The contribution of reverse shoulder arthroplasty to utilization of primary shoulder arthroplasty

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Background: We assessed the contribution of reverse shoulder arthroplasty to overall utilization of primary shoulder arthroplasty and present age- and sex-stratified national rates of shoulder arthroplasty. We also assessed contemporary complication rates, mortality rates, and indications for shoulder arthroplasty, as well as estimates and indications for revision arthroplasty.

Methods: We used the Nationwide Inpatient Samples for 2009 through 2011 to calculate estimates of shoulder arthroplasty and assessed trends using Joinpoint (National Cancer Institute, Bethesda, MD) regression.

Results: The cumulative estimated utilization of primary shoulder arthroplasty (anatomic total shoulder arthroplasty, hemiarthroplasty, and reverse shoulder arthroplasty) increased significantly from 52,397 procedures (95% confidence interval [CI], 47,093-57,701) in 2009 to 67,184 cases (95% CI, 60,638-73,731) in 2011. Reverse shoulder arthroplasty accounted for 42% of all primary shoulder arthroplasty procedures in 2011. The concomitant diagnosis of osteoarthritis and rotator cuff impairment was found in only 29.8% of reverse shoulder arthroplasty cases. The highest rate of reverse shoulder arthroplasty was in the 75- to 84-year-old female subgroup (77 per 100,000 persons; 95% CI, 67-87). Revision cases comprised 8.8% and 8.2% of all shoulder arthroplasties in 2009 and 2011, respectively, and 35% of revision cases were because of mechanical complications/loosening whereas 18% were because of dislocation.

Conclusions: The utilization of primary shoulder arthroplasty significantly increased in just a 3-year time span, with a major contribution from reverse shoulder arthroplasty in 2011. Indications appear to have expanded because a large percentage of patients did not have rotator cuff pathology. The burden from revision arthroplasties was also substantial, and efforts to optimize outcomes and longevity of primary shoulder arthroplasty are needed.

Level of evidence: Epidemiology Study, Database Analysis.

Keywords: Reverse shoulder arthroplasty; utilization

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An increasing utilization of shoulder arthroplasty has been reported in the United States from 1993 to 2008.\textsuperscript{15,16} This increase in utilization is disproportionate to the increase in population. The recent increase in utilization of total shoulder arthroplasty is likely partly attributable to the approval of a reverse shoulder arthroplasty device by the US Food and Drug Administration (FDA) in 2003.\textsuperscript{9} However, national estimates on the contribution of reverse shoulder arthroplasty to the overall utilization of shoulder arthroplasty are not available. These data will assist patients, clinicians, and policymakers who are stakeholders in understanding the burden of shoulder arthropathies requiring surgical intervention and perform appropriate resource allocation.

The objectives of our study were to assess the contribution of reverse shoulder arthroplasty to overall utilization of primary shoulder arthroplasty and present age- and sex-stratified national rates of shoulder arthroplasty. We also assessed contemporary complication rates, mortality rates, and indications for shoulder arthroplasty, as well as estimates and indications for revision arthroplasty.

**Materials and methods**

**Databases**

We used the Nationwide Inpatient Sample databases for 2009 through 2011. The Nationwide Inpatient Sample is part of the Healthcare Cost and Utilization Project and is sponsored by the Agency for Healthcare Research and Quality.\textsuperscript{14} It is the largest all-payer inpatient database available in the United States.\textsuperscript{14} The Nationwide Inpatient Sample uses sampling techniques to enable nationally representative estimates.\textsuperscript{14} The Nationwide Inpatient Sample has been validated by an independent contractor and against the National Hospital Discharge Survey.\textsuperscript{28,43} Further details on the database, sampling techniques, and validation can be found elsewhere.\textsuperscript{14,28,43}

