RESEARCH ARTICLE

A Comparison of Complications and Survivorship after Reverse Total Shoulder Arthroplasty for Proximal Humerus Fracture compared with Cuff Tear Arthropathy

Kevin Y. Wanga, BA; Amil R. Agarwal, BA; Matthew J. Best, MD; John G. Mawn, MD; Pramod. Kamalapathy, BA; Uma. Srikumaran, MD,MBA, MPH

Research performed at the Johns Hopkins University School of Medicine, BA, USA

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Abstract

Objectives: Traditionally used to treat rotator cuff tear arthropathy (CTA), reverse total shoulder arthroplasty (RTSA) is becoming increasingly utilized for the treatment of proximal humeral fractures (PHF). The purpose of this study was to use a matched cohort analysis to assess differences in 90-day complications as well as 2-year and 5-year implant survival between patients undergoing RTSA for CTA and patients undergoing RTSA for PHF.

Methods: Patients with at least a 5-year follow-up who underwent primary RTSA for either PHF or CTA were identified in a national database (PearlDiver Technologies) using current procedural terminology (CPT) and international classification of diseases (ICD) 9 and 10 codes. Patients with a surgical indication of PHF were matched with patients with a surgical indication of CTA based on age, sex, Charlson Comorbidity Index, smoking status, and obesity (body mass index (BMI)>30). All-cause revision at the 2-year and 5-year postoperative time intervals were assessed. Reimbursements for the surgical care episode up to the 30-day, 90-day, and 1-year postoperative intervals were also assessed. Bivariate analysis was performed with a significance set at $P<0.05$.

Results: In total, 802 PHF patients were matched with 802 CTA patients. Compared to CTA patients, PHF patients undergoing RTSA were significantly at increased risk of atrial fibrillation, anemia, and heart failure within 90 days of surgery. Notably, there was no significant difference in all-cause revision surgery at 2-year and 5-year postoperative intervals or hospital reimbursements at the 30-day, 90-day, and 1-year postoperative intervals.

Conclusion: Preoperative indication appears to be an important driver of healthcare utilization for RTSA, as PHF patients undergoing RTSA have a higher risk of short-term postoperative complications compared to CTA patients. However, there is no difference in hospital reimbursement for the two indications of RTSA, suggesting that current payment modalities may not appropriately adjust for risk based on the surgical indication.

Level of evidence: III

Keywords: CTA, PHF, Reverse total shoulder arthroplasty, RTSA, Proximal humeral fractures, Rotator cuff tear arthropathy, Surgical indications

Introduction

With the increasing national focus on value-based care in the United States, it is important to understand factors contributing to postoperative outcomes and healthcare costs.[1] For surgical care, different preoperative indications for the same surgery can result in varying costs for the episode of care.[2] Many current

Corresponding Author: Amil R. Agarwal, Department of Orthopaedic Surgery, George Washington Hospital, Washington DC, USA
EMAIL: amil_agarwal@gwmail.gwu.edu

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bundled payment systems for surgical care reimburse based on Medicare Severity Diagnosis-Related Groups (DRG), which account for the cost of the procedure as well as short-term postoperative care.[3-6] This reimbursement method does not adjust for specific diagnosis codes and thus cannot discriminate risk between the same procedure performed for different indications.[2,7-8] To improve the accuracy of payment estimations for surgical care, more work is needed to establish preoperative indication as a driver of healthcare utilization and overall costs of care.

From 2012 to 2017, reverse total shoulder arthroplasty (RTSA) increased from 7.3 cases per 100,000 people to 19.3 cases per 100,000 people.[9] Although RTSA is more commonly utilized for CTA, the incidence of RTSA for PHF increased by 406% from 2005 to 2012.[10-12] Prior research has primarily assessed the use of RTSA for CTA and PHF separately, reporting low rates of complications following RTSA for either indication.[7-13] However, at present, there is a paucity of literature directly comparing complications and implant survivability of RTSA for CTA and PHF, and no previous studies assessing differences in reimbursement.

