There were significant differences in all demographic respects over time, including mean age ($P = .0002$), sex, racial distribution, and insurance status ($P < .0001$). Mean LOS decreased consistently over time from 2.14 in 2016 to 1.66 in 2020, as mean costs of care increased over the same timespan from $74,525 to $82,664 ($P < .0001$ for both). Primary diagnoses differed significantly as well ($P < .0001$). Though osteoarthritis was already the leading diagnosis in 2016, accounting for 48.8% of cases, the proportion of patients who underwent rTSA for osteoarthritis grew to 56.4% by 2020. Detailed trends in rTSA are reported in Table VII.

Table IV
Hospital characteristics.

	aTSA (n = 48,890)	rTSA (n = 93,320)	Hemiarthroplasty (n = 9855)	*P* value
Setting (%)				<.0001
Urban	43,606 (89.2)	83,889 (87.6)	8659 (88.4)	
Rural	5284 (10.8)	11,919 (12.4)	1142 (11.7)	
Teaching status (%)				<.0001
Nonacademic	27,771 (56.8)	52,791 (56.1)	5256 (53.6)	
Academic	21,119 (43.2)	42,017 (43.9)	4545 (46.4)	
Size (%, in beds)				<.0001
0-99	4357 (8.9)	8875 (9.3)	801 (8.2)	
100-199	9328 (19.1)	17,257 (18.0)	1810 (18.5)	
200-299	8064 (16.5)	16,699 (17.4)	1675 (17.1)	
300-399	7478 (15.3)	14,710 (15.4)	1410 (14.4)	
400-499	6361 (13.0)	1163 (12.3)	1092 (11.1)	
>500	13,302 (27.2)	26,504 (27.7)	3013 (30.7)	
Region (%)				<.0001
South	20,843 (42.6)	47,360 (49.4)	4386 (44.8)	
Midwest	13,083 (26.8)	25,180 (26.3)	2382 (24.3)	
West	8014 (16.4)	11,510 (12.0)	1809 (18.5)	
Northeast	6950 (14.2)	11,758 (12.3)	1224 (12.5)	

aTSA, anatomic total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty.

Table V
Baseline comorbidities (%).

	aTSA (n = 48,890)	rTSA (n = 93,320)	Hemiarthroplasty (n = 9855)	*P* value
Hypertension	28,206 (57.7)	57,462 (60.0)	5169 (52.7)	<.0001
Obesity	11,381 (23.3)	20,017 (20.9)	1911 (19.5)	<.0001
Chronic pulmonary disease	8913 (18.2)	20,605 (21.5)	2007 (20.5)	<.0001
Hypothyroidism	7956 (16.3)	18,584 (19.4)	1524 (15.6)	<.0001
Depression	7800 (16.0)	16,936 (17.7)	1592 (16.2)	<.0001
Uncomplicated DM	6916 (14.2)	15,588 (16.3)	1405 (14.3)	<.0001
Complicated hypertension	3882 (7.9)	12,398 (12.9)	992 (10.1)	<.0001
Renal failure	3066 (6.3)	9675 (10.1)	781 (8.0)	<.0001
DM with complications	2729 (5.6)	8396 (8.8)	751 (7.7)	<.0001
Autoimmune / collagen disorder	2243 (4.6)	6482 (6.8)	571 (5.8)	<.0001
Electrolyte imbalance	2035 (4.2)	7431 (7.8)	837 (8.5)	<.0001
Congestive heart failure	1844 (3.8)	6380 (6.7)	576 (5.9)	<.0001
Neurologic disorder	1276 (2.6)	3860 (4.0)	643 (6.6)	<.0001
Peripheral vascular disease	1225 (2.5)	3694 (3.9)	308 (3.1)	<.0001
Liver disease	736 (1.5)	1735 (1.8)	261 (2.7)	<.0001
Coagulopathy	654 (1.3)	1882 (2.0)	221 (2.3)	<.0001
Drug abuse	639 (1.3)	1158 (1.2)	223 (2.3)	<.0001
Alcohol abuse	520 (1.1)	1488 (1.6)	324 (3.3)	<.0001
Iron deficiency anemia	456 (0.9)	1867 (2.0)	199 (2.0)	<.0001
Pulmonary circulation disorder	333 (0.7)	1277 (1.3)	122 (1.2)	<.0001
Cardiac valve disease	326 (0.7)	1024 (1.1)	78 (0.8)	<.0001
Malignancy	241 (0.5)	645 (0.7)	148 (1.5)	<.0001
Chronic blood loss anemia	163 (0.3)	444 (0.5)	58 (0.6)	<.0001
Psychosis	130 (0.3)	333 (0.4)	85 (0.9)	<.0001
Lymphoma	109 (0.2)	288 (0.3)	32 (0.3)	<.0001
Peptic ulcer disease	107 (0.2)	326 (0.3)	22 (0.2)	<.0001
Paralysis	73 (1.5)	235 (0.3)	29 (0.3)	<.0001
Weight loss	68 (0.1)	501 (0.5)	119 (1.2)	<.0001
HIV/AIDS	49 (0.1)	41 (0.04)	22 (0.2)	<.0001
Metastatic cancer	39 (0.1)	190 (0.2)	74 (0.8)	<.0001