**Shoulder arthroplasty procedures and associated diagnosis codes**

There is 1 principal International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis and procedure code for each record in the Nationwide Inpatient Sample. There are up to an additional 24 diagnosis codes and 14 procedure codes. Each record in the Nationwide Inpatient Sample represents an inpatient admission (and not a unique patient). We used ICD-9-CM procedure codes to ascertain cases of primary total shoulder arthroplasty (81.80), hemiarthroplasty (81.81), and total elbow arthroplasty (81.84). Cases of revision arthroplasty were determined using the ICD-9-CM procedure code 81.97.\textsuperscript{1} However, this code is not specific to the shoulder and is described as revision arthroplasty of the upper extremity (henceforth referred to as “revision arthroplasty”). We calculated the number of primary total elbow arthroplasty and wrist, hand, and finger arthroplasty procedures during our study period to validate our assumption that most upper extremity arthroplasty procedures were performed for the shoulder. Reverse shoulder arthroplasty was not assigned an ICD-9-CM procedure code (81.88) until October 1, 2010.\textsuperscript{9} Hence, national estimates for reverse shoulder arthroplasty can be calculated for the first time using ICD-9-CM codes for 2011. Although reverse shoulder arthroplasty national estimates were only calculated for the year 2011, we used data from 2010 (after FDA approval of reverse shoulder arthroplasty) when assessing characteristics and complications of reverse shoulder arthroplasty. Because reverse shoulder arthroplasty has a specific ICD-9-CM procedure code for the year 2011, it is reasonable to assume that the code 81.80 was assigned to cases of anatomic total shoulder arthroplasty for this year.

Indications for shoulder arthroplasty were determined using ICD-9-CM diagnosis codes. The diagnosis of osteoarthritis was determined if the record contained a diagnosis code for primary or secondary osteoarthritis of the shoulder or arm. Proximal humeral fractures included fractures of the humeral head, surgical neck, anatomic neck, and greater tuberosity. ICD-9-CM codes were also used to identify patients with rotator cuff disorders such as rotator cuff tear, strain, or syndrome. ICD-9-CM diagnosis codes were used to determine complications such as pulmonary embolism and postoperative infections, as well as potential causes for revision arthroplasty such as loosening, dislocation, prosthetic or periprosthetic fracture, osteolysis, and other mechanical complications. Further details on the ICD-9-CM codes used for our analysis are included in the Appendix. The Nationwide Inpatient Sample databases only permit assessment of in-hospital complications and deaths.

**Statistical analysis**

We estimated population-based numbers of patients undergoing anatomic total shoulder arthroplasty, hemiarthroplasty, reverse shoulder arthroplasty, and total elbow arthroplasty, as well as revision arthroplasty, in the United States for the years 2009, 2010, and 2011 by using sampling weights provided by the Nationwide Inpatient Sample. The sampling weights in the Nationwide Inpatient Sample were calculated within each sampling stratum as the ratio of discharges in the American Hospital Association survey data for non-rehabilitation community hospitals to discharges in the sample.\textsuperscript{14} We calculated confidence intervals (CIs) around the point estimates using strata and cluster variables.

We calculated age- and sex-stratified procedural rates per 100,000 persons by using 2009-2011 population estimates for a given age group by sex and year from the US Census Bureau.\textsuperscript{36-38} Because a separate code for reverse shoulder arthroplasty did not exist before October 1, 2010,\textsuperscript{9} it is likely that cases of reverse shoulder arthroplasty were coded as total shoulder arthroplasty or hemiarthroplasty in 2009 and 2010. Hence, we report cumulative primary shoulder arthroplasty (henceforth also referred to as “shoulder arthroplasty”) rates per 100,000 persons stratified by age and sex for the years 2009 to 2011. We used Joinpoint regression analysis to assess changes in the utilization of primary shoulder arthroplasty. A software program developed by the Surveillance Research Program of the National Cancer Institute was used for this purpose.\textsuperscript{25} Joinpoint regression permits assessment of significant changes in slopes of linear trend and provides an average annual percent change that summarizes trend over a period.\textsuperscript{24}

We also present unweighted proportions of patients by diagnosis, in-hospital complications, and in-hospital deaths for all 3 years of the study combined. Statistical analyses were conducted
using SAS for Windows (version 9.3; SAS Institute, Cary, NC, USA).