The primary purpose of this study was to compare 90-day postoperative complications and 2-year and 5-year implant survival between patients undergoing RTSA for CTA and patients undergoing RTSA for PHF while controlling for pre-operative medical complexity. A secondary objective was to compare hospital reimbursements between PHF patients and CTA patients undergoing RTSA at the 30-day, 90-day, and 1-year postoperative intervals. We hypothesized that patients undergoing RTSA for PHF would have a more complicated postoperative course without any significant differences in reimbursement.

Materials and Methods

This study was exempt from institutional review board approval. A retrospective cohort analysis was conducted using the PearlDiver Database (Mariner subset) data from 2010 to 2018. PearlDiver is a national claims database (www.pearldiverinc.com; 10435 Marble Creek Circle Colorado Springs, CO 80908) that uses claims data from all payer types derived from provider networks and longitudinally tracks patients based upon unique patient identifiers. The Mariner dataset includes records of over 121 million patients that can be identified based on the International Classification of Diseases 9th and 10th modification (ICD9/10) diagnosis codes and procedure codes, as well as Current Procedural Terminology (CPT) codes. First, patients with RTSA were identified using ICD9/10 procedure codes. These patients were stratified into two groups: those with PHF and those with CTA based on ICD9/10 diagnosis codes. These billing codes and their definitions can be found in Supplementary File 1. Patients were only included if they had at least a 5-year follow-up. Of the 53,733 patients in the Mariner dataset who underwent an RTSA from 2010 to 2018, 6,133 patients were included based on our inclusion and exclusion criteria [Figure 1]. From this cohort, 864 patients with PHF were matched with 2,319 patients with CTA [Figure 1].

Patient demographics included age, gender, Charlson Comorbidity Index (CCI), obesity (BMI>30), and smoking status. Primary outcomes for this study included 90-day readmission rates, all-cause revision within 2 or 5 years of RTSA, and 90-day postoperative medical complications,

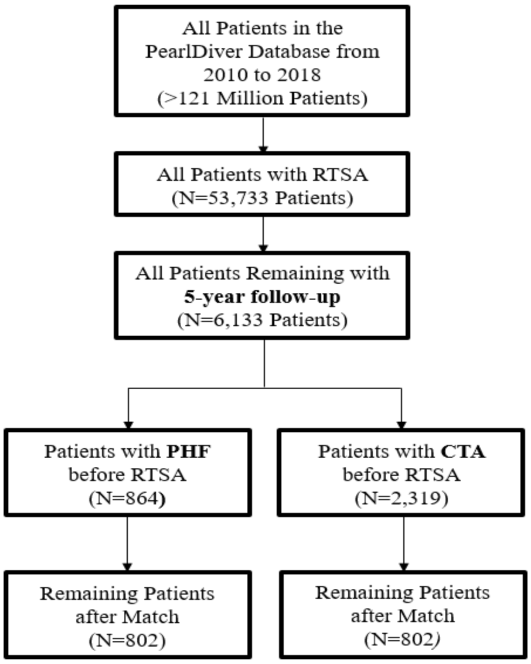

Figure 1. Patient Inclusion and Exclusion Criteria

including renal failure, anemia, atrial fibrillation, arrhythmias without atrial fibrillation, bleeding complications, blood transfusions, cellulitis, pneumonia, stroke, death, deep vein thrombosis (DVT), pulmonary embolism (PE), heart failure, respiratory failure, urinary tract infections, and sepsis. Readmission is defined as any new inpatient record following discharge from the index procedure in a certain period. Readmissions are not specific to the index procedure but are any hospital admissions within 90-day s following the procedure. Secondary outcomes included 30-day, 90-day, and 1-year average hospital reimbursements.

Reimbursements in the database are not charges for services but rather payments to hospitals and providers. The Mariner dataset can observe the average reimbursements of an index procedure as well as the episode of care reimbursements accrued in any specified postoperative interval. In this study, we observed the average episode of care hospital reimbursements within 30-day, 90-day, and 1-year from RTSA.