aTSA, anatomic total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty; *DM*, diabetes mellitus type 2; *HIV/AIDS*, human immunodeficiency virus/acquired immunodeficiency syndrome.

Shoulder HA cases have seen a decrease in numbers from 2232 in 2016 to 1354 in 2020. Demographic characteristics, including age, sex, racial distribution, and insurance status, demonstrate no significant differences over this 5-year period. However, there was a significant increase in costs of care, with a mean of $69,527 in 2016 vs. $80,720 in 2020 ($P < .0001$). Primary diagnoses differ significantly across the years as well ($P < .0001$). Osteoarthritis, the leading diagnosis in 2016, accounting for 39.4% of HAs, was superseded by proximal humerus fracture by 2020, which accounted for the greatest proportion of cases at 23.1%. There is no linear directionality observed in comorbid conditions for the HA cohort, but significant differences exist nonetheless for obesity, complicated hypertension, renal failure, complicated DM2, and congestive heart failure. Table VIII depicts these in detail along with other characteristics of this cohort.

Discussion

This study demonstrated in a contemporary cohort that the volume of primary rTSA in the United States has continued to increase from 2016 to 2020. Concurrently, the number of primary

Table VI
Annualized trends in aTSA.

	Overall (n = 48,890)	2016 (n = 9810)	2017 (n = 10,700)	2018 (n = 10,017)	2019 (n = 10,376)	2020 (n = 7987))	*P* value
Mean age ± SD	66.7 ± 9.2	66.7 ± 9.3	66.9 ± 9.3	66.9 ± 9.3	66.8 ± 9.2	66.6 ± 9.0	.6078
Sex (%)							.005
Female	24,294 (49.8)	4896 (49.9)	5323 (49.8)	5088 (50.8)	5170 (50.0)	3817 (48.0)	
Male	24,521 (50.2)	4914 (50.1)	5377 (50.3)	4929 (49.2)	5161 (50.0)	4140 (52.0)	
Race (%)							<.0001
White	43,317 (88.6)	8847 (90.5)	9433 (88.2)	8824 (88.1)	9128 (88.0)	7085 (88.7)	
