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BASIC SCIENCE

Increasing incidence of primary reverse and anatomic total shoulder arthroplasty in the United States

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Background: The purpose of this study was to determine the incidence of primary reverse total shoulder arthroplasty (RTSA) and anatomic total shoulder arthroplasty (TSA) in the United States and examine changes in age- and sex-based procedure rates. A secondary goal was to determine the incidence of hemiarthroplasty.

Methods: Using nationally representative data along with US Census data, we identified >508,000 cases of primary RTSA, anatomic TSA, and shoulder hemiarthroplasty from 2012 to 2017. Trends in the incidence of each procedure were analyzed, and sex- and age-adjusted procedure rates were calculated.

Results: From 2012 to 2017, the population-adjusted incidence of primary RTSA increased from 7.3 cases per 100,000 persons (22,835 procedures) to 19.3 cases per 100,000 (62,705 procedures); anatomic TSA increased from 9.5 cases per 100,000 (29,685 procedures) to 12.5 cases per 100,000 (40,665 procedures); and hemiarthroplasty decreased from 3.7 cases per 100,000 (11,695 procedures) to 1.5 cases per 100,000 (4930 procedures). These trends were observed among male and female patients, as well as all age groups. The greatest increase in incidence was seen in male patients as well as patients aged 50-64 years undergoing RTSA.

Conclusion: The incidence of primary RTSA and incidence of anatomic TSA have increased substantially in the United States from 2012 to 2017 whereas the incidence of hemiarthroplasty has decreased.

Level of evidence: Epidemiology Study; Large Database Analysis

Keywords: Total shoulder arthroplasty; incidence; reverse total shoulder arthroplasty; anatomic total shoulder arthroplasty; RTSA; TSA

Reverse total shoulder arthroplasty (RTSA) was approved by the US Food and Drug Administration (FDA) in 2004 for the treatment of rotator cuff arthropathy. Since that time, the indications for the procedure have expanded to include glenohumeral osteoarthritis, proximal humerus fractures, inflammatory arthritis, pseudoparalysis, and revision surgery.[1,5,6,11,13,14,21,26] More recently, RTSA has shown promising results in the treatment of proximal humerus malunion and irreparable rotator cuff tears.[17,24]

The use of RTSA and anatomic total shoulder arthroplasty (TSA) has been increasing in the United States. Prior studies using national data did not report on trends in RTSA utilization.[3,12,19,22,29] Due to because of a limitation in coding, national data included RTSA and anatomic TSA under the same *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) procedure code (80.80) until 2010, when a unique RTSA code was created (80.88).[2] Since that time, several studies have

This study was exempt from review by our institutional review board because it did not qualify as human subjects research.

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analyzed RTSA and TSA using administrative data through 2011, the first year with distinct coding for RTSA, but none of the groups reported on trends or changes in the national incidence, as only 1 year of RTSA data was assessed.[19,22,29] Understanding national trends in shoulder arthroplasty is important to improve cost-effectiveness and to identify changes in practice patterns or outcomes that are not appreciated in smaller studies.

The purpose of this study was to determine the incidence of primary RTSA and anatomic TSA in the United States and examine changes in age- and sex-based procedure rates. A secondary goal was to analyze trends in the utilization of shoulder hemiarthroplasty. We hypothesized that there would be a dramatic increase in the number of primary RTSA and anatomic TSA procedures performed, with a concomitant decrease in hemiarthroplasty, from 2012 to 2017.

Materials and methods

This was a retrospective, epidemiologic study using US national hospital data.

Data source

Data from the National Inpatient Sample (NIS) of the Healthcare Cost and Utilization Project, Agency for Healthcare Research and Quality, were used for this study. The NIS is the largest all-payer database of inpatient hospital stays in the United States.[9] The NIS, which was first published in 1988 and has been released annually through 2017, includes clinical and utilization information such as International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-9) diagnosis and procedure codes (prior to October 1, 2015); ICD-10-CM and *Procedure Coding System* diagnosis and procedure codes (beginning October 1, 2015); patient demographic data, hospital characteristics, sources of payment; total charges, lengths of hospital stay, and comorbidity measures.[9] Using a complex weighting design, the database provides national estimates with data from >35 million hospitalizations. Beginning in 2012, the NIS was redesigned to provide better national estimates including sampling discharge records from all hospitals participating in the Healthcare Cost and Utilization Project, rather than a sample of hospitals from which all discharges were retained, as in prior years.[8] Therefore, we chose 2012 as our first year of study and ended with 2017, which is the most recent year available.