Propensity Score Matching

Propensity score matching was used to control for confounding variables between the PHF and CTA groups. The propensity score was defined as the conditional probability of having undergone RTSA based on age, CCI, obesity, and smoking status. The selection of these potential predictor variables was based upon prior work examining risk factors for failure of TSA.[11,14] Matching was conducted using 1:1 nearest neighbor matching between the PHF and CTA cohorts.

Statistical Analysis

Data on patient demographics, complications, and surgical outcomes were analyzed with univariate analysis using the R software provided by PearlDiver. After the PHF and CTA groups were matched, univariate analyses were performed to analyze our outcome measures. A p-value of <0.05 was used as the cutoff for significance for all tests.

Results

Patient Demographics

In total, 802 patients that underwent RTSA for PHF were matched with 802 patients that underwent RTSA for CTA. Following propensity score matching, there were no comorbidities between the two cohorts [Table 1]. Detailed demographic data is displayed in Table 1.

Table 1. Demographic Information for PHF and CTA Patients Undergoing RTSA

Category	Total	PHF-RTSA		CTA-RTSA		
	Number	Number	Percent	Number	Percent	P-Value
Total	1,604	802	-	802	-	
Age	-	-	-	-	-	1.00
<60	76	38	4.74%	38	4.74%	-
60-70	416	208	25.94%	208	25.94%	-
70-80	1112	556	69.33%	556	69.33%	-
CCI	-	-	-	-	-	1.00
0	324	162	20.20%	162	20.20%	-
1	436	218	27.18%	218	27.18%	-
2	296	148	18.45%	148	18.45%	-
3	234	117	14.59%	117	14.59%	-
>3	314	157	19.58%	157	19.58%	-
Gender	-	-	-	-	-	1.00
Male	190	95	11.85%	95	11.85%	-
Female	1414	707	88.15%	707	88.15%	-
Obesity*	624	312	38.90%	312	38.90%	1.00
Smoking	196	98	12.22%	98	12.22%	1.00

CCI: Charlson Comorbidity Index; PHF-RTSA: Patients undergoing reverse total shoulder arthroplasty for proximal humerus fracture; CTA-RTSA: Patients undergoing reverse total shoulder arthroplasty for cuff tear arthropathy; PHF: Proximal humerus fracture; CTA: Cuff tear arthropathy
*Obesity is defined as Body Mass Index > 30

90-Day Medical Complications

Compared to CTA patients, PHF patients undergoing RTSA were at significantly increased risk of 90-day medical complications, including atrial fibrillation (11.97% vs. 8.23%, p=0.013), anemia (5.24% vs. 3.24%, p=0.047), and heart failure (5.86% vs. 3.62%, p=0.034) [Table 2]. There was no significant difference in 90-day readmission rates between patients with PHF and CTA who underwent RTSA [Table 2].

Table 2. 90-Day Postoperative Complication Rates between PHF and CTA Patients Undergoing RTSA

Category	*Total*	*PHF-RTSA*		*CTA-RTSA*		
	Number	*Number*	*Percent*	*Number*	*Percent*	*P-value*
	1,604	*802*	*-*	*802*	*-*	*-*
Readmission	*85*	*47*	*5.86%*	*38*	*4.74%*	*0.316*
Renal Failure	*29*	*18*	*2.24%*	*11*	*1.37%*	*0.19*
Anemia	*68*	*42*	*5.24%*	*26*	*3.24%*	*0.047*
Arrhythmia w/ afib	*162*	*96*	*11.97%*	*66*	*8.23%*	*0.013*
Arrhythmia w/o afib	*66*	*38*	*4.74%*	*28*	*3.49%*	*0.208*
Bleeding complication	*14*	*9*	*1.12%*	*5*	*0.62%*	*0.282*
Blood Transfusion	*38*	*23*	*2.87%*	*15*	*1.87%*	*0.189*
Cellulitis	*43*	*24*	*2.99%*	*19*	*2.37%*	*0.44*
Pneumonia	*46*	*27*	*3.37%*	*19*	*2.37%*	*0.231*
Stroke	*29*	*13*	*1.62%*	*16*	*2.00%*	*0.574*
Death	*6*	*3*	*0.37%*	*3*	*0.37%*	*1*
DVT	*25*	*14*	*1.75%*	*11*	*1.37%*	*0.545*
Heart Failure	*76*	*47*	*5.86%*	*29*	*3.62%*	*0.034*
Pulmonary embolism	*26*	*11*	*1.37%*	*15*	*1.87%*	*0.429*
Respiratory Complication	*14*	*9*	*1.12%*	*5*	*0.62%*	*0.282*
UTI	*111*	*60*	*7.48%*	*51*	*6.36%*	*0.376*
Sepsis	*10*	*6*	*0.75%*	*4*	*0.50%*	*0.525*