Black	2438 (5.0)	486 (5.0)	508 (4.8)	483 (4.8)	547 (5.3)	414 (5.2)	
Asian	2362 (4.9)	356 (3.6)	651 (6.1)	603 (6.0)	569 (5.5)	340 (4.3)	
Other	582 (1.2)	87 (0.9)	108 (1.0)	107 (1.1)	132 (1.3)	148 (1.9)	
Payer category (%)							.389
Private	14,916 (36.9)	3125 (37.3)	3290 (36.7)	3115 (37.2)	3066 (36.3)	2320 (36.8)	
Medicare	22,585 (55.9)	4608 (55.0)	5028 (56.1)	4691 (56.0)	4770 (56.5)	3488 (55.4)	
Medicaid	1924 (4.8)	423 (5.1)	418 (4.7)	356 (4.3)	387 (4.6)	340 (5.4)	
Workers' compensation	868 (2.2)	186 (2.2)	194 (2.2)	180 (2.2)	179 (2.1)	129 (2.1)	
Other	148 (0.4)	31 (0.4)	30 (0.3)	29 (0.4)	35 (0.4)	23 (0.4)	
Mean LOS ± SD	1.45 ± 1.19	1.57 ± 1.12	1.51 ± 1.10	1.45 ± 1.15	1.39 ± 1.38	1.28 ± 1.09	<.0001
Mean cost ± SD (USD)	65,657 ± 35,334	60,941 ± 28,351	63,870 ± 30,826	65,722 ± 35,576	67,818 ± 35,359	70,954 ± 45,884	<.0001
Primary diagnoses (%)							<.0001
Osteoarthritis	42,389 (86.9)	8479 (86.7)	9310 (87.3)	8651 (86.8)	8988 (86.8)	6961 (87.4)	
Proximal humerus hardware failure	1812 (3.7)	318 (3.3)	390 (3.7)	373 (3.7)	402 (3.9)	329 (4.1)	
Inflammatory arthritis	1545 (3.2)	311 (3.2)	331 (3.1)	331 (3.4)	329 (3.2)	231 (2.9)	
Avascular necrosis	1110 (2.3)	223 (2.3)	238 (2.2)	238 (2.5)	242 (2.3)	161 (2.0)	
Posttraumatic arthritis	633 (1.3)	138 (1.4)	139 (1.3)	139 (1.2)	140 (1.4)	92 (1.2)	
Unspecified arthropathy	488 (1.0)	162 (1.7)	100 (0.9)	78 (0.8)	81 (0.8)	67 (0.8)	
Proximal humerus fracture	383 (0.8)	69 (0.7)	81 (0.8)	81 (0.7)	85 (0.8)	79 (1.0)	
Rotator cuff tear	224 (0.5)	44 (0.5)	45 (0.4)	45 (0.5)	54 (0.5)	34 (0.4)	
Proximal humerus malunion / nonunion	170 (0.4)	38 (0.4)	36 (0.3)	45 (0.5)	37 (0.4)	14 (0.2)	

aTSA, anatomic total shoulder arthroplasty; *LOS*, length of stay; *SD*, standard deviation; *USD*, United States dollar.

Table VII
Annualized trends in rTSA.