**Results**

The utilization of primary shoulder arthroplasty (anatomic total shoulder arthroplasty, hemiarthroplasty, and reverse shoulder arthroplasty) increased significantly from 52,397 procedures (95% CI, 47,093-57,701) in 2009 to 67,184 procedures (95% CI, 60,638-73,731) in 2011 (Table I). Joinpoint regression identified 1 significant phase of increase in the utilization of primary shoulder arthroplasty with an average annual percent change of 13.2. The estimates for reverse shoulder arthroplasty were only calculated for 2011, when 21,916 procedures (95% CI, 18,796-25,035) were performed, accounting for 42% of all primary shoulder arthroplasty procedures in 2011. There was an increase in the overall number of upper extremity revision procedures performed from 2009 to 2011 (from 5,070 procedures to 6,028 procedures). However, revision arthroplasty procedures as a proportion of all shoulder arthroplasty procedures remained stable during the study period (8.8% in 2009 vs 8.2% in 2011). Our assumption that a majority of upper extremity procedures were performed for the shoulder was valid because only 7% of all primary upper extremity arthroplasty procedures were performed for the elbow, wrist, hand, and fingers between 2009 and 2011.

The rate of primary shoulder arthroplasty was highest in the 75- to 84-year-old female age group (133 per 100,000 persons in 2009 [95% CI, 120-146] and 170 per 100,000 persons in 2011 [95% CI, 154-186]) (Fig. 1). Women in the 65- to 74-year-old age group had the next highest rate of primary shoulder arthroplasty (96 per 100,000 persons in 2009 [95% CI, 86-1,050] and 119 per 100,000 persons in 2011 [95% CI, 108-131]). Among men, 75- to 84-year-old persons had the highest utilization of primary shoulder arthroplasty, with a rate of 79 per 100,000 persons (95% CI, 69-90) in 2009 and 113 per 100,000 persons (95% CI, 101-125) in 2011. The highest rate of reverse shoulder arthroplasty in 2011 was in the 75- to 84-year female subgroup (77 per 100,000 persons; 95% CI, 67-87) (Table II). The rate of revision arthroplasty was highest in the 75- to 84-year-old age group in female persons in 2009 (10 per 100,000 persons; 95% CI, 8-12) but decreased to 9 per 100,000 persons (95% CI, 7-12) in this age group in 2011 (Fig. 2). Among men aged 75 to 84 years, the revision arthroplasty rate increased from 6 per 100,000 persons (95% CI, 4-8) in 2009 to 10 per 100,000 persons (95% CI, 7-12) in 2011.

Hemiarthroplasty and reverse shoulder arthroplasty had the highest in-hospital mortality rates: 0.28% and 0.24%, respectively (Table III). In-hospital complication rates were low for all primary and revision arthroplasty procedures and ranged between 0.0% for postoperative infections/wound complications after anatomic total shoulder arthroplasty to 0.78% for postoperative infections/wound complications after reverse shoulder arthroplasty. The in-hospital length of stay was 2.6 days (SD, 2.4 days) for primary reverse shoulder arthroplasty as compared with 2.1 days (SD, 1.4 days) for primary anatomic total shoulder arthroplasty.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>2009 Estimate (95% CI)</th>
<th>2010 Estimate (95% CI)</th>
<th>2011 Estimate (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemiarthroplasty</td>
<td>19,394 (17,777-21,012)</td>
<td>18,713 (17,053-20,373)</td>
<td>15,860 (14,484-17,236)</td>
</tr>
<tr>
<td>Anatomic total shoulder arthroplasty</td>
<td>NA* (NA)</td>
<td>NA (NA)</td>
<td>29,414 (26,145-32,682)</td>
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<tr>
<td>Reverse shoulder arthroplasty</td>
<td>NA (NA)</td>
<td>NA (NA)</td>
<td>21,916 (18,796-25,035)</td>
</tr>
<tr>
<td>Cumulative primary shoulder arthroplasty</td>
<td>52,397 (47,093-57,701)</td>
<td>62,695 (55,971-69,419)</td>
<td>67,184 (60,638-73,731)</td>
</tr>
<tr>
<td>Elbow arthroplasty</td>
<td>2,775 (2,386-3,164)</td>
<td>2,973 (2,507-3,439)</td>
<td>2,987 (2,551-3,423)</td>
</tr>
<tr>
<td>Revision upper extremity arthroplasty</td>
<td>5,070 (3,977-6,162)</td>
<td>5,970 (4,650-7,290)</td>
<td>6,028 (4,990-7,065)</td>
</tr>
</tbody>
</table>

