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# Characteristics and risk factors for 90-day readmission following shoulder arthroplasty

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**Background:** Anatomic total shoulder arthroplasty (TSA) and reverse TSA are the standard of care for end-stage shoulder arthritis. Advancements in implant design, perioperative management, and patient selection have allowed shorter inpatient admissions. Unplanned readmissions remain a significant complication. Identification of risk factors for readmission is prudent as physicians and payers prepare for the adoption of bundled care reimbursement models. The purpose of this study was to identify characteristics and risk factors associated with readmission following shoulder arthroplasty using a large, bi-institutional cohort.
**Methods:** A total of 2805 anatomic TSAs and 2605 reverse TSAs drawn from 2 geographically diverse, tertiary health systems were examined for unplanned inpatient readmissions within 90 days following the index operation (primary outcome). Forty preoperative patient sociodemographic and comorbidity factors were tested for their significance using both univariable and multivariable logistic regression models, and backward stepwise elimination selected for the most important associations for 90-day readmission. Readmissions were characterized as either medical or surgical, and subgroup analysis was performed. A short length of stay (discharge by postoperative day 1) and discharge to a rehabilitation or skilled nursing facility were also examined as secondary outcomes. Parameters associated with increased readmission risk were included in a predictive model.
**Results:** Within 90 days of surgery, 175 patients (3.2%) experienced an unanticipated readmission, with no significant difference between institutions ($P = .447$). There were more readmissions for surgical complications than for medical complications (62.9% vs. 37.1%, $P < .001$). Patients discharged to a rehabilitation or skilled nursing facility were significantly more likely to be readmitted (13.1% vs. 8.8%, $P = .049$), but a short inpatient length of stay was not associated with an increased rate of 90-day readmission (42.9% vs. 41.3%, $P = .684$). Parameter selection based on predictive ability resulted in a multivariable logistic regression model composed of 16 preoperative patient factors, including reverse TSA, revision surgery, right-sided surgery, and various comorbidities. The area under the receiver operator characteristic curve for this multivariable logistic regression model was 0.716.
**Conclusion:** Risk factors for unplanned 90-day readmission following shoulder arthroplasty include reverse shoulder arthroplasty, surgery for revision and fracture, and right-sided surgery. Additionally, there are several modifiable and nonmodifiable risk factors that can be used to ascertain a patient's readmission probability. A shorter inpatient stay is not associated with an increased risk of readmission, whereas discharge to post–acute care facilities does impose a greater risk of readmission. As scrutiny around health care cost increases, identifying and addressing risk factors for readmission following shoulder arthroplasty will become increasingly important.

Institutional review board approval was received from Duke University Medical Center (Payment-Relevant Outcomes Involving Shoulder/Elbow Surgery; reference ID 319817) and Rush University Medical Center (Predictive Modeling for Bundled Payment-Relevant Outcomes in Patients; ORA no. 19061306-IRB01).

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Total shoulder arthroplasty (TSA) is a well-established treatment modality for severe glenohumeral arthritis. The procedure results in pain relief, increased functional capacity, and improved patient satisfaction.[33] Moreover, long-term survivorship has been increasingly reported with promising results.[12,35] Procedural volume surrounding TSA is increasing as a result of an aging population and increased access to fellowship-trained arthroplasty surgeons.[18] The incidence of shoulder arthroplasties performed between 2011 and 2014 increased by 24%, with a projected increase in volume of 300%-700% by 2030.[13,32,33] Additionally, reverse TSA (rTSA) has become a widely used alternative to the standard anatomic implant as its initial indication of cuff tear arthropathy has expanded to include proximal humeral fractures, revision arthroplasty, oncologic reconstruction, inflammatory arthropathy, and glenohumeral osteoarthritis with and without glenoid bone loss.[8,24,29] Although rTSA is associated with a higher complication rate than anatomic TSA (aTSA), the literature is inconsistent in reporting these rates, somewhere between 14% and 75%.[10,34]