	Overall (n = 95,808)	2016 (n = 14,781)	2017 (n = 17,435)	2018 (n = 19,358)	2019 (n = 23,644)	2020 (n = 20,590)	*P* value
Mean age ± SD	71.3 ± 8.5	71.5 ± 8.7	71.5 ± 8.6	71.4 ± 8.5	71.3 ± 8.4	71.1 ± 8.4	.0002
Sex (%)							<.0001
Female	58,273 (60.9)	9232 (62.5)	10,847 (62.2)	11,857 (61.3)	14,120 (59.8)	12,217 (59.6)	
Male	37,424 (39.1)	5549 (37.5)	6588 (37.8)	7500 (38.8)	9487 (40.2)	8300 (40.5)	
Race (%)							<.0001
White	85,242 (89.0)	13,350 (90.8)	15,483 (89.3)	17,178 (89.1)	20,879 (88.7)	18,352 (89.6)	
Black	4711 (4.9)	725 (4.9)	823 (4.8)	953 (5.0)	1167 (5.0)	1043 (5.1)	
Asian	4320 (5.5)	484 (3.3)	862 (5.0)	957 (5.0)	1206 (5.1)	811 (4.0)	
Other	1072 (1.1)	142 (1.0)	173 (1.0)	185 (1.0)	284 (1.2)	288 (1.4)	
Payer category (%)							<.0001
Private	14,955 (20.2)	2415 (19.9)	2771 (20.0)	2988 (19.6)	3674 (20.6)	3077 (20.6)	
Medicare	53,886 (72.7)	8825 (72.7)	10,134 (73.0)	11,164 (73.4)	12,963 (72.5)	10,800 (71.8)	
Medicaid	2702 (3.6)	421 (3.5)	521 (3.8)	521 (3.4)	606 (3.4)	633 (4.2)	
Workers' compensation	2329 (3.1)	435 (3.6)	409 (3.0)	479 (3.2)	566 (3.2)	440 (2.9)	
Other	282 (0.4)	39 (0.3)	42 (0.3)	62 (0.4)	66 (0.4)	73 (0.5)	
Mean LOS ± SD	1.87 ± 2.03	2.13 ± 2.13	2.02 ± 2.00	1.88 ± 2.04	1.79 ± 1.89	1.66 ± 2.18	<.0001
Mean cost ± SD (USD)	78,622 ± 42,265	74,512 ± 38,616	75,897 ± 39,044	77,612 ± 43,186	80,465 ± 42,256	82,714 ± 45,904	<.0001
Primary diagnoses (%)							<.0001
Osteoarthritis	51,150 (54.0)	7134 (48.8)	9022 (52.4)	10,463 (54.7)	13,086 (56.0)	11,445 (56.3)	
Rotator cuff tear	12,120 (12.8)	2161 (14.8)	2224 (12.9)	2273 (11.9)	2943 (12.6)	2519 (12.4)	
Proximal humerus fracture	11,394 (12.0)	1853 (12.7)	2139 (12.4)	2348 (12.3)	2628 (11.3)	2426 (11.9)	
Proximal humerus hardware failure	6268 (6.6)	1853 (12.7)	2139 (12.4)	2348 (12.3)	2628 (11.3)	2426 (11.9)	
Unspecified arthropathy	4760 (5.0)	971 (6.6)	906 (5.3)	963 (5.0)	1040 (4.5)	880 (4.3)	
Inflammatory arthritis	4140 (4.4)	660 (4.5)	748 (4.3)	840 (4.4)	1027 (4.4)	865 (4.3)	
Proximal humerus malunion / nonunion	2293 (2.4)	381 (2.6)	438 (2.5)	462 (2.4)	552 (2.4)	460 (2.3)	
Posttraumatic arthritis	1393 (1.5)	241 (1.7)	286 (1.7)	334 (1.8)	287 (1.2)	245 (1.2)	
Avascular necrosis	1158 (1.2)	182 (1.2)	223 (1.3)	241 (1.3)	286 (1.2)	226 (1.1)	

LOS, length of stay; *SD*, standard deviation; *rTSA*, reverse total shoulder arthroplasty; *USD*, United States dollar.

aTSA and HA cases has decreased over the same time period. By 2020, primary rTSA accounted for nearly 70% of all primary shoulder arthroplasty cases in this nationally sampled cohort, an increase from 55% of all cases in 2016. Glenohumeral osteoarthritis has remained the most common indication for aTSA and has increasingly become an indication for rTSA, accounting for 56% of all rTSA cases in 2020. Additionally, the number of surgeons performing rTSA has increased over the study period, while the

Table VIII
Annualized trends in hemiarthroplasty.