NA*, not available.

* Not available because total shoulder arthroplasty codes were the same for anatomic and reverse total shoulder arthroplasty in 2009 and until October 1, 2010.

**Figure 1** Yearly estimates of primary shoulder arthroplasty per 100,000 persons in United States by age group and sex. Green lines represent women, and blue lines represent men. Shoulder arthroplasty includes anatomic total shoulder arthroplasty, hemiarthroplasty, and reverse shoulder arthroplasty.
Osteoarthritis was the most common indication for anatomic total shoulder arthroplasty (90.1% of patients), hemiarthroplasty (42.8% of patients), and reverse shoulder arthroplasty (53.2% of patients) (Table IV). Patients undergoing reverse shoulder arthroplasty had rotator cuff tear/syndrome in 52.5% of cases. The concomitant diagnosis of osteoarthritis and rotator cuff disorder was found in only 29.8% of cases. The indications for revision arthroplasty included mechanical causes (22% of cases), dislocation (18% of cases), aseptic loosening (13% of cases), and prosthetic or periprosthetic fracture (8% of cases) (Fig. 3).

### Discussion

We assessed recent estimates of utilization of primary and revision shoulder arthroplasty in the United States. We also determined the contribution of reverse shoulder arthroplasty to overall utilization of primary shoulder arthroplasty and present age- and sex-stratified national rates of shoulder arthroplasty. We found that the utilization of primary shoulder arthroplasty has significantly increased in just a 3-year span from 2009 to 2011, with a major contribution from reverse shoulder arthroplasty in 2011. There was also a substantial yearly revision arthroplasty rate of 8.2% to 8.8% from 2009 to 2011. Although complication and mortality rates of shoulder arthroplasty were low, reverse shoulder arthroplasty had higher rates than anatomic total shoulder arthroplasty.

Kim et al. used the Nationwide Inpatient Samples from 1993 to 2008 and reported an increase from an estimated 13,837 primary shoulder arthroplasty procedures in 1993 to 46,951 procedures in 2008 (increases of 339% from 1993 and 246% from 1999). In contrast, the utilization of total knee arthroplasty increased from an estimated 262,601 procedures in 1999 to 615,050 procedures in 2008 (an increase of 135% from 1999). Kim et al postulated that some of the growth in shoulder arthroplasty was due to the approval of reverse shoulder arthroplasty by the FDA in 2003. However, reverse shoulder arthroplasty did not have a dedicated ICD-9-CM procedure code, and therefore, the contribution of reverse shoulder arthroplasty to the overall growth in shoulder arthroplasty could not be determined from this study. For the first time, the 2011 Nationwide Inpatient Sample permits calculations of reverse shoulder arthroplasty estimates because the Centers for Medicare & Medicaid Services assigned reverse shoulder arthroplasty a dedicated ICD-9-CM procedure code that was effective on October 1, 2010. Our study shows that in a short span of 3 years, there has been significant growth in the utilization of primary shoulder arthroplasty, and reverse shoulder arthroplasty comprised 42% of all primary shoulder arthroplasty procedures in 2011. Although the growth in primary shoulder arthroplasty was greater than that for total knee arthroplasty between 1999 and 2008, the absolute utilization of shoulder arthroplasty is only a fraction of the utilization of total knee arthroplasty. Moreover, the advent of the reverse shoulder prosthesis represents a substantial improvement in prosthetic strategy for shoulder arthroplasty; such a parallel does not exist for total knee arthroplasty.