Postoperative complications are important to characterize as payers begin to shift away from a traditional fee-for-service model toward bundled care reimbursement, particularly complications within the initial episode of care. Historically, fee-for-service payments were determined by each health care service provided, thus incentivizing the volume of health care delivered, often at the expense of quality.[23] The Centers for Medicare & Medicaid Services (CMS), in response to climbing medical costs, has aimed to incentivize value-based systems, in which all care is provided under a predetermined dollar amount (‘‘bundled payment’’).[38] The Bundled Payments for Care Improvement initiative was introduced in 2013 for joint arthroplasty and has resulted in post–acute care savings.[20,30] In accordance with this initiative, any unanticipated expenditures within 90 days are covered by this bundled payment. This payment model, adopted in hip and knee arthroplasty, has a renewed focus as an area of policy change (ie, recent removal from the Medicare inpatient-only list) in shoulder arthroplasty and several experimental bundled care programs have been sampled at the practice level, resulting in substantial savings.[30,43] Health systems that are able to anticipate and minimize unplanned readmissions while simultaneously improving quality will be at a substantial advantage relative to peer institutions in avoiding penalties when value-based care models become ubiquitous.

Readmission following TSA is considered a significant adverse event in the postoperative period. Several drivers for readmission exist, some of which may be preventable. The concept of ‘‘never events’’ has been introduced, which are complications deemed to be avoidable if appropriate evidence-based medicine is practiced.[6,27] CMS increasingly penalizes hospitals for treatment of such complications, de-incentivizing poor-quality care. This further emphasizes quality care measures and outcomes as CMS and payers scrutinize perioperative management. Therefore, the need to not only improve quality but also understand risk factors for readmission has never been more prudent.

The purpose of this study was to analyze a large cohort of TSA patients from 2 institutions to determine various risk factors, modifiable and nonmodifiable, for unanticipated readmission in the 90 days following surgery. Given the information presented earlier, an understanding of factors that portend a greater risk of subsequent care in the bundle period is essential for delivery of high-quality, cost-effective care and will be integral in guiding policy going forward. Finally, developing risk prediction tools can provide insight into decision making for both providers and patients during the preoperative and perioperative periods.

## Materials and methods

Large institutional cohorts of consecutive shoulder arthroplasty patients from 2 geographically diverse, high-volume health systems were assembled, in compliance with an inter-institutional data use agreement. To ensure consistency in data collection, structured query language (SQL) was used to pull data from the electronic medical record (EMR) system of each institution. The shared SQL used a comprehensive list of codes to capture comorbidity profiles (Elixhauser Comorbidity Index [ECI]) to standardize data collection across institutions (Supplementary Appendix S1).[1,2] Surgical procedures were performed by 19 surgeons between July 2013 and May 2019 at institution 1 and from June 2007 through February 2020 at institution 2. Both institutions serve as large tertiary referral centers, increasing the likelihood that any perioperative adverse events such as readmissions would be observed within each system rather than losing patients to outside institutions for follow-up.

Although all shoulder arthroplasties performed during the study period were gathered, several strict exclusion criteria were applied, including hemiarthroplasty, oncologic shoulder reconstruction by tumor surgeons, and antibiotic spacer placement for infection. Reimplantation procedures after antibiotic spacer placement were considered revisions and were included in the study cohort. The final arthroplasty cohort was limited to anatomic and reverse shoulder arthroplasty procedures, and a combination of surgical postings and manual chart review was used to identify arthroplasties performed for proximal humeral fractures as well as revisions with metal hardware present from either prior arthroplasty or previous open reduction–internal fixation.

The ECI was used as a standardized and validated measure of patient comorbidity burden. The ECI consists of 30 comorbidity "buckets," each containing related *International Classification of Diseases, Ninth Revision* or *International Classification of Diseases, Tenth Revision* codes. Each comorbidity is a binary variable considered positive if a patient has any of the included diagnoses present in his or her problem list at the time of surgery. On the basis of work from the Healthcare Cost and Utilization Project and the University of Manitoba, the data were extracted using SQL code written specifically to allow for easy adoption by outside institutions.[1,2,14,25] We collected age, body mass index (BMI), sex, laterality, and American Society of Anesthesiologists physical status score, as well as marital status, smoking status, and preoperative albumin level within 60 days of surgery (when available). The primary outcome of interest was unplanned 90-day readmission, a binary variable that was extracted so as to exclude scheduled inpatient admissions (eg, elective surgery). A patient's medical record number was used to identify readmission within 90 days after surgery. Readmissions were characterized as either medical or surgical based on the primary diagnosis. Secondary outcomes were also collected, including discharge to a rehabilitation facility or a skilled nursing facility (SNF) and discharge at least by postoperative day 1 ("short stay").

