

Total shoulder arthroplasty versus reverse total shoulder arthroplasty

Outcome comparison in osteoarthritis patients with or without concurrent rotator cuff deficiency

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Abstract

Osteoarthritis (OA) is a common shoulder disorder that impacts shoulder functions. Shoulder arthroplasty is often required to restore function and quality of life. Reverse total shoulder arthroplasty (RSA), which was originally designed mainly for irreparable rotator cuff damage, has gained popularity in recent years for the treatment of advanced shoulder OA instead of the clinically standard total shoulder arthroplasty (TSA). However, this RSA has some nonnegligible flaws such as higher complications rate and economic cost, not mention the following problems caused by irreversible physical structural damage. Therefore, the employment of RSA needs to be carefully considered. This study aimed to compare TSA and RSA in OA patients with or without rotator cuff damage to better guide clinical decision making. We believe the radical use of RSA in patients without rotator cuff deficiency may cause more harm than good.

We queried the Nationwide Inpatient Sample (NIS) database from 2011 to 2014 to collect information on OA patients who received TSA and RSA. Patients were divided into 2 groups of comparison according to the presence of rotator cuff deficiency and matched with propensity score analysis.

A total of 57,156 shoulder arthroplasties were identified. RSA patients in the rotator cuff deficiency group had significant higher transfusion rates and longer hospital stays. RSA patients without rotator cuff deficiency had a statistically significantly higher number of implant-related mechanical complications, acute upper respiratory infections and postoperative pain. Overall, RSA incurred higher costs in both groups.

For OA patients with rotator cuff deficiencies, RSA has its benefits as complication rates were comparable to TSA. For those patients without rotator cuff deficiencies, the use of RSA should be reconsidered as there were more complications with higher severity.

Abbreviations: HA = hemiarthroplasty, ICD-9-CM = International Classification of Diseases-9th Revision-Clinical Modification, NIS = Nationwide Inpatient Sample, OA = osteoarthritis, RSA = reverse total shoulder arthroplasty, TSA = total shoulder arthroplasty.

Keywords: arthroplasty, osteoarthritis, reverse total shoulder arthroplasty, rotator cuff, total shoulder arthroplasty

1. Introduction

Osteoarthritis (OA) of the glenohumeral joint often result in painful shoulders.^[1,2] In cases when surgical intervention is warranted, joint replacement has been recommended by the American Academy of Orthopedic Surgeons (AAOS) as it has been shown to

result in significant improvement of pain, quality of life, function, and overall patient health.^[3-11] Moreover, total shoulder arthroplasty (TSA) has been recommended by AAOS over hemiarthroplasty (HA) due to better outcomes and less chance of revision.^[12]

Reverse total shoulder arthroplasty (RSA) was first developed by Grammont in 1980s specifically for the management of

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The authors have no competing interests.

The datasets generated during and/or analyzed during the current study are publicly available. The National (Nationwide) Inpatient Sample (NIS) is the largest publicly available all-payer inpatient care database in the United States, containing data on more than 7 million hospital stays. All data used in this study is available online.

Ethical approval: The study protocol has been approved by ShenZhen University Ethics Committee.

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irreparable rotator cuff damage, complex fractures as well as a salvage option for previously failed conventional TSA, in which the rotator cuff tendons are deficient.^[13–16] The congruent joint surfaces of the reverse ball-and-socket design provides inherent stability, due to its altered center of shoulder joint rotation that increases the deltoid moment arm thus enhance the torque produced by deltoid, as a result, it compensates for the deficiency of RC and improve the shoulder elevation in these patients.^[13,17–19]

Notably, RSA has some disadvantages that limit its wide usage; first of all, the RSA prosthesis is much more expensive than the other prosthesis.^[20] Secondly, RSA has high risk of shoulder dislocation,^[21,22] which causes repeated pain and suffering to patients as well as additional healthcare cost for treatment. Moreover, previous studies reported higher surgical complications rates such as mechanical loosening, infection,^[23] and hemorrhage^[24] in patients who received RSA compared to TSA.

