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Early aseptic reoperation after shoulder arthroplasty increases risk of subsequent prosthetic joint infection

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Background: Despite the success of anatomic total shoulder arthroplasty (TSA) and reverse shoulder arthroplasty (RSA), the clinical course of some patients necessitates operative intervention in the acute postoperative period. In this study, we evaluate the risk of subsequent prosthetic joint infection (PJI) in patients who undergo an aseptic reoperation within 90 days of primary shoulder arthroplasty.

Method: A retrospective review of patients with primary TSA and RSA was performed using a commercially available national database (PearlDiver Inc., Fort Wayne, IN, USA). Queries were performed with use of International Classification of Diseases, Ninth Revision and Tenth Revision and Current Procedural Technology codes. Patients were divided into cohorts based on undergoing aseptic reoperation, reoperation for PJI, or no reoperations within 90 days of index procedure. Primary outcome was subsequent PJI within 1 year of index procedure. Observed PJI rates were compared using chi-square analysis. Risk factors for PJI were compared using logistic regression.

Results: From 2010 to 2018, a total of 96,648 patients underwent primary shoulder arthroplasty: 46,810 underwent TSA and 49,838 underwent RSA. The rate of aseptic reoperation within 90 days was 0.72% and 1.5% in the TSA and RSA cohorts, respectively. At 1 year postoperatively, patients who underwent an aseptic reoperation within 90 days had an elevated risk of subsequent PJI compared with the overall rate of PJI in the TSA (3.54% vs. 0.75%; $P < .001$) and RSA (3.08% vs. 0.73%; $P < .001$) cohorts. On multivariate logistic regression analysis, aseptic reoperation within 90 days was identified as a significant risk factor for subsequent PJI in the TSA cohort (odds ratio, 14.19; $P < .001$) and RSA cohort (odds ratio, 8.38; $P < .001$). The most common indication for aseptic reoperation was postoperative prosthetic joint instability in both the TSA (31%) and RSA (49%) cohorts.

Conclusion: Aseptic reoperation within 90 days of primary TSA or primary RSA was associated with a notably increased risk of subsequent PJI.

Anatomic total shoulder arthroplasty (TSA) and reverse shoulder arthroplasty (RSA) continue to grow in popularity with expanding indications. Despite continuous advancements in techniques and technology for each of these procedures, periprosthetic joint infections (PJIs) continue to plague patients at a reported rate ranging from 0.5% to 5.0%.[4,11,13–16,20,24] The consequences of PJI are devastating for patients and represent a significant economic burden for our healthcare system.[15,20,23] Several studies have identified risk factors associated with PJI in TSA and RSA.[13,14,16,24] Understanding these factors enables surgeons to identify patients with increased risk, optimize modifiable factors, and counsel patients appropriately.

Early reoperation for aseptic indications has been identified in the total hip arthroplasty and total knee arthroplasty literature as a significant risk factor for subsequent development of PJI.[5,7,8] To our knowledge, no study has been published which examines early aseptic reoperation after primary shoulder arthroplasty as a risk factor for subsequent development of PJI. The objective of this study was to determine if there is an elevated risk of PJI for those patients who require aseptic reoperation within 90 days after primary shoulder arthroplasty.

Materials and methods

Patient records were queried from PearlDiver (PearlDiver Inc., Fort Wayne, IN, USA), a commercially available national database of

This study was conducted solely with use of a commercially available national database and is exempt from institutional review board approval.

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Table I
Total shoulder arthroplasty and reverse shoulder arthroplasty cohort demographics.

Variable	Total shoulder arthroplasty	Reverse shoulder arthroplasty
Number of patients	46810	49838
Age, mean (SD)	67 (8.3)	70.9 (6.9)
Gender, n (%)		
Male	21819 (46.6)	17973 (36.1)
Female	24991 (53.4)	31865 (63.9)
CCI, mean (SD)	1.32 (1.85)	1.56 (2.12)
Diabetes diagnosis, n (%)	15814 (33.8)	20571 (41.3)
Obesity diagnosis, n (%)	11477 (24.5)	13481 (27.0)
Aseptic reoperation within 90 d, n (%)	339 (0.72)	747 (1.50)
Reoperation for PJI within 90 d, n (%)	110 (0.23)	160 (0.32)
No reoperation within 90 d, n (%)	46,361 (99.1)	48,931 (98.2)

CCI, Charlson comorbidity index; *PJI*, prosthetic joint infection; *SD*, standard deviation.

administrative claims. The data set used for this study was MShoulder which includes patients from a 122-million-patient population across all payer types (commercial insurance, Medicare, Medicaid, cash, and government plans) who had shoulder arthroplasty between January 1, 2010 and June 30, 2018. In total, there are 191,486 distinct patients in the data set, including medical records and indications for surgery. Access to the database was granted by PearlDiver Technologies for the purpose of academic research. The database was stored on a password protected server maintained by PearlDiver. International Classification of Diseases, Ninth Revision and Tenth Revision (ICD-9/ICD-10) and Current Procedural Technology (American Medical Association, Chicago, IL, USA) codes can be searched in isolation or in combination with one another to yield the number of patients with matching claims.