## Statistical analysis

Univariable analysis was first conducted on all patient factors to evaluate the significance of each variable in isolation as a risk factor for unplanned 90-day readmission. Next, a multivariable logistic regression model was created from all variables to calculate their adjusted significance for readmission. This model consisted of 40 variables, and to avoid overfitting bias, backward stepwise elimination was used to refine the model to only those predictors showing sufficient adjusted significance for unplanned readmission. These parameters were selected for inclusion in a final model. Odds ratios (ORs) and confidence intervals were then calculated, in addition to the $\chi^2$ importance of each variable relative to the others.

The $\chi^2$ test was used to determine whether a significant association existed between unplanned readmission and the secondary outcomes; the $\chi^2$ test was also used to ensure that no differences in readmission rates existed between the institutions. Comparison of slopes using pooled error variance analysis was performed to compare readmission rates between aTSA and rTSA. Medical and surgical readmissions were compared by use of the $\chi^2$ test for categorical variables, and the Kruskal-Wallis *H* test was used to determine differences in continuous variables. R software (version 3.6.0; R Foundation for Statistical Computing, Vienna, Austria) was used for all statistical analysis, as well as several packages (rms and Hmisc).[21,22] $P < .05$ corresponds to a significant result.

## Results

A total of 5410 anatomic (n = 2805, 52%) and reverse (n = 2605, 48%) shoulder arthroplasties across 2 institutions were examined for unplanned inpatient readmissions within 90 days of surgery. We observed 175 readmissions (3.2%), with no significant difference in rates between institutions (3.5% vs. 3.1%, $P = .447$). Patients discharged to a rehabilitation facility or SNF rather than discharged home experienced a significantly higher 90-day readmission rate (13.1% vs. 8.8%, $P = .049$); however, there was no difference in readmissions after multivariable analysis was performed ($P = .713$). A short inpatient length of stay (discharge by postoperative day 1) did not result in an increased rate of unplanned readmissions (42.9% vs. 41.3%, $P = .684$) (Table I).

On unadjusted univariable analysis, the strongest patient factors associated with 90-day readmission were reverse shoulder arthroplasty (70.9% vs. 47.4%, $P < .001$), revision status or prior metal hardware (16.6 vs. 8.5, $P < .001$), and surgery for proximal humerus fracture (9.1% vs. 3.4%, $P < .001$). These and other associations remained when adjusting for sociodemographic or comorbidity factors on multivariable analysis (Table I). Annual readmission rates for rTSA did not change significantly over the period studied and did not differ significantly from those of aTSA ($P = .981$) (Fig. 1). Preoperative albumin level in isolation was not significantly associated with 90-day readmission (3.7 g/dL vs. 3.7 g/dL, $P = .458$), and as albumin levels were determined in only 10% of cases, the variable was excluded from further analysis.

The aforementioned multivariable model composed of all parameters was then narrowed, via backward stepwise elimination, to 16 preoperative patient factors, chosen for their adjusted importance in predicting unplanned 90-day readmission. ORs with 95% confidence intervals were first calculated for each of these 16 variables (Fig. 2). In order of $\chi^2$ importance, the identified variables were reverse shoulder arthroplasty, revision surgery or prior metal hardware, psychosis, hypertension, diabetes, alcohol dependence, fracture, rheumatoid collagen disorder, marital status (single/no partner), weight loss, complicated diabetes, congestive heart failure, lymphoma, depression, laterality (right), and cardiac arrhythmia (Fig. 3). The area under the receiver operator characteristic curve for this predictive model was 0.716 (Fig. 4). Although model parameters were limited to preoperative variables to maximize clinical utility, the inclusion of surgical duration improved the predictive accuracy to 0.724.