Patient selection

We identified all observations with a primary listed procedure of RTSA, anatomic TSA, or shoulder hemiarthroplasty from 2012 to 2017 using ICD-9-CM procedure codes (for observations prior to October 1, 2015) and ICD-10-CM procedure codes (for observations beginning October 1, 2015). For cases of RTSA, we used ICD-9-CM procedure code 81.88 or ICD-10-CM procedure code 0RRJ00Z or 0RRK00Z (right or left RTSA). For cases of anatomic TSA, we used ICD-9-CM procedure code 81.80 or ICD-10-CM procedure code 0RRJ0JZ or 0RRK0JZ (replacement of right or left shoulder joint), 0RRJ0J6 plus 0RRJ0J7 (replacement of right shoulder joint—glenoid surface and humeral surface), or 0RRK0J6 plus 0RRK0J7 (replacement of left shoulder joint—glenoid and humeral surface). For cases of hemiarthroplasty, we used ICD-9-CM procedure code 81.81 or ICD-10-CM procedure code 0RRJ0J6 or 0RRRK0J6 (replacement of right or left shoulder joint—humeral surface) without 0RRJ0J7 or 0RRK0J7 (replacement of right or left shoulder joint—glenoid surface). Any cases with a revision procedure code (ICD-9-CM procedure code 81.97 or ICD-10-CM procedure codes 0RWJxxx or 0RWKxxx) or primary diagnosis code indicating a possible revision case (ICD-9-CM diagnosis codes 996.4x, 996.66, 996.69, 996.77, and 996.79 or ICD-10-CM diagnosis code T84xxx) were excluded.

Statistical analysis

National estimates of each shoulder arthroplasty type were calculated using the weighting design created by the NIS. Overall incidence rates were calculated using US Census data for each respective year.[27] The sex-adjusted incidence and age-adjusted incidence were calculated using sex-specific and age-specific population data, respectively, for each year. ICD-9-CM or ICD-10-CM diagnosis codes were assessed for each procedure and the most common diagnoses were tabulated. Data were analyzed using IBM SPSS Statistics for Windows software (version 23.0 [released 2015]; IBM, Armonk, NY, USA).

Results

Overall, 22,835 primary RTSA procedures were performed in 2012 whereas the number performed in 2017 nearly tripled to 62,705 RTSA procedures. The number of anatomic TSA procedures increased from 29,685 in 2012 to 40,665 in 2017. The number of shoulder hemiarthroplasty procedures decreased by nearly half, from 11,695 in 2012 to 4930 in 2017 (Table I). Figure 1 displays the trends of all 3 surgical procedures from 2012 to 2017.

Of the 3 shoulder procedures analyzed, RTSA showed the largest increase in incidence, increasing from a national incidence of 7.3 cases per 100,000 persons in 2012 to 19.3 cases per 100,000 persons in 2017. The national incidence of anatomic TSA also increased but to a lesser extent, from 9.5 cases per 100,000 persons in 2012 to 12.5 cases per 100,000 persons in 2017. The national incidence of hemiarthroplasty decreased from 3.7 per 100,000 persons in 2012 to 1.5 per 100,000 persons in 2017 (Table II).

Sex- and age-adjusted incidence rates also changed over time (Tables III and IV). Among the 3 procedures, the largest increase in the sex-adjusted incidence occurred in male patients undergoing RTSA, with an incidence of 5.3 cases per 100,000 men in 2012 compared with 15.1 cases per 100,000 men in 2017. The highest rate of any procedure was in female patients undergoing RTSA, with an incidence of 23.2 cases per 100,000 women in 2017 (Table III). The age-adjusted incidence of RTSA and anatomic TSA

Table I Number of procedures performed by year in the United States

	2012	2013	2014	2015	2016	2017
RTSA	22,835	28,625	35,495	45,380	53,665	62,705
Anatomic TSA	29,685	32,730	34,485	36,180	38,345	40,665
Hemiarthroplasty	11,695	9990	8195	7080	5840	4930

RTSA, reverse total shoulder arthroplasty; *TSA*, total shoulder arthroplasty.