Traditionally, TSA has been the standard treatment for shoulder OA. However, in the recent years, the use of RSA has increased rapidly and became preferred over TSA even when rotator cuff deficiency is not present.^[20,25]

The purpose of current study is to investigate the complication rates associated with RSA surgery when used for the treatment of different conditions, and more specifically, the postoperative outcome of OA patients with or without rotator cuff deficiency who were treated with either TSA or RSA, providing further evidence to guide surgical decision for the surgical management of OA.

2. Methods

2.1. Study design and data source

This study is a descriptive study. The clinical information of patients was queried from the Nationwide Inpatient Sample (NIS) from 2011 to 2014, a database released by the Healthcare Cost and Utilization Project. The NIS database contains all-payer data on hospital inpatient stays from States participating in the Healthcare Cost and Utilization Project (HCUP). Each year of the NIS includes over 7 million inpatient stay data. It gathered more than 100 features from each of the discharges,

including demographical information, hospital information, comorbidities, diagnoses during the stay, types of procedures, etc. The tremendous size of the NIS data provides significant benefits for the understanding of clinical problems from a statistical perspective.

2.2. Data extraction and processing

Using the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes, we identified patients who underwent primary procedures as TSA (81.80), RSA (81.88), HA (81.81) during the period from 2011 to 2014. There were totally 57,156 samples extracted, 25,554 for TSA, 22,337 for RSA, and 9265 for HA. To further analyze the data, we categorized OA patients into 2 groups based on the presence of rotator cuff deficiencies (Fig. 1). Postoperative complications, length of hospital stay, costs, were recorded. A list of procedure codes used are listed in Supplemental Table 4, <http://links.lww.com/MD/H62>.

2.3. Data analysis

In order to compare the differences between the outcomes of TSA and RSA in the patients with or without rotator cuff deficiencies, patients were matched using a propensity score analysis method. The baseline characteristics used for matching included age, gender, race, hospital location, bed-size, ownership of hospital, and twenty-nine comorbidities which have already been measured in the NIS data. Additionally, 7 rotator cuff related diagnoses were added to the group with rotator cuff deficiencies. All the characteristics passed the normality test and were then fit into a logistic regression model to calculate propensity scores which can be used to identify similar patients for each group. Patients in different groups with closest score were matched and each patient could only be match once. Wilcoxon rank-sum tests were used to evaluate differences for numerical variables, while Chi-squared tests were used for categorical variables. A *P*-value <0.05 was considered statistically significant. All statistical data analyses were performed using SAS 9.4 software and Python.