Boguski et al. used 2012 data on 3,119 shoulder arthroplasty cases from 100 hospitals in 18 states to characterize variation in the utilization of reverse shoulder arthroplasty across hospitals and the effect of hospital volume on this variation. They reported wide variation between 0% and 100% (mean, 42.3%) in the use of reverse shoulder arthroplasty across hospitals. They also found that hospitals with a high total shoulder arthroplasty replacement volume had a lower variation in reverse shoulder arthroplasty use than low-volume hospitals. In our study, reverse shoulder arthroplasty accounted for 42% of all primary shoulder arthroplasty cases. This is similar to the finding reported by Boguski et al except that our study also includes hemiarthroplasty in this calculation. Thus, the utilization of reverse shoulder arthroplasty was substantial and may possibly comprise a majority of shoulder arthroplasty procedures in the future. Despite the high reverse shoulder arthroplasty utilization, there are only a
few studies documenting improved pain and functional outcomes after reverse shoulder arthroplasty and data on long-term outcomes from robustly designed longitudinal studies are lacking. Reverse shoulder arthroplasty is a complex surgical procedure. Prior studies have also reported high rates of complications such as scapular notching, glenoid dissociation (due to baseplate failure or loosening), acromial/scapular spine fracture, and dislocation. Reoperation rates of 12% and 33% were reported in 2 prior studies. These rates are higher than the 8.2% to 8.8% overall revision arthroplasty rates reported in our study. Reverse shoulder arthroplasty also had a substantially higher in-hospital mortality rate and postoperative infection/wound complication rate as compared with anatomic total shoulder arthroplasty in our study. Our data also showed a higher mean length of stay after reverse shoulder arthroplasty as compared with anatomic total shoulder arthroplasty. Thus, the increased utilization of reverse shoulder arthroplasty needs further assessment.

Reverse shoulder arthroplasty was initially described by Grammont and Baulot and is principally indicated in cases of glenohumeral arthritis associated with instability as a result of a functionally or anatomically deficient rotator cuff in elderly persons; however, our data show that the concomitant diagnosis of osteoarthritis and rotator cuff disorder was coded in only 29.8% of cases undergoing reverse shoulder arthroplasty. This is likely because the indications for reverse shoulder arthroplasty have expanded to include isolated large rotator cuff tears, proximal humeral fractures, cases of revision arthroplasty, and younger patients. Reverse shoulder arthroplasty recently has also been described to produce good results in patients with...
primary glenohumeral osteoarthritis and biconcave glenoids without rotator cuff impairment. \(^{20}\)

Day et al\(^{19}\) used the Nationwide Inpatient Samples to project future growth in shoulder arthroplasty procedures. They presented an estimated growth rate of 205\% for hemiarthroplasty and 353\% for revision arthroplasty between 2007 and 2015. Per our estimates, the cumulative rate of shoulder arthroplasty increased by 60\% between 2007 and 2011. Although this rate is slower than that estimated by Day et al and may not reach 205\% by 2015, the growth is substantial. Possible contributors to this growth include the addition of reverse shoulder arthroplasty to shoulder arthroplasty procedures, expansion of indications for shoulder arthroplasty, and an increasing elderly population. Other reasons may include serving an unmet need in patients who did not previously have awareness of or access to primary shoulder arthroplasty that has been reliably shown to provide pain relief and improve functional outcomes in patients with shoulder arthropathies and fractures. \(^{7,11,18,26,35}\) Orthopaedic surgeons may also have increased awareness and expertise in performing shoulder arthroplasty over the past decade, thus improving patient access.