w/: with; w/o: without; afib: atrial fibrillation; MI: myocardial infarction; DVT: deep vein thrombosis; UTI: urinary tract infection; PHF-RTSA: Patients undergoing reverse total shoulder arthroplasty for proximal humerus fracture; CTA-RTSA: Patients undergoing reverse total shoulder arthroplasty for cuff tear arthropathy; PHF: Proximal humerus fracture; CTA: Cuff tear arthropathy

2-Year and 5-Year Rates of Revision Surgery

In terms of implant survival, there were no significant differences in all-cause revision surgeries between the PHF and CTA groups at the 2-year or 5-year postoperative intervals (p>0.05 for both) [Table 3]. A Kaplan-Meier curve for 5-year implant survival is displayed in [Figure 2].

Table 3. All-cause Revision Rates between PHF and CTA Patients Undergoing RTSA

Category	Total	PHF-RTSA		CTA-RTSA		
	Number	*Number*	*Percent*	*Number*	*Percent*	*P-value*
	1,604	802	-	802	-	-
2-Year All Cause Revision	53	22	2.74%	31	3.87%	0.209
5-Year All Cause Revision	75	33	4.11%	42	5.24%	0.287

PHF-RTSA: Patients undergoing reverse total shoulder arthroplasty for proximal humerus fracture; CTA-RTSA: Patients undergoing reverse total shoulder arthroplasty for cuff tear arthropathy; PHF: Proximal humerus fracture; CTA: Cuff tear arthropathy

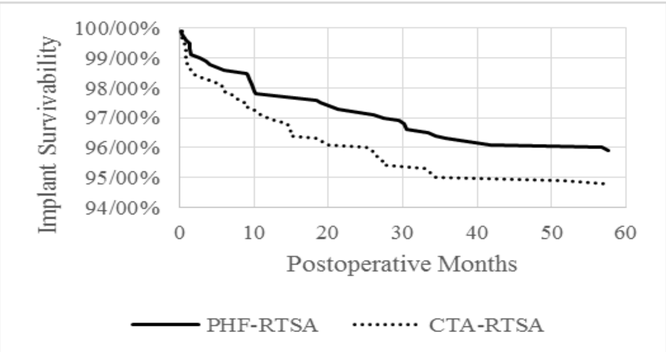

Figure 2. Kaplan Meier Curves for 5-Year Implant Survival following RTSA in Matched PHF and CTA Patients Hospital Reimbursements

There were no significant differences in reimbursements between PHF patients and CTA patients undergoing RTSA at the 30-day, 90-day or 1-year postoperative intervals (p>0.05 for all) [Table 4].

Table 4: 30-Day, 90-Day, and 1-Year Average Reimbursements for PHF and CTA Undergoing RTSA

Category	PHF-RTSA	CTA-RTSA	
	Number	Number	P-value
30-Day Reimbursements	$23,339.04	$22,138.72	0.503
90-Day Reimbursements	$25,033.06	$24,60202	0.620
1-Year Reimbursements	$34,641.91	$34,645.57	0.579

PHF-RTSA: Patients undergoing reverse total shoulder arthroplasty for proximal humerus fracture; CTA-RTSA: Patients undergoing reverse total shoulder arthroplasty for cuff tear arthropathy; PHF: Proximal humerus fracture; CTA: Cuff tear arthropathy