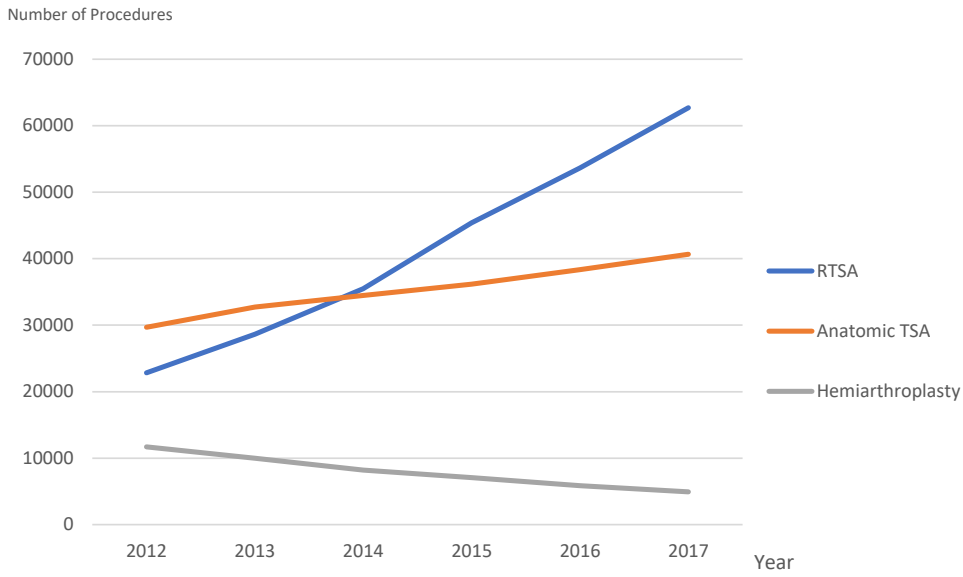

Figure 1 Annual procedure volume from 2012 to 2017. *RTSA*, reverse total shoulder arthroplasty; *TSA*, total shoulder arthroplasty.

Table II Incidence of procedures per 100,000 persons by year in the United States

	2012	2013	2014	2015	2016	2017
RTSA	7.3	9.1	11.1	14.1	16.6	19.3
Anatomic TSA	9.5	10.4	10.8	11.3	11.9	12.5
Hemiarthroplasty	3.7	3.2	2.6	2.2	1.8	1.5

RTSA, reverse total shoulder arthroplasty; *TSA*, total shoulder arthroplasty.

increased in all age groups whereas the age-adjusted incidence of hemiarthroplasty decreased in all age groups over the study period (Table IV).

The most common diagnosis in cases of primary RTSA in 2012 was cuff tear arthropathy (50.1%), followed by osteoarthritis (23.6%). In 2017, cuff tear arthropathy accounted for 43.8% of primary diagnoses for RTSA whereas osteoarthritis accounted for 32.9% of primary diagnoses. For anatomic TSA, osteoarthritis was the most common primary diagnosis in 2012 and 2017. The most common primary diagnosis in cases of hemiarthroplasty in 2012 and 2017 was osteoarthritis, followed by proximal humerus fracture (Table V).

Discussion

This study demonstrates that the incidence of primary RTSA and anatomic TSA is increasing in the United States whereas the rate of shoulder hemiarthroplasty is decreasing. The most dramatic change occurred in patients undergoing primary RTSA as the overall rate nearly tripled over the

Table III Sex-adjusted incidence per 100,000 persons by procedure type from 2012 to 2017

	2012		2013		2014		2015		2016		2017	
	Procedures	Incidence	Procedures	Incidence	Procedures	Incidence	Procedures	Incidence	Procedures	Incidence	Procedures	Incidence
RTSA												
Male	8115	5.3	10,165	6.5	13,120	8.4	17,255	10.9	20,605	13.0	24,295	15.1
Female	14,720	9.2	18,460	11.5	22,375	13.8	28,125	17.2	33,030	20.1	38,410	23.2
Anatomic TSA												
Male	14,455	9.4	16,155	10.4	17,035	10.9	18,120	11.5	19,265	12.1	20,395	12.7
Female	15,230	9.5	16,575	10.3	17,450	10.8	18,050	11.1	19,055	11.6	20,270	12.3
Hemiarthroplasty												
Male	4470	2.9	3800	2.4	3190	2.0	2935	1.9	2380	1.5	2150	1.3
Female	7225	4.5	6190	3.9	5005	3.1	4145	2.5	3455	2.1	2780	1.7

RTSA, reverse total shoulder arthroplasty; *TSA*, total shoulder arthroplasty.