	Overall (n = 9801)	2016 (n = 2232)	2017 (n = 2312)	2018 (n = 1878)	2019 (n = 1825)	2020 (n = 1354)	*P* value
Mean age ± SD	64.1 ± 13.5	64.4 ± 13.0	64.2 ± 13.3	64.3 ± 13.5	64.2 ± 13.8	63.5 ± 13.8	.421
Sex (%)							.130
Female	5181 (52.9)	1227 (55.0)	1213 (52.5)	1005 (53.5)	935 (51.3)	699 (51.7)	
Male	4618 (47.1)	1005 (45.0)	1099 (47.5)	873 (46.5)	889 (48.7)	654 (48.3)	
Race (%)							.061
White	8451 (87.3)	1974 (88.4)	1980 (85.6)	1614 (85.9)	1548 (84.8)	1161 (85.8)	
Black	557 (5.8)	117 (5.2)	141 (6.1)	111 (5.9)	102 (5.6)	76 (5.6)	
Asian	534 (5.52)	112 (5.0)	156 (6.8)	130 (6.9)	147 (8.1)	93 (6.9)	
Other	140 (1.5)	29 (1.3)	35 (1.5)	23 (1.2)	28 (1.5)	24 (1.8)	
Payer category (%)							.178
Private	2868 (35.4)	689 (36.0)	693 (35.9)	524 (33.7)	524 (35.8)	381 (35.6)	
Medicare	4022 (49.6)	966 (50.5)	959 (49.6)	796 (51.1)	706 (48.3)	506 (47.3)	
Medicaid	774 (9.5)	150 (7.8)	178 (9.2)	155 (10.0)	154 (10.5)	120 (11.2)	
Workers' compensation	325 (4.0)	79 (4.1)	79 (4.1)	63 (4.1)	50 (3.4)	42 (3.9)	
Other	123 (1.5)	29 (1.5)	24 (1.2)	19 (1.2)	28 (1.9)	20 (1.9)	
Mean LOS ± SD	2.14 ± 3.89	2.07 ± 2.68	2.20 ± 3.72	2.00 ± 3.28	2.12 ± 4.73	2.32 ± 5.26	.181
Mean cost ± SD (USD)	69,527 ± 53,941	63,867 ± 43,959	68,158 ± 52,965	68,159 ± 50,081	71,854 ± 55,795	80,720 ± 70,809	<.0001
Primary diagnoses (%)							<.0001
Osteoarthritis	3459 (36.7)	853 (39.4)	858 (38.4)	674 (37.6)	604 (34.4)	402 (21.2)	
Proximal humerus fracture	2294 (24.3)	586 (27.1)	557 (23.4)	420 (23.4)	383 (21.8)	297 (23.1)	
Proximal humerus hardware failure	1857 (19.7)	298 (13.8)	364 (16.3)	368 (20.5)	436 (24.8)	357 (2.7)	
Avascular necrosis	757 (8.0)	161 (7.4)	192 (8.1)	146 (8.1)	133 (7.6)	107 (8.3)	
Unspecified arthropathy	330 (3.5)	76 (3.5)	86 (3.9)	59 (3.3)	56 (3.2)	42 (3.3)	
Proximal humerus malunion / nonunion	213 (2.3)	49 (2.3)	54 (2.4)	42 (2.3)	39 (2.2)	27 (2.1)	
Rotator cuff tear	210 (2.2)	64 (3.0)	43 (1.8)	33 (1.8)	40 (2.3)	26 (2.0)	
Inflammatory arthritis	200 (2.1)	52 (2.4)	47 (1.6)	28 (1.6)	48 (2.7)	20 (1.6)	
Posttraumatic arthritis	108 (1.2)	26 (1.2)	31 (1.4)	25 (1.4)	16 (0.9)	9 (0.7)	

LOS, length of stay; *SD*, standard deviation.

number of surgeons performing aTSA and HA has simultaneously decreased.

The results of this study represent an updated assessment of the trends in shoulder arthroplasty in the United States. Recent studies investigating trends in shoulder arthroplasty have been limited to include data through the calendar year 2017.[2,19,23] Using the National Inpatient Sample, Rabinowitz et al noted a 22% annualized increase in rTSA from 2011 to 2016, twice that of aTSA, with rTSA volume surpassing aTSA volume in 2014.[19] Similarly, Wagner et al demonstrated an annual volume increase for rTSA and aTSA of 191.3% and 38.5%, respectively, from 2011 to 2017 with a similar 60% decrease in HA volume.[23] Furthermore, Best et al reported a total of 64,215 shoulder arthroplasty cases in 2012 with 33.56% rTSA, 46.23% aTSA, and 18.21% HA, which increased to 108,300 total cases in 2017 with 57.90% rTSA, 37.55% aTSA and 4.55% HA.[2] This data is consistent with Modor Intelligence's Shoulder Replacement Market Analysis, which projects a continued annual growth rate of 8.16% from 2022-2027.[26] These previous estimates through 2017 are similar to those of the current study, and our data provide continued expansion of these trends, demonstrating that rTSA accounts for nearly 70% of all shoulder arthroplasty in 2020.