Patients that received anatomic TSA were identified in inpatient records using ICD-9 code 81.80 and ICD-10 codes 0RRJ0JZ and 0RRK0JZ. Patients that received RSA were identified using ICD-9 code 81.88 and ICD-10 codes 0RRJ00Z and 0RRK00Z. Patients were excluded from the analysis if there was a history of revision arthroplasty, hardware removal, pathologic fracture, active or chronic infection, or malignancy/metastatic disease. A full list of inclusion and exclusion criteria codes is provided in Appendix A.1. Demographic data and preexisting clinical characteristics were queried directly from the database and included age, gender, diagnosis of obesity, diagnosis of diabetes, and Charlson comorbidity index (CCI) (Tables I and II).

Patients were queried from the database using ICD-P-9/10 and Current Procedural Technology codes to identify two cohorts in the RSA group and TSA group: patients with aseptic reoperation in first 90 days postoperatively and patients with no operative intervention in first 90 days postoperatively. The rate of PJI at 1 year after primary procedure was then queried and compared. PJI was defined by procedural codes indicating a deep joint infection requiring a surgical intervention to exclude any superficial wound complications. A list of PJI criteria codes is provided in Appendix A.2. The primary diagnosis leading to reoperation in the first 90 days was queried and separated into groupings of prosthetic dislocation, periprosthetic fracture, prosthetic loosening or implant failure, prosthetic stiffness, adjacent local fractures (ie, of the acromion or scapula), rotator cuff disease (TSA only). A list of joint complication codes is available in Appendix A.3.

Statistical analysis

The data are reported using summary statistics, including means and standard deviations for continuous variables and counts and percentages for categorical variables. Microsoft Excel software was used to perform chi-square analyses of 1-year infection rates of the cohorts. Risk factors for PJI were assessed individually and in a multivariate model using R statistical software (R Project for Statistical Computing, Vienna, Austria) integrated in the PearlDiver software. The risk factors included were age, gender, diagnosis of obesity at time of primary shoulder arthroplasty, diagnosis of diabetes at time of primary shoulder arthroplasty, and CCI. All statistical tests were 2-sided, and *P* values less than .05 were considered statistically significant.

Table II
Prosthetic joint infection rates at 1 year, total shoulder arthroplasty.

Cohort	n (%)	PJI at 1 yr (%)	*P* value
All patients with TSA	46810	0.75	-
PJI within 90 d	110 (0.23)	-	-
Reoperation within 90 d	339 (0.72)	3.54	<.0001
No surgery or PJI within 90 d	46,361 (99.1)	0.49	<.0001

PJI, prosthetic joint infection; *RSA*, reverse shoulder arthroplasty; *TSA*, total shoulder arthroplasty (anatomic).

Results

Between January 1, 2010 and June 30, 2018 102,752 patients were identified in the Pearldiver database as receiving primary shoulder arthroplasty, 96,648 of which did not meet any of the exclusion criteria. Of these patients, 270 (0.28%) had a PJI and 1086 (1.1%) had an aseptic reoperation within 90 days of the index shoulder arthroplasty surgery. The overall rate of PJI was 0.74% at 1 year after shoulder arthroplasty.

The patients were divided into cohorts based on surgery type with 46,810 patients in the TSA cohort and 49,838 in the RSA cohort. In the TSA cohort, 339 (0.72%) patients underwent aseptic reoperation and 110 (0.23%) had a PJI in the first 90 days after primary surgery. In the RSA cohort, 747 (1.50%) underwent aseptic reoperation and 160 (0.32%) has a PJI within 90 days of primary surgery. Demographic data for these cohorts can be viewed in Table I.

TSA cohort

The overall observed rate of PJI at 1 year after primary TSA was 0.75%. Patient who underwent an aseptic reoperation within the first 90 days after primary TSA had a subsequent PJI rate of 3.54% ($P < .001$) at 1 year postoperatively. Patient who had no aseptic reoperation or PJI within the first 90 days had a PJI rate of 0.49% ($P < .001$) at 1 year (Table II). Univariate analysis of risk factors found that patients who underwent aseptic reoperation within 90 days had an elevated risk of PJI at 1 year (odds ratio [OR], 15.23; 95% confidence interval [CI] 10.77-21.01; $P < .001$). Additional significant factors included age (OR, 0.95; 95% CI 0.94-0.96; $P < .001$), male gender (OR, 1.24; 95% CI 1.03-1.50; $P = .023$), and obesity (OR, 1.26; 95% CI 1.05-1.52; $P = .014$). Diabetes and CCI did not reach significance (Table III). After multivariate analysis, only reoperation within 90 days (OR, 14.19; 95% CI 9.99-19.69; $P < .001$) and age (OR, 0.95; 95% CI 0.94-0.96; $P < .001$) remained significant (Table III).

The most common indication for reoperation within 90 days after primary TSA was prosthetic dislocation (31%) followed by rotator cuff tear (26.3%) and implant loosening or mechanical issue (15.6%). All indications for reoperation