Table IV Age-adjusted incidence per 100,000 persons by procedure type from 2012 to 2017

	2012		2013		2014		2015		2016		2017	
	Procedures	Incidence	Procedures	Incidence	Procedures	Incidence	Procedures	Incidence	Procedures	Incidence	Procedures	Incidence
RTSA												
18-49 yr	195	0.1	260	0.2	360	0.3	475	0.3	505	0.4	460	0.3
50-64 yr	3820	6.2	4275	6.9	6305	10.0	8380	13.3	9900	15.6	11,835	18.7
65-79 yr	13,480	42.9	17,655	53.7	21,485	62.4	27,675	77.6	33,115	89.1	39,320	101.9
≥80 yr	5335	44.7	6435	55.0	7345	62.3	8850	74.4	10,145	84.9	11,090	90.7
Anatomic TSA												
18-49 yr	1205	0.9	1185	0.9	1240	0.9	1370	1.0	1435	1.0	1540	1.1
50-64 yr	8945	14.6	10,735	17.3	11,385	18.1	11,965	19.0	12,985	20.5	13,080	20.6
65-79 yr	16,370	52.1	17,935	54.6	18,825	54.7	19,865	55.7	20,950	56.4	22,860	59.2
≥80 yr	3165	26.5	2875	24.6	3035	25.7	2980	25.1	2975	24.9	3185	26.0
Hemiarthroplasty												
18-49 yr	1240	0.9	1055	0.8	920	0.7	995	0.7	775	0.6	775	0.6
50-64 yr	3715	6.1	3270	5.3	2815	4.5	2415	3.8	1920	3.0	1680	2.6
65-79 yr	4845	15.4	3975	12.1	3195	9.3	2625	7.4	2275	6.1	1895	4.9
≥80 yr	1895	15.9	1685	14.4	1265	10.7	1045	8.8	870	7.3	580	4.7

RTSA, reverse total shoulder arthroplasty; *TSA*, total shoulder arthroplasty.

Table V Most common diagnoses (based on diagnosis codes) by procedure type

	2012		2017	
	Diagnosis	% of patients with diagnosis	Diagnosis	% of patients with diagnosis
RTSA				
1st common	Cuff tear arthropathy/OA with RCT	50.1	Cuff tear arthropathy/OA with RCT	43.8
2nd most common	Osteoarthritis	23.6	Osteoarthritis	32.9
3rd most common	Proximal humerus fracture	11.2	Proximal humerus fracture	14.2
Anatomic TSA				
1st common	Osteoarthritis	91.9	Osteoarthritis	97.1
2nd most common	Rheumatoid arthritis	4.1	Rheumatoid arthritis	2.8
3rd most common	Aseptic necrosis head of humerus	2.2		
Hemiarthroplasty				
1st common	Osteoarthritis	44.5	Osteoarthritis	53.2
2nd most common	Proximal humerus fracture	37.9	Proximal humerus fracture	34.5
3rd most common	Cuff tear arthropathy/OA with RCT	12.5	Osteonecrosis	12.0

RTSA, reverse total shoulder arthroplasty; *TSA*, total shoulder arthroplasty; *OA*, osteoarthritis; *RCT*, rotator cuff tear.
The most common diagnoses (based on diagnosis codes) are listed and may not add up to 100%.

6-year study period. This marked growth in RTSA was observed across both sexes and all age groups.