Further analysis of readmissions showed that there were more surgical readmissions than medical readmissions in the 90-day postsurgical period (62.9% vs. 37.1%, $P < .001$) (Table II, Supplementary Table S1). Patients readmitted for medical reasons did not differ in age, sex, BMI, or smoking status from patients admitted for surgical complaints; however, patients readmitted for medical reasons did have a higher average American Society of Anesthesiologists score (2.7 vs. 2.6, $P = .047$). Readmissions following rTSA did not differ regarding medical vs. surgical reasons ($P = .745$). Revision surgery showed a higher rate of

**Table I** Demographic information and comorbidity profiles of patients readmitted within 90 days of index surgery compared with patients not requiring readmission

| Preoperative variables | 90-d readmission (n = 175, 3.2%), % | No 90-d readmission (n = 5235; 96.8%), % | *P* value | |
|---|---|---|---|---|
| | | | Unadjusted univariable | Adjusted multivariable |
| Surgery: reverse | 70.9 | 47.4 | <.001 | <.001 |
| Revision | 16.6 | 8.5 | <.001 | .001 |
| Fracture | 9.1 | 3.4 | <.001 | .056 |
| Age | 38.9 | 1.3 | .303 | .295 |
| Male sex | 42.3 | 48.0 | .138 | .665 |
| BMI | 17.7 | 0.6 | .167 | .847 |
| ASA score of 3 or 4 | 58.9 | 45.8 | .001 | .646 |
| Partner status: single | 41.7 | 32.1 | .005 | .084 |
| Smoking | 48.6 | 46.7 | .532 | .975 |
| Laterality: right | 61.1 | 55.6 | .150 | .125 |
| ECI | | | | |
| AIDS or HIV | 0.0 | 0.0 | .890 | .967 |
| Alcohol dependence | 2.9 | 0.7 | .003 | .050 |
| Deficiency anemia | 18.3 | 13.6 | .075 | .391 |
| Cardiac arrhythmia | 17.1 | 10.3 | .004 | .064 |
| Rheumatoid collagen disorder | 11.4 | 6.9 | .024 | .094 |
| Blood loss anemia | 0.0 | 0.5 | .780 | .890 |
| Congestive heart failure | 9.1 | 3.6 | <.001 | .132 |
| Chronic pulmonary disease | 22.3 | 16.0 | .026 | .445 |
| Coagulation deficiency | 2.3 | 1.7 | .589 | .840 |
| Depression | 21.1 | 13.2 | .003 | .160 |
| Diabetes | 18.3 | 12.3 | .019 | .060 |
| Diabetes—complicated | 9.7 | 4.9 | .005 | .162 |
| Drug abuse | 0.6 | 0.2 | .296 | .501 |
| Hypertension | 64.0 | 56.0 | .036 | .020 |
| Hypertension—complicated | 13.1 | 8.3 | .023 | .552 |
| Hypothyroidism | 16.0 | 16.0 | .986 | .496 |
| Liver disease | 2.3 | 1.6 | .471 | .862 |
| Lymphoma | 1.7 | 0.4 | .019 | .054 |
| Electrolyte disorder | 10.3 | 9.1 | .584 | .358 |
| Metastatic cancer | 0.0 | 0.2 | .815 | .918 |
| Neurologic disease | 7.4 | 5.0 | .154 | .590 |
| Paralysis | 1.7 | 0.5 | .031 | .328 |
| Peripheral vascular disease | 2.9 | 2.9 | .995 | .630 |
| Psychosis | 5.1 | 1.4 | <.001 | .034 |
| Pulmonary circulatory disorder | 0.0 | 0.4 | .801 | .860 |
| Renal failure | 9.7 | 6.9 | .146 | .846 |
| Tumor without metastasis | 1.1 | 1.1 | .906 | .587 |
| Peptic ulcer disease | 0.0 | 0.2 | .815 | .928 |
| Valvular disease | 1.7 | 3.8 | .161 | .097 |
| Weight loss | 2.3 | 0.4 | .001 | .088 |
| Short stay | 42.9 | 41.3 | .684 | .152 |
| Discharge to SNF or rehabilitation facility | 13.1 | 8.8 | .049 | .713 |

*BMI*, body mass index; *ASA*, American Society of Anesthesiologists; *ECI*, Elixhauser Comorbidity Index; *AIDS*, acquired immunodeficiency syndrome; *HIV*, human immunodeficiency virus; *SNF*, skilled nursing facility.

readmissions for surgical reasons (24.5% vs. 3.1%, $P < .001$). No differences were observed in medical or surgical readmissions based on short length of stay or discharge location.