The popularity of rTSA has grown since its approval by the FDA in 2004 and has expanded in indication greatly beyond massive irreparable rotator cuff tears and rotator cuff arthropathy.[3,5,8,13] Our data demonstrate that osteoarthritis has become the most common indication for rTSA, now accounting for 56% of all cases, followed by rotator cuff arthropathy and proximal humerus fracture. Similarly, osteoarthritis remains the primary indication for approximately 87% of aTSA cases, followed by proximal humerus hardware failure and inflammatory arthropathy. Several studies using data prior to 2017 have corroborated these findings of shoulder arthroplasty indications.[2,11,15] In a study spanning nine different countries, Lübbeke et al demonstrated that that the most common indication for shoulder arthroplasty was osteoarthritis, followed by rotator cuff arthropathy.[15] Similarly, within the Finnish Registry, Harjula et al noted that osteoarthritis was the most common indication for both aTSA and rTSA.[11] However, Best et al cited rotator cuff arthropathy as the most common indication for rTSA, while osteoarthritis remained the most common indication for aTSA.[2] A possible explanation for the differences in primary diagnosis coding may be due to specificity in primary diagnosis coding, which significantly improved following the introduction of ICD-10 diagnosis and procedure codes in the third quarter of 2015. Thus, our study captures the first five years of ICD-10 coding with regards to primary indications for shoulder arthroplasty; however, continued assessment of indications and outcomes by indication for total shoulder arthroplasty is warranted.

The number of orthopedic surgeons performing rTSA increased over the study period (+11.9%), while the number of surgeons performing aTSA and HA decreased (−14.3% and −41.1%, respectively). One potential explanation for this expansion may be an increasing number of surgeons undergoing fellowship training in shoulder and elbow surgery, which has been growing rapidly and doubled from 2003 to 2013.[12] However, Zmistowski et al noted that only one-third of total shoulder arthroplasty cases are performed by fellowship-trained shoulder and elbow surgeons.[25] Similarly, Somerson et al noted that while the highest volume shoulder arthroplasty surgeons had shoulder and elbow fellowship training, these surgeons accounted for only 28% of providers, whereas 40% of providers had sports medicine fellowship training.[22] Considering this increased prevalence of rTSA noted by Farley et al there remains concern regarding the projected revision burden in the future.[9] Taken together, these findings indicate that the increase in subspecialty fellowship training following orthopedic surgery

residency supports the data found within this study on the expanding number of surgeons performing rTSA.

This study is not without limitations. As with all administrative databases, the findings of this study are reliant on accurate coding entered within the database and thus are subject to potential coding errors. The primary indication for surgery is determined by ICD-10-Clinical Modification (CM) diagnosis codes; while these codes are far more specific than ICD-9-CM codes utilized prior to 2016, they do not provide specific details for the indications of each surgery. However, given the number of patients included within the study, we do not expect these to affect the results in favor of one procedure and skew the proportions of procedures performed. Furthermore, our results are in concordance with previous estimates of primary indication for shoulder arthroplasty.[11,15]

The strengths of this study warrant mention. This study included over 154,000 individual patient files from a nationally representative database using data up to the 2020 calendar year, thus expanding upon previous estimates available through 2017. The use of specific ICD-10 procedural and diagnosis codes allowed for more precise inclusion criteria compared to previously published literature. Additionally, we were able to assess the number of individual surgeons performing rTSA, aTSA, and HA across all study years to assess overall practice patterns within a cohort of more than 2000 surgeons. To our knowledge, this represents one of the largest contemporary cohorts investigating the changes in practice patterns for shoulder arthroplasty. The findings of this investigation provide robust evidence to support previous claims that rTSA has continued to gain popularity in its use and indications. Future studies focused on the effects of these expanding indications and utilization on long-term patient outcomes are warranted.

Conclusion

The volume of primary rTSA in the United States has continued to increase from 2016 to 2020 with concurrent decreases in the number of primary aTSA and HA cases performed. Primary rTSA accounts for nearly 70% of all primary shoulder arthroplasty cases. The number of surgeons performing rTSA continues to increase, while there has been a decrease in the number of surgeons performing aTSA and HA. These findings should provide an updated assessment of shoulder arthroplasty utilization and indication in a nationwide, representative cohort and should prompt future study on the ramifications of increased rTSA utilization.

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