As reported by Kim et al,\(^{16}\) there was also a growth in orthopaedic surgeon density between 2008 and 2010, from 5.8 to 7.2 surgeons per 100,000 persons. The American Academy of Orthopaedic Surgeons recently estimated that the orthopaedic surgeon density further increased to 8.7 per 100,000 persons in 2012.\(^{74}\) There also has been a rapid increase in dedicated shoulder surgery fellowships since the mid 1990s. Although the relationship between orthopaedist density and rates of surgery is debated,\(^{39,41}\) it is possible that the increase in density of surgeons with expertise in performing shoulder surgery is one of the factors that has contributed to the increase in rates of shoulder arthroplasty.

Female persons had higher utilization rates of primary shoulder arthroplasty procedures, including those for reverse shoulder arthroplasty. This finding is in agreement with previous reports.\(^{16}\) The highest utilization of reverse shoulder arthroplasty was in the 75- to 84-year-old age groups. Because there is an increasing rate of rotator cuff impairment (symptomatic and asymptomatic) with increasing age,\(^{21,31,33,44}\) it is possible that reverse shoulder arthroplasty was the preferred option in older patients needing shoulder arthroplasty. Overall primary shoulder arthroplasty rates were also the highest in 75- to 84-year-old women, followed by 65- to 74-year-old women and then by 75- to 84-year-old men, likely because of a higher incidence of osteoarthritis with increasing age. The rates of primary shoulder arthroplasty were substantially lower in patients aged 85 years or older likely because of concerns of surgical morbidity and death and the ability of patients to participate in postoperative rehabilitation. The in-hospital mortality rate and length of stay were higher for hemiarthroplasty and reverse shoulder arthroplasty (as opposed to primary anatomic shoulder arthroplasty) likely because these patients were older and a larger proportion of patients undergoing hemiarthroplasty had a proximal humeral fracture that is cause for additional morbidity and death.

Although our data permit calculation of nationally representative shoulder arthroplasty rates, our study has a few limitations. These include the use of ICD-9-CM codes that are not entirely specific to the procedure of interest. Hence, procedures such as resurfacing of the humeral head or glenoid may be included in the total shoulder arthroplasty or hemiarthroplasty estimates. However, these only form a small fraction of shoulder arthroplasty procedures and may also be coded using a nonspecific shoulder arthroplasty/repair code of 81.83. We were also unable to ascertain yearly estimates for reverse shoulder arthroplasty in 2009 and 2010 because of the lack of an ICD-9-CM code specific to reverse shoulder arthroplasty. Hence, reverse shoulder arthroplasty procedures in 2009 and in most of 2010 were likely coded as total shoulder arthroplasty or hemiarthroplasty. We used the revision arthroplasty code of 81.97 as has been previously described.\(^{3}\) However, the ICD-9-CM code of 81.83 may also be assigned to cases of revision shoulder arthroplasty. Code 81.83 is described as “other repairs of shoulder” and may also include shoulder procedures using an internal fixation device or external traction or fixation. Hence, we did not use code 81.83 to calculate cases of revision arthroplasty in our study and likely underestimated the utilization of revision arthroplasty. Our data source also does not specifically allow for recognition of revision reverse shoulder arthroplasty cases because a specific corresponding ICD-9-CM procedure code does not exist. More specific details on complications of hemiarthroplasty such as those due to tuberosity healing, complications of total shoulder arthroplasty such as glenoid loosening, and complications of reverse shoulder arthroplasty such as instability cannot be ascertained from our data.

### Conclusion

The utilization of primary shoulder arthroplasty has substantially increased in just a 3-year time span from 2009 to 2011, with a major contribution from reverse shoulder arthroplasty in 2011. Efforts to understand the long-term outcomes of reverse shoulder arthroplasty are needed. The practice of reverse shoulder arthroplasty utilization in patients without rotator cuff impairments also needs further assessment, given the large proportion of patients without concomitant osteoarthritis and rotator cuff impairment undergoing reverse shoulder arthroplasty. There was a low in-hospital complication and mortality rate after primary and revision shoulder arthroplasty, and mechanical complications and dislocation were the main causes of revision arthroplasties. The burden from revision arthroplasties in the United States is also substantial, and assessments of strategies
to optimize longevity and outcomes of primary shoulder arthroplasty are needed.

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Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jse.2014.06.055.

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