These findings demonstrate changes and updated national data from previous studies using the NIS. Kim et al[12] investigated trends in TSA and hemiarthroplasty from 1993 to 2008 in the United States and showed that both the hemiarthroplasty incidence and TSA incidence increased each year of the study, in contrast to our study, which shows a decreasing trend in hemiarthroplasty. They also found that hemiarthroplasty was the more common treatment until 2006, at which point TSA became the more commonly performed procedure.[12] Our study demonstrates that since that time, hemiarthroplasty has been less commonly used, with only 4930 procedures performed in 2017 compared with >20,000 procedures performed in 2008 in the study of Kim et al. It is important to note that they were not able to analyze rates of RTSA procedures because a distinct ICD-9-CM procedure code for RTSA was not created until 2010, after the final analysis year in their study. Finally, the number of TSA procedures performed in the final year of the study by Kim et al was 26,000 (which included both RTSA and anatomic TSA together), which is much lower than the finding in our final study year showing >103,000 RTSA and anatomic TSA procedures.[12]

The most recent national estimates using the NIS included data for 2011 and were reported in at least 3 studies.[19,22,29] Padegimas et al[19] estimated the incidence and future projections of shoulder arthroplasty (combining hemiarthroplasty, anatomic TSA, and RTSA) using the NIS from 2002 to 2011. They did not isolate RTSA from anatomic TSA and, therefore, did not report any findings regarding the RTSA incidence. Additionally, their projections overestimated the true incidence of TSA, at least through the years of our study until 2017. Westermann et al[29] also analyzed the NIS from 2002 to 2011. They found that 21,000 RTSAs, 29,000 anatomic TSAs, and 15,000 hemiarthroplasties were performed in 2011. These findings were substantiated in a study by Schairer et al,[22] who reported on single-year data from the 2011 NIS. Moreover, Day et al[4] investigated shoulder arthroplasty rates using 100% of the Medicare sample for 2011 and showed slightly lower values for each procedure.

Comparing the results of our study with those of other national registries shows that similar trends in shoulder arthroplasty utilization have occurred in other countries. A 2017 report by Lübbeke et al[15] described trends using shoulder registries from 9 different countries and showed that the annual incidence rate of shoulder arthroplasty nearly tripled from the early 2000s through the 2010s. By 2014, the incidence of shoulder arthroplasty ranged from 16 to 20 per 100,000 population in Australia, New Zealand, and Denmark.[15] The country with the highest incidence was Germany, with a rate of 34 per 100,000 population in 2012.[15] Analysis of arthroplasty design from 2006 through 2014 showed large increases in the proportion of RTSA use in several countries, with the greatest increases in RTSA seen in Norway (52%, increased from 12%) and New Zealand (56%, increased from 2%).[15] In a study of the

Finnish Arthroplasty Register, Harjula et al[7] reported an increase in utilization of 500% for anatomic TSA and 4500% for RTSA from 2004 to 2015, with rates of 15 per 100,000 person-years for male patients and 26 per 100,000 person-years for female patients. Lübbeke et al showed that the most common indicating diagnosis for shoulder arthroplasty in 9 different countries was osteoarthritis, followed by cuff tear arthropathy. Harjula et al corroborated this finding, showing that osteoarthritis was the most common indication for both anatomic TSA and RTSA. They noted that cuff tear arthropathy was recorded if patients had osteoarthritis with a rotator cuff tear and that some patients with only osteoarthritis may have had a missing cuff tear diagnosis and, therefore, were miscategorized as having osteoarthritis when they actually had cuff tear arthropathy.[7] This finding may have some effect on the diagnosis codes in our study as well, given that there was no *International Classification of Diseases, Ninth Revision* code—nor is there currently a specific *International Classification of Diseases, Tenth Revision* code—for rotator cuff arthropathy and many surgeons code these patients as having osteoarthritis with rotator cuff tear or solely as having osteoarthritis.

There are several possible explanations for the increase in the use of RTSA and anatomic TSA in the United States. First, the indications for RTSA have expanded since its initial approval by the FDA in 2004 for rotator cuff arthropathy. Although not specifically approved by the FDA, indications have expanded to include proximal humeral fractures, glenohumeral arthritis with glenoid bone loss, inflammatory arthritis, revision surgery, and irreparable rotator cuff tears with pseudoparalysis even in the absence of osteoarthritis.[1,5,6,11,13,14,21,26] More orthopedic surgery residents are undergoing specialty fellowship training and the number of fellowship-trained shoulder surgeons is increasing in the United States.[10] Horst et al[10] showed that the number of shoulder and elbow fellows doubled from 2003 to 2013, which is during the early part of our study. Thus, a greater number of surgeons are being trained with higher-volume shoulder arthroplasty exposure, which may also contribute to the higher rates of RTSA and anatomic TSA being performed. Another explanation for the rise in RTSA procedures being performed is the aging population. The largest increase for any procedure was seen for RTSA and was observed in the group aged 50-64 years. Although the population of this age group, according to US Census records, increased by 2 million during the study period of 2012-2017, the composition of such patients within the total US population remained the same, at 20%.[27] These data allude to additional factors contributing to the rise in RTSA and anatomic TSA procedures outside of an aging population alone.