## Discussion

The results of this large bi-institutional cohort study demonstrate higher 90-day readmissions with rTSA,

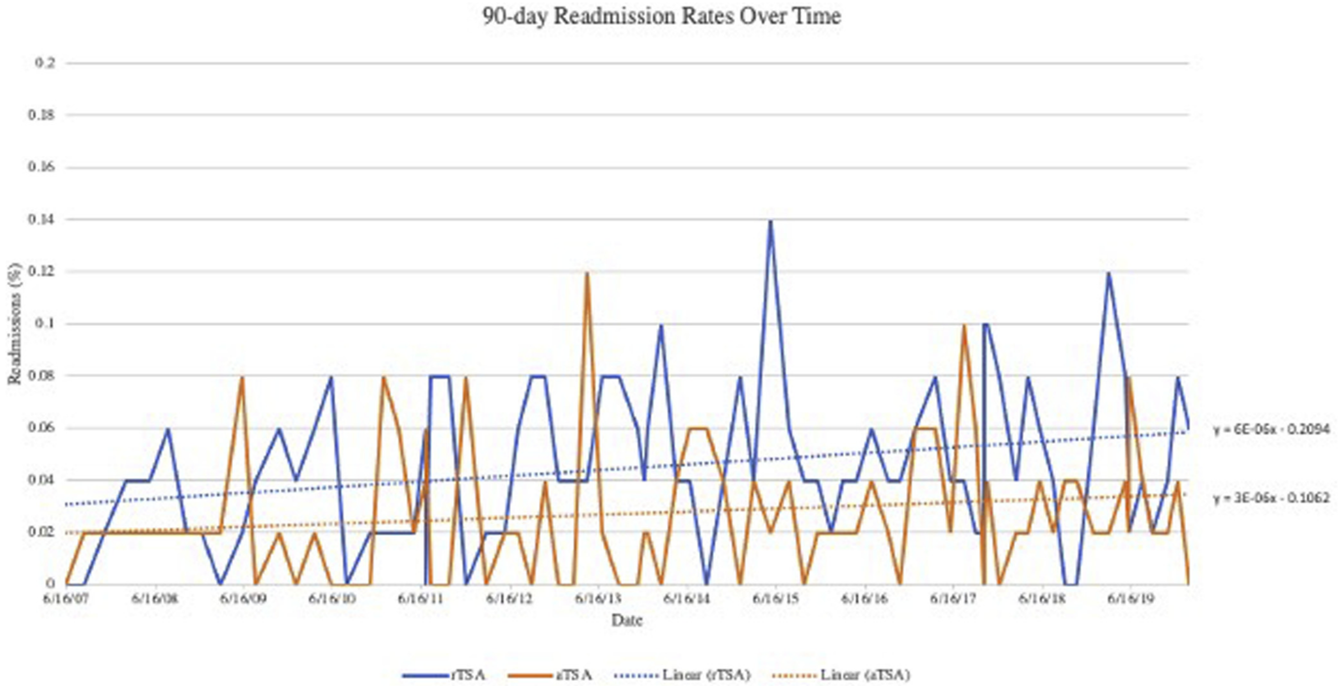


**Figure 1** Ninety-day readmission rates for anatomic total shoulder arthroplasty *(aTSA)* and reverse total shoulder arthroplasty *(rTSA)* from 2007 to 2020.

discharge to a facility, revision surgery, fracture, and right-sided surgery. Shorter inpatient stay did not portend an increased readmission risk, whereas discharge to a rehabilitation facility did increase the readmission risk. This study details a predictive model for unplanned readmissions within 90 days of shoulder arthroplasty, using 16 easily obtained, standardized preoperative variables. As it is based entirely on preoperative variables, this model will allow for improved identification of patients at higher risk of readmission in a clinical setting prior to surgery.