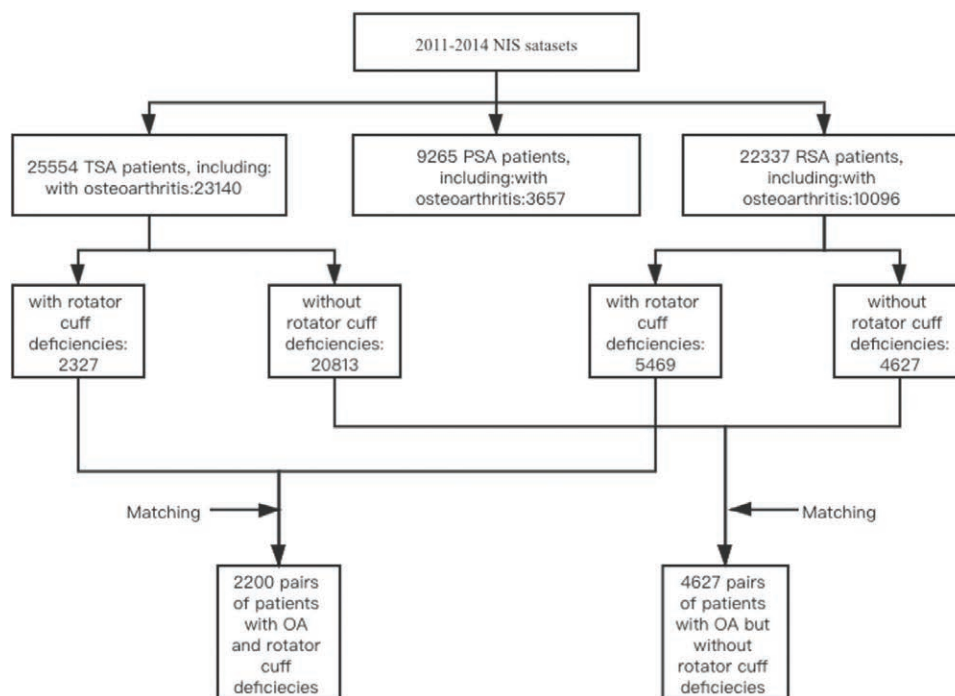


Figure 1. The sample selection and matching process.

3. Results

3.1. Patient demographic

A total of 57,156 shoulder arthroplasties were identified in the NIS database (44.7% TSAs, 16.21% HAs, and 39.08% RSAs) from 2011–2014 (Table 1). For TSA, 50.70% and 49.21% of patients were female and male, respectively. The average age of TSA patients was 67.31 ± 9.66 years of age. For HA, 62% and 38% of patients were female and male, respectively. The average age of HA patients was 66.18 ± 13.5 years of age. For RSA, 63.79% and 36.21% of patients were female and male, respectively. The average age of RSA patients was 72.38 ± 8.93 years of age. Other hospital related demographic data was displayed in Supplementary Table 1, <http://links.lww.com/MD/H62>.

3.2. Primary diagnoses

A list of diagnoses for each procedure is presented in Table 2 as defined by ICD-9-CM (International Classification of Disease, Ninth Revision, Clinical Modification). Five most common diagnoses were listed: osteoarthritis, arthropathy, aseptic necrosis, rotator cuff injuries, humeral fractures. Osteoarthritis was the most common diagnosis for all 3 procedures (90.55%, 39.47%, 45.20% for TSA, HA, RSA, respectively) with a total of 26,893 counts (64.55%).

3.3. Trend of different procedures

From 2011 to 2013, TSA was the most performed procedure compared to RSA and HA with a steady percentage of 45 (Fig. 2A). The percentage of TSA experienced a decline in 2014 (43%) and was overtaken by RSA (46%) for the most performed

surgery, which had been increasing steadily since 2011. On the other hand, the percentage of HA was the lowest in 2011 and has been gradually decreasing since 2011.

When examining specifically for patients with OA who underwent surgery, the most performed surgery was TSA at 60% with a slight decline started in 2013 (Fig. 2B). RSA was the second most performed surgery started at 22.5% and increased to 32.8% in 2014. HA was the least performed and has been steadily decreasing since 2011 to 6%.

A breakdown of procedures for patients with OA and rotator cuff deficiency was examined. RSA was the most performed procedure started at 55% and gradually increased to 70% (Fig. 2C). The second most performed surgery was TSA, started at 32% and progressively decreased to 25%. HA was the least performed, started at 11% and decreased to 5%.

For OA patients but without rotator cuff deficiency (Fig. 2D), TSA was the most performed started at 70%, which slightly increased then fell back to 72%. HA experienced a steady decline and was overtaken by RSA in 2012. RSA increased from 15 to 19% and HA decreased to 8% in 2014.

3.4. Postoperative complications

Postoperative outcomes were compared between TSA and RSA, the main subjects of interest. Only patients with OA were analyzed. To minimize confounding factors and reduce sample variability, patients were matched by age, sex, race, geographic location, and comorbidities. Unmatched and matched patient demographic data can be found in Supplementary Table 2, <http://links.lww.com/MD/H62> and Supplementary Table 3, <http://links.lww.com/MD/H62>, respectively.