One important finding of this study is the increase in RTSA procedures observed in patients aged $<$ 65 years. Historically, the majority of patients undergoing RTSA have been elderly, with a mean age of 73 years.[22] This study found a $>$3-fold increase in the incidence of RTSA in the 50- to 64-year-old age group, which was a higher increase than in any other age group. The increase in this demographic may be due in part to several studies demonstrating good outcomes with RTSA in patients aged $<$ 55-60 years.[17,18,23,28] In our study, the increase in the incidence of RTSA was small in patients aged $<$ 50 years. Although in the hip and knee population, patients aged $<$ 50 years are undergoing total hip and knee replacement at increasing rates, this study confirms that TSA in this age group is still uncommon, with rates of 1.1 per 100,000 for anatomic TSA and 0.3 per 100,000 for RTSA.[13,16]

A continued increase in the utilization of RTSA is expected as the indications for this surgical procedure expand, surgical expertise increases, and technology improves. An irreparable rotator cuff tear poses a difficult condition for shoulder surgeons, and RTSA provides predictable pain relief and functional improvement in a majority of patients.[24] Sevivas et al[24] performed a comprehensive systematic review and meta-analysis and showed that patients with irreparable massive rotator cuff tears had a high likelihood of achieving improvements in pain and function after RTSA. Although this study excluded the diagnosis of shoulder fracture as an indication for RTSA, the use of RTSA for acute proximal humeral fractures and subsequent complications such as malunion and avascular necrosis will potentially increase the use of RTSA.[20,25] In a study of 42 patients who underwent RTSA for post-traumatic sequelae of proximal humeral fractures with tuberosity malunion, Raiss et al[20] showed that RTSA provided functional improvement with almost all patients giving satisfactory, good, or very good subjective assessments at a mean of 4 years' follow-up.

As demonstrated in this study, the NIS database has strengths and weaknesses. Coding error is a known weakness of any large database and is dependent on the hospital's documentation practice. Additionally, the NIS does not collect long-term patient data, so longitudinal follow-up assessment is not possible. The indications for surgery are determined by the primary ICD-9-CM or ICD-10-CM diagnosis codes, but these codes do not always provide enough detail or specificity to elucidate the exact indication for surgery in each case. However, our primary goal was to assess the incidence of RTSA and anatomic TSA, not comorbidities or indicating diagnoses. Furthermore, the indicating diagnosis codes in our study are consistent with those in other nationally representative studies in the United States and other countries.[7,11,15] In patients undergoing RTSA, the most common indicating diagnosis in this study was cuff tear arthropathy whereas the second most common diagnosis was osteoarthritis. It is possible that some patients with a diagnosis code for osteoarthritis also had rotator cuff pathology but the majority of cuff tear arthropathy diagnoses were still captured for both 2012 and 2017, as this was the most common diagnosis for RTSA. Although the use of RTSA for osteoarthritis may be

increasing, further studies are needed to confirm this change in patients with intact rotator cuffs. One strength of the NIS is that it can provide national estimates for various conditions and procedures that cannot be analyzed with single-surgeon or even multiple-hospital cohorts. Additionally, the NIS redesigned its hospital sampling method starting with the 2012 data year to provide better national estimates.[8]

Conclusion

The incidence trends reported in this study show a more dramatic increase in TSA total shoulder arthroplasty than in previous reports. This is especially true for RTSA, for which the incidence of annual procedures performed nearly tripled from 2012 to 2017. This increase was observed across male and female patients, as well as all age groups studied. Conversely, this study demonstrates a steady decrease in the incidence of hemiarthroplasty over time. Knowledge of these national trends in the context of the described international trends is important to improve cost-effectiveness and to understand changes in practice patterns that are not appreciated in smaller studies.

Disclaimer

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