Discussion

In the present study, patients who underwent RTSA for PHF were found to have significantly higher rates of 90-day medical complications compared to patients who underwent RTSA for CTA, with no significant differences in 2-year and 5-year implant survival or hospital reimbursements. In other words, our results show that if two medically similar patients undergo RTSA, one for CTA and another for PHF, the PHF patient is at higher risk for medical complications. Current reimbursement models use past medical history to adjust reimbursement for differences in the expected complication rate. Our data suggest that this is an oversimplification. A more accurate model would account for both medical history and surgical indication. Understanding these differences in complication rates by indicating the same procedure can also help inform appropriate risk adjustment for comparative quality assessments between providers or hospitals.1,7

Few studies have directly compared complication rates and outcomes between patients undergoing RTSA for CTA and PHF, and no studies have compared hospital reimbursements between these cohorts.7,15-17 In a sample of 1,006 patients derived from a national database, Liu et al. reported that patients undergoing RTSA for PHF were significantly more likely to require transfusion, have a longer length of stay after surgery, and be discharged to an inpatient facility compared to CTA patients undergoing RTSA.17 In a separate retrospective series comparing 725 patients who underwent TSA for CTA and 646 patients who underwent TSA for PHF, Lung et al. found that the PHF patients had a higher risk of postoperative dislocation, non-home discharge, and transfusion.15 Finally, in a recent review comparing 108 patients who underwent RTSA for fracture versus 2,876 patients who underwent TSA for "elective" indications such as cuff arthropathy or osteoarthritis, Crespo et al. found that RTSA for fracture was associated with a longer hospital length of stay and more intraoperative blood loss. However, no differences were detected in postoperative adverse events or functional outcome measures beyond 1-year postoperatively.15 The increased rates of 90-day complications in the PHF group relative to the CTA group demonstrated in our study are supported by Liu et al.'s work and may be due to the decreased capacity for preoperative medical optimization in urgent PHF cases compared to elective CTA cases.17-21 Although the study showed higher 90-day medical complications for PHF indicated RTSA, there was no difference in 90-day readmissions between the two indications. The worse postoperative course attributed to PHF of longer length of stay increased blood loss, and transfusion rates can be attributed to the first hospital stay. Our results suggest that surgeons and perioperative teams should anticipate a worse complication profile and a potential increase in healthcare utilization for patients undergoing RTSA for PHF compared to CTA. This increased healthcare utilization may mostly be attributed to the first hospital stay.

From a financial perspective, the increased postoperative complications for PHF patients relative to CTA patients carry major implications at the payer, hospital, and healthcare system levels. Since 1983, Medicare and Medicaid have priced reimbursements based on the mean cost of a DRG for an associated surgical episode of care.[3-4,22] In recent years, other bundled payment systems have emerged to incentivize value-based surgical care by setting a standard reimbursement amount for a particular care episode that is calculated to be inclusive of the estimated potential costs incurred in the immediate postoperative setting. In the case of RTSA, reimbursement is priced based on either DRG 483 (major joint reconstruction or upper extremity reattachment with major complications) or DRG 484 (major joint reconstruction or upper extremity reattachment without major complications).23 These DRG codes are differentiated based on the presence of comorbidities. However, within this DRG system, there is currently no price adjustment for preoperative indication, despite evidence that PHF patients may require more healthcare utilization compared to CTA patients following the same RTSA procedure.[2,17] As such, the DRG system may be improved by accounting for both medical comorbidities and surgical indications.

Our study demonstrates equivalent reimbursement for RTSA performed for PHF and CTA up to the 1-year postoperative mark, which is expected given historical evidence that billing is based principally on the procedure performed and not the indication.[2,17] However, from a hospital's perspective, the healthcare utilization and subsequent costs of PHF patients undergoing RTSA may be higher than that of CTA patients. This difference in healthcare utilization may not be presently reflected in reimbursements from the payer, which likely places a financial burden on patients, hospitals, and the overall healthcare system.[24] The discrepancy between reimbursement and healthcare utilization for RTSA performed for CTA and PHF demonstrated in the present study can be used to improve bundle payment estimations, reduce inefficient resource allocation for procedures with different indications, and risk-adjust quality comparisons made between providers and hospitals.[2]