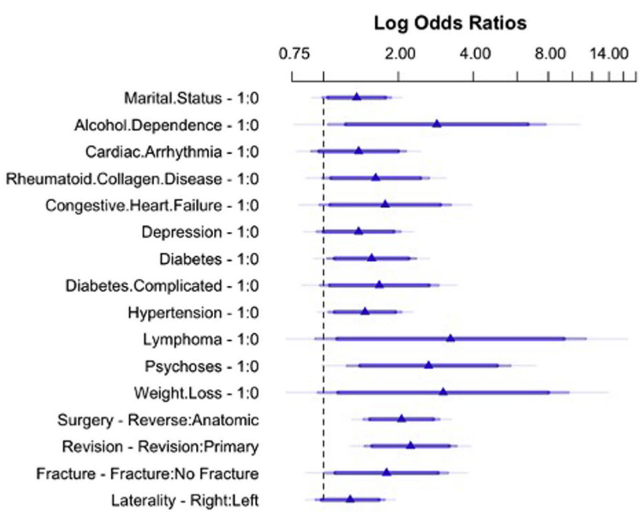


**Figure 2** Adjusted odds ratios of various surgical parameters and effect on readmission.

We report a readmission rate of 3.2% at 90 days after TSA, slightly lower than rates quoted in the literature. Results from a multi-state inpatient database consisting of 14,602 TSA patients revealed a 90-day readmission rate of 6.0%, comparable to reported readmission rates in other series (4.5%-6.7% at 90 days).[26,27,36] Single-provider high surgical volumes have been associated with lower

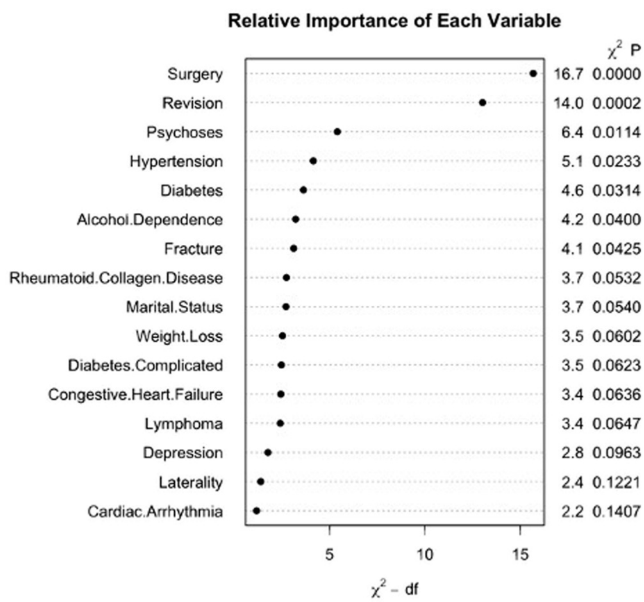


**Figure 3** Variables associated with increased risk of readmission with relative $\chi^2$ importance. *df*, degrees of freedom.

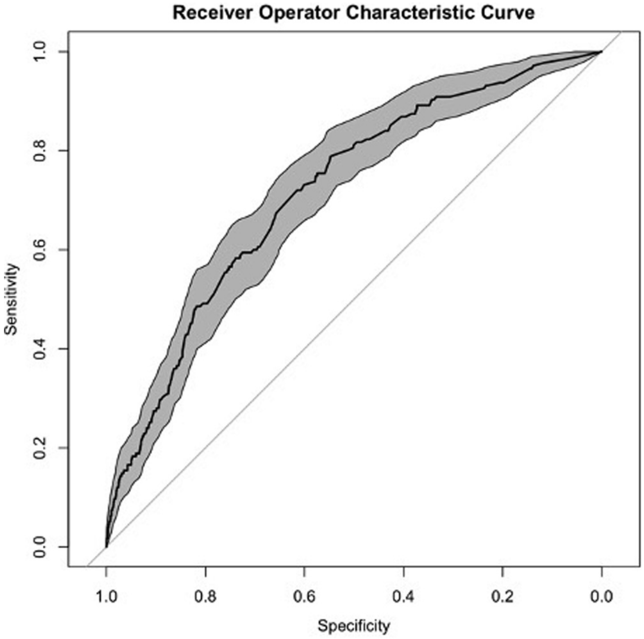


**Figure 4** Receiver operator characteristic curve for predictive modeling of 90-day readmission following shoulder arthroplasty.

complication rates in hip and knee arthroplasty, and this may have contributed to the lower readmission rate seen in our study.[40]