OA patients were grouped by the presence of rotator cuff deficiency. In the rotator cuff deficiency group (Table 3, left side), significant higher number of transfusions was found for RSA patients (70

Table 1
Demographic characteristics of all patients undergo shoulder arthroplasties.

| | TSA | HA | RSA | Unprofiled | P value |
|----------------------------|----------------|--------------|----------------|------------|---------|
| Sex | | | | | |
| Female (%) | 12,972 (50.79) | 5736 (62) | 14,244 (63.79) | 38 | <0.000 |
| Male (%) | 12,566 (49.21) | 3516 (38) | 8084 (36.21) | | |
| Age at surgery | | | | | |
| n | 25,546 | 9260 | 22,332 | 18 | <0.000 |
| Mean (SD), yr | 67.31 (9.66) | 66.18 (13.5) | 72.38 (8.93) | | |
| Race | | | | | |
| White (%) | 21,150 (90.47) | 7403 (87.1) | 18,171 (89.03) | 4869 | <0.000 |
| Black (%) | 1003 (4.29) | 430 (5.06) | 897 (4.39) | | |
| Hispanic (%) | 669 (2.86) | 399 (4.69) | 783 (3.84) | | |
| Asian/Pacific islander (%) | 95 (0.41) | 56 (0.66) | 91 (0.45) | | |
| Native American (%) | 78 (0.33) | 34 (0.4) | 77 (0.38) | | |
| Others (%) | 383 (1.64) | 177 (2.08) | 391 (1.92) | | |
| Total (%) | 25,554 (44.71) | 9265 (16.21) | 22,337 (39.08) | | |

P value was calculated by chi-squared test for categorical variables and 1-way ANOVA test for numerical variables. HA = hemiarthroplasty; RSA = reverse total shoulder arthroplasty; TSA = total shoulder arthroplasty.

Table 2
Primary diagnosis for patients with different shoulder arthroplasties.

| Diagnosis | TSA n(%) | HAn(%) | RSAn(%) | Overall |
|---------------------|----------------|--------------|----------------|----------------|
| Osteoarthritis | 23,140 (90.55) | 3657 (39.47) | 10,096 (45.2) | 36,893 (64.55) |
| Arthropathy | 1044 (4.09) | 341 (3.68) | 3166 (14.17) | 4551 (7.96) |
| Aseptic necrosis | 424 (1.66) | 616 (6.65) | 168 (0.75) | 1208 (2.11) |
| Rotator cuff injury | 131 (0.51) | 212 (2.29) | 4235 (18.96) | 4578 (8.01) |
| Humeral fracture | 276 (1.08) | 3629 (39.17) | 3078 (13.78) | 6983 (12.22) |
| others | 539 (2.11) | 810 (8.74) | 1594 (7.14) | 2943 (5.15) |
| Overall | 25,554 (44.71) | 9265 (16.21) | 22,337 (39.08) | 57,156 (100) |

TSA = total shoulder arthroplasty, HA = hemiarthroplasty, RSA = reverse total shoulder arthroplasty.

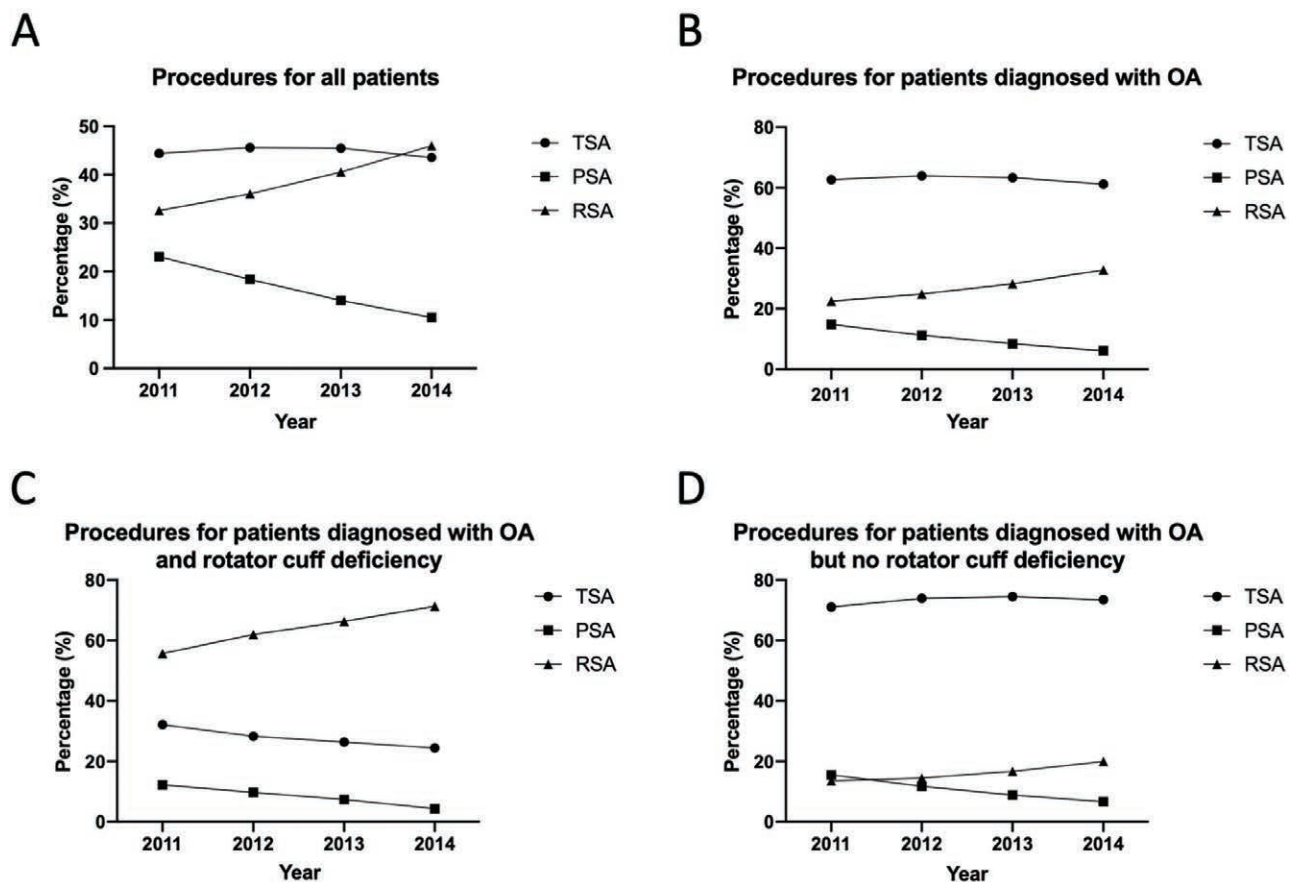


Figure 2. Trends of primary shoulder arthroplasties 2011–2014. (A) All procedures combined. (B) Procedures for patients diagnosed with OA. (C) Patients with OA and rotator cuff deficiency. (D) Patients with OA but not rotator cuff deficiency.

vs 97, $P = .0399$). Length of hospital stay was significantly higher for RSA patients (1.93 vs 2.01 days, $P = .0021$). In OA patients without rotator cuff deficiency (Table 3, right side), statistical significant was found for the number of implant-related mechanical complication (8 vs 29, $P = .0007$), acute upper respiratory infections (0 vs 6, $P = .0312$), acute postoperative pain (85 vs 130, $P = .0023$). Length of hospital stay was higher in RSA patients (2.08 vs 2.25 days, $P < .0001$). Regarding total cost of surgery, TSA had lower costs compared to RSA in both groups ($P < .0001$ in both groups).

4. Discussion

In this study, we queried the NIS database to investigate surgical outcomes of TSA and RSA for OA patients with and without rotator cuff deficiency. RSA was originally designed for repair of rotator cuff injury and shoulder pseudoparalysis,^[13,26,27] therefore, we wanted to evaluate if the use of RSA in place of the clinically standard TSA was justified for OA patients without rotator cuff deficiency.

Initially we had gathered data on HA, the focus was gradually shifted to focus on comparing TSA to RSA as HA has fallen out of favor over the years for the management of OA.

According to our data (Fig. 2) and also results from previous studies, RSA has a trend of increasing popularity each year.^[20,28] It has even surpassed TSA and became the most performed shoulder arthroplasty procedure in 2014 (Fig. 2A) due to its expanded indications for other shoulder arthropathies.^[29–36]

Although TSA remains the most frequently performed arthroplasty for OA patients, RSA increased over 10% (Fig. 2B) since 2011 from 22.5 to 32.8%. Upon further analysis of this data, in OA patients with rotator cuff deficiency (Fig. 2C), there was a dramatic increase of RSA performed (55–70%), while TSA experienced a

decline from 32 to 25%. In OA patients without rotator cuff deficiency (Fig. 2D), TSA remained high with a slight decline in 2014 (72%), while RSA had a gradual increase (15 to 19%), although not as dramatic as in patients with rotator cuff deficiency. Among all OA patients who underwent RSA, only 54.17% (5469 out of 10,096, Supplementary Table 2, <http://links.lww.com/MD/H62>) of the study patients had rotator cuff or bursa deficiencies. For these patients, complication profiles are very similar between TSA and RSA (Table 3), only the rate of blood transfusion in RSA patients was higher than TSA patients. Although the length of hospital stay and surgical cost are significantly higher than TSA patients, RSA is still a good option considering the surgical benefits of RSA for patients with rotator cuff deficiency. RSA restores balance to the shoulder as it is designed to restore tension to the deltoid and keeps the center of joint rotation within the glenoid fossa,^[37,38] which is necessary when the rotator cuff is insufficient.^[39–41]

On the other hand, there were as high as 45.83% (4627 out of 10,096, Supplementary Table 2, <http://links.lww.com/MD/H62>) of OA patients without rotator cuff that received RSA. For these patients, the benefit of RSA was limited. Furthermore, there were greater incidence of postoperative complications in patients who received RSA. The number of patients who had mechanical complication (8 vs 29), acute upper respiratory infection (6 vs 0, RSA vs TSA), acute pain (130 vs 85, RSA vs TSA), and blood transfusions (306 vs 182, RSA vs TSA) are significantly higher. Besides, after RSA, the stability and mobility of the glenohumeral joint become dependent on the deltoid.^[42] As a result, there is a higher requirement for postoperative physiotherapy,^[43,44] which results in higher costs. Moreover, given the higher rate of multiple complications, and especially when the surgical cost of RSA and length of hospital stay are significantly higher, the use of RSA instead of TSA in patients without rotator cuff deficiencies may not be justified.

Table 3

Complications, length of stay, and cost of osteoarthritis patients with or without rotator cuff deficiencies undergo TSA or RSA.

| Variables | With rotator cuff deficiency | | | | Without rotator cuff deficiency | | | |
|------------------------------------|------------------------------|-------------------|---------|------------------|---------------------------------|-------------------|---------|------------------|
| | TSA | RSA | P value | OR (95% CI) | TSA | RSA | P value | OR (95% CI) |
| Mechanical complication of implant | 6 (0.27) | 4 (0.18) | 0.7536 | 0.67 (0.19–2.36) | 8 (0.17) | 29 (0.63) | 0.0007 | 3.64 (1.66–7.97) |
| Nervous system complications | 1 (0.05) | 1 (0.05) | 1 | 1 (0.06–16) | 5 (0.11) | 5 (0.11) | 1 | 1 (0.29–3.46) |
| Cardiac complications | 10 (0.45) | 9 (0.41) | 1 | 0.9 (0.36–2.22) | 18 (0.39) | 25 (0.54) | 0.3593 | 1.39 (0.76–2.55) |
| Peripheral vascular complications | 2 (0.09) | 1 (0.05) | 1 | 0.5 (0.05–5.52) | 1 (0.02) | 3 (0.06) | 0.6249 | 3 (0.31–28.86) |
| Respiratory complications | 7 (0.32) | 6 (0.27) | 1 | 0.86 (0.29–2.55) | 23 (0.5) | 11 (0.24) | 0.0572 | 0.48 (0.23–0.98) |
| Digestive system complications | 3 (0.14) | 3 (0.14) | 1 | 1 (0.2–4.96) | 15 (0.32) | 7 (0.15) | 0.1333 | 0.47 (0.19–1.14) |
| Urinary complications | 6 (0.27) | 11 (0.5) | 0.3314 | 1.84 (0.68–4.98) | 29 (0.63) | 29 (0.63) | 1 | 1 (0.6–1.68) |
| Postoperative shock | 0 (0) | 2 (0.09) | 0.4999 | — | 0 (0) | 4 (0.09) | 0.1249 | — |
| Hemorrhage or hematoma | 4 (0.18) | 6 (0.27) | 0.7536 | 1.5 (0.42–5.33) | 12 (0.26) | 17 (0.37) | 0.4575 | 1.42 (0.68–2.97) |
| Postoperative infection | 1 (0.05) | 1 (0.05) | 1 | 1 (0.06–16) | 2 (0.04) | 1 (0.02) | 1 | 0.5 (0.05–5.51) |
| Urinary tract infection | 25 (1.14) | 27 (1.23) | 0.8892 | 1.08 (0.63–1.87) | 79 (1.71) | 101 (2.18) | 0.1137 | 1.28 (0.95–1.73) |
| Acute upper respiratory infections | 2 (0.09) | 0 (0) | 0.4999 | 0 (0.01–5.54) | 0 (0) | 6 (0.13) | 0.0312 | — |
| Acute postoperative pain | 68 (3.09) | 67 (3.05) | 1 | 0.98 (0.7–1.39) | 85 (1.84) | 130 (2.81) | 0.0023 | 1.54 (1.17–2.04) |
| Chronic postoperative pain | 1 (0.05) | 0 (0) | 1 | 0 (0.02–14.9) | 1 (0.02) | 0 (0) | 1 | 0 (0.02–14.9) |
| Transfusion | 70 (3.18) | 97 (4.41) | 0.0399 | 1.4 (1.03–1.92) | 182 (3.93) | 306 (6.61) | <0.0001 | 1.73 (1.43–2.09) |
| Length of stay | 1.93 (1.12) | 2.01 (1.07) | 0.0021 | RSA-TSA0.08 | 2.08 (1.33) | 2.25 (1.52) | <0.0001 | RSA-TSA0.17 |
| Mean (SD) | 2 | 2 | | | 2 | 2 | | |
| Median | 16960.36 (6915.39) | 19468.65 (7723.6) | <0.0001 | RSA-TSA2508.29 | 16860.74 (6800.91) | 19816.6 (8362.91) | <0.0001 | RSA-TSA2955.86 |
| Cost | 15694.5 | 18018.86 | | | 15,536 | 18212.88 | | |

P value was calculated by Chi-squared test or Fisher exact test for categorical variables, and t-test or Wilcoxon rank-sum test for numerical variables. CI = confidence interval, OR = odds ratio, RSA = reverse total shoulder arthroplasty, SD = standard deviation, TSA = total shoulder arthroplasty.

Although the indications for RSA have been expanded in the last few years,^[35,45] RSA is still being applied outside of the indicated conditions. However, once RSA has been done, future revision will be very difficult due to severely altered anatomy.^[46–48] Furthermore, considering the high rate of complication and cost, surgeons should carefully reconsider the use of RSA outside of its indications.

There are some limitations in this study. First, the data was collected from the online database, many details were not applicable, this makes it difficult to in-depth analyze. Second, this study only analyzed data between 2011 and 2014, the data after 2014 was not included, an updated analysis will renew our Acknowledgments.

5. Conclusions

With the help National Inpatient Sample database, more impactful studies involving larger number of patients can be conducted to better understand and compare surgical outcomes between procedures. We found that the use of RSA in the management of OA patients without rotator cuff deficiency had significantly more complications compared to those managed with TSA. Surgeons may need to reconsider when attempting to perform RSA in these patients. Future studies may need to focus on identifying factors causing higher risk of postoperative complications for RSA compared to TSA in this patient population to further improve the safety of shoulder arthroplasties.

Author contributions

Haifeng Liu, Daping Wang, and Zeling Long conceived the project idea. Haifeng Liu, Zeling Long, and Hanzhong Yu designed the project, collected data, and performed data analysis. Haifeng Liu, Zeling Long, Tony Chieh-Ting Huang, and Hanzhong Yu wrote the manuscript. Daping Wang, Yicun Wang supported and supervised the findings of this work. All authors contributed to the final manuscript. All authors have read and approved the final submitted manuscript.

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