A similar discrepancy between reimbursement and healthcare utilization has been demonstrated in patients undergoing total hip arthroplasty (THA) for femoral neck fracture and THA for osteoarthritis. THA for femoral neck fracture is a more complicated care episode than elective THA for osteoarthritis, but both are reimbursed with the same DRG.[2] A concern with bundled payments is the practice of "cherry-picking," where providers choose to perform procedures for patients at lower risk of complications, as these care episodes are more likely to be contained within the price of the pre-established bundled payment.[14,16,25] For instance, a surgeon may choose to perform RTSAs for CTA patients more than for PHF patients due to the higher likelihood of a positive outcome. In such cases, adjusting DRGs and overall payment models based on surgical indications may have a powerful role in reducing "cherry-picking" and providing equal access to care.[26]

Finally, it is important to note that our study demonstrated no significant difference in 2-year or 5-year implant survival between PHF and CTA patients undergoing RTSA. Our matched 2-year failure rates are slightly higher than those in previous studies, which report RTSA failure rates of 3.2% for RTSA following PHF and 3.7% for RTSA following CTA.[27-29] However, no previous studies have directly compared implant survival between these cohorts. The relative lack of preoperative planning for PHF patients relative to CTA patients may increase the risk of healthcare utilization for short-term postoperative complications. Still, this difference in planning capacity does not appear to impact revision surgery rates at the 2-year and 5-year postoperative intervals, suggesting that indication may not influence the rate of a surgeon's outcomes. With some bundled payment plans now covering costs for up to 2-years following surgery, we provide evidence that prices should primarily adjust for indications based on the difference in risk of short-term medical complications between PHF and CTA and less for long-term revision surgery risk. [17,30,31] More work is needed to validate these findings of equivalent implant survival between the two groups.

The conclusions drawn from this study should be interpreted with an understanding of its limitations. First, operative treatment of PHF is a decision primarily made based on fracture classification, fracture displacement, and underlying patient demands, none of which we could assess with the PearlDiver database. Similarly, we could not assess the severity of CTA in our dataset. However, the granularity of our dataset is sufficient for establishing a significant difference in postoperative complications and equivalence in implant survival between PHF and CTA patients, even though we are unable to control for the severity of musculoskeletal impairment. Second, we are able to determine hospital reimbursements but not direct hospital costs. However, we can infer that cumulative hospital costs are likely higher in the PHF cohort due to their increased risks of postoperative complications. We are also unable to control our analyses for reimbursement modality (i.e., bundled payment, fee-for-service). Third, the PearlDiver database does not capture functional outcomes, so we were unable to report changes in functional scores in our cohort of patients. Fourth, since we used an administrative claims database, our results are liable to bias stemming from coding errors. However, any such coding errors would, in theory affect both the PHF and CTA cohorts and thus not contribute to notable bias in our findings. Finally, the use of propensity score matching in our study to isolate PHF and CTA cohorts with similar patient characteristics and comorbidities may be viewed as a limitation due to the potential selection bias inherent to the matching process. However, we believe that our study ultimately benefits from its matched design, as it is important that our analysis was conducted on cohorts with similar comorbidity profiles. This allows us to establish preoperative PHF as an independent risk factor for postoperative complications following TSA.

Conclusion

Preoperative indication appears to be an important driver of healthcare utilization for RTSA, as PHF patients undergoing RTSA have a higher risk of short-term postoperative complications compared to CTA patients. However, there is no difference in hospital reimbursement for the two indications of RTSA, suggesting that current payment modalities may not appropriately adjust for risk based on the surgical indication.

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Kevin Y. Wanga BA[1]
Amil R. Agarwal BA [2]
Matthew J. Best MD [3]
John G. Mawn MD [1]
Pramod. Kamalapathy BA [4]
Uma. Srikumaran MD, MBA, MPH [1]

1. Johns Hopkins Department of Orthopedic Surgery, Charter Drive, Columbia, USA
2. Department of Orthopedic Surgery, George Washington School of Medicine and Health Sciences, Washington DC, USA
3. Massachusetts General Hospital, Department of Orthopedic Surgery, Boston, MA, USA
4. Department of Orthopedic Surgery, University of Virginia, Charlottesville, VA, USA

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