Several studies have focused on risk factors for readmission following TSA. Basques et al[4] analyzed the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database and found 30-day readmission to be associated with a history of heart disease and hypertension. Moreover, morbid obesity, diabetes mellitus, vascular disease, congestive heart failure, lung disease, and depression have all been linked with increased readmission rates following TSA.[9] We found similar risk factors, with the addition of fracture cases, marital status (single/no partner), alcohol dependence, and several additional comorbidities listed in Figure 2. An interesting finding was that our analysis revealed that the greatest risk factor for readmission was reverse shoulder arthroplasty, even after controlling for the older population and more severe comorbidity profile inherent in patients undergoing this procedure compared with anatomic arthroplasty.

It remains uncertain why rTSA is so strongly tied with readmission in this study cohort. On further analysis of medical vs. surgical complications, significantly more readmissions were attributable to surgical etiologies; however, there was no difference in medical vs. surgical readmissions when rTSA was evaluated via subgroup analysis ($P = .745$). Schairer et al[37] reported that >82% of readmissions following inpatient TSA were related to medical complications; however, rTSA only made up 10.6% of the study population cases, whereas our study is composed of nearly 50% rTSA cases and no hemiarthroplasty cases.

**Table II** Patient characteristics and surgical variables related to both medical and surgical complications warranting readmission

| Preoperative variables | Unplanned 90-d readmission | | *P* value |
|---|---|---|---|
| | Medical | Surgical | |
| n (%) | 65 (37.1) | 110 (62.9) | <.001 |
| Average age, yr | 70 | 66.9 | .087 |
| BMI | 30.6 | 31.1 | .869 |
| Sex: female, n (%) | 43 (66.2) | 58 (52.7) | .082 |
| Smoking status: current or former, n (%) | 30 (46.2) | 55 (50) | .412 |
| ASA score, n (%) | | | |
| 1 | 1 (1.5) | 1 (0.9) | .047 |
| 2 | 21 (32.3) | 49 (44.5) | |
| 3 | 37 (56.9) | 58 (52.7) | |
| 4 | 6 (9.2) | 2 (1.8) | |
| Surgery, n (%) | | | |
| Reverse | 47 (72.3) | 77 (70.0) | .745 |
| Revision | 2 (3.1) | 27 (24.5) | <.001 |
| Fracture | 9 (13.8) | 7 (6.4) | .097 |
| Discharge time: short stay (<30 h), n (%) | 41 (63.1) | 59 (53.6) | .223 |
| Discharge location: SNF or rehabilitation facility, n (%) | 8 (12.3) | 15 (13.6) | .801 |

*BMI*, body mass index; *ASA*, American Society of Anesthesiologists; *SNF*, skilled nursing facility.

Reverse TSA does have its own unique complication profile—specifically higher rates of instability and acromial stress fractures, which may in turn contribute to surgical readmissions. Scott et al[39] evaluated 25,196 patients through the National Readmission Database and found that the most common reason for readmission following rTSA was device complication, accounting for 68% of readmissions. Similarly, the National Inpatient Sample demonstrated that rTSA was associated with 6.2 times higher odds of perioperative implant-related complications ($P < .001$).[7] The results of our study suggest that reverse shoulder arthroplasty may carry an increased risk of both medical and surgical complications when compared with aTSA.

An interesting result of our univariable analysis was the finding that patients undergoing right-sided surgery were 28% more likely to experience a readmission compared with those undergoing left-sided surgery (the *P* value in the multivariable model dropped to .125 but still survived parameter selection for inclusion in the overall model). Although no information was available regarding the hand dominance of patients in the data set, the markedly higher proportion of the general population that is right-handed suggests that surgery affecting the dominant arm may lead to increased disability (real or perceived) in the acute postsurgical window. No studies to date have commented on laterality in the context of readmissions. Antonacci et al[3] compared 92 consecutive patients who underwent same-day discharge with 52 patients who underwent inpatient rTSA and found no difference in readmissions, despite a higher incidence of right-sided surgery in the inpatient group (69.2% vs. 52.2%, $P = .069$). The results of our study suggest there may be some increased disability associated with right-sided surgery, but further dedicated research is needed to explore this relationship.

This study did not show any increased readmission risk with short-stay surgery, which was used as a proxy for outpatient surgery, which was not routinely performed during the study period. This finding is in agreement with several other recent studies, which have failed to link short stays and ambulatory surgery with readmissions.[3,5,9] Discharge to an SNF or inpatient rehabilitation facility was found to be associated with an increased risk of readmission on univariable analysis; however, this association weakened when multivariable analysis was performed ($P = .713$). Chung et al[11] reported on 26,023 patients undergoing primary TSA in the National Readmission Database and similarly found discharge to an SNF to impart an increased risk of readmission (OR, 1.50 [95% confidence interval, 1.05-2.14]). Likewise, several studies in hip and knee arthroplasty have demonstrated a similar trend regarding facility discharge and higher 90-day readmission rates.[31,44] Validated tools that offer insight into patients who benefit from a facility discharge or are at risk of readmission after total joint arthroplasty are invaluable to providers.[16,17] Discharge to a facility may provide a lower threshold for readmission as systems are in place for communication and transportation to a hospital if something unexpected occurs in the postoperative course. Further research is required to determine whether post–acute care facilities are independent risk factors for readmission following TSA.

We used a predictive model for unplanned readmission following shoulder arthroplasty based on strictly preoperative factors. The model constructed in this study demonstrated an area under the receiver operator characteristic curve of 0.716, surpassing the ‘‘useful accuracy’’ threshold of 0.70.[15,28] Previous studies have attempted to devise risk calculators for adverse events or to apply previously validated generalizable risk calculators to the total shoulder patient population. Gowd et al[19] used the National Surgical Quality Improvement Program (NSQIP) database to develop a patient-specific risk calculator to predict various 30-day perioperative adverse events and found hematocrit level, BMI, and operative time to be significant outcome predictors. Traven et al[41] used the same registry and applied the modified 5-factor Frailty Index, a validated risk stratification tool, as a predictor of postoperative complications, demonstrating the modified 5-factor Frailty Index score to be a strong predictor of readmission (OR, 1.3) and death (OR, 2.1).[42] These models, which were constructed from nationally available databases, may be susceptible to errors inherent within these databases, such as coding inaccuracies and omissions. Moreover, the predictive accuracy of our model surpassed the accuracy of a similar model applied to a total joint population.[17] This model only uses preoperative variables, which further amplifies the utility of this proposed risk calculator, as opposed to other models that rely on intraoperative parameters to accurately predict readmission risk.[17,19]

There are several important strengths of this study. This is the largest institutional shoulder arthroplasty cohort reported to date, with a robust sample of both reverse and anatomic shoulder arthroplasty patients from geographically diverse regions. The multivariable logistic regression model was generated from a wide variety of tested variables and showed adequate preliminary accuracy. However, several limitations are worth mention. Although the 2 institutions involved in the study are tertiary referral centers with a large catchment, the data set is limited in its geographic diversity, potentially limiting the applicability, and merits further validation by outside institutions. Despite recognizing several comorbidities, such as psychosis and alcohol dependence, as risk factors for readmission, coding limitations prevented us from discerning disease status, such as active alcohol use disorder vs. a history of the disease. Further research is necessary to characterize the effect of each of these comorbidities on readmission risk. Another limitation of this study involves the service location in which care was provided. The EMR system used by one of the institutions involved in the study contains the records of inpatients only (outpatient surgery is performed at a different physical location, managed under a different EMR system). This potentially introduces selection bias, as patients indicated for surgery in the inpatient setting may have more comorbidities and a higher risk of readmission than those in the outpatient setting. Although large tertiary referral centers generally capture any postoperative complications, it is possible that some readmissions were missed if patients presented to an unaffiliated hospital for treatment.

## Conclusion

This study reports on 90-day readmission rates and risk factors following shoulder arthroplasty. Reverse TSA is associated with the highest risk of readmission, whereas a short length of stay does not impart greater risk. Surgical complications accounted for more readmissions than did medical complications within the early postoperative period. We present the results of a novel risk prediction tool that generates the risk of unplanned 90-day readmission from various preoperative patient characteristics, allowing for use in a clinical setting. An understanding of risk factors associated with readmission will help to improve resource allocation and expenses surrounding TSA.

## Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

## Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2021.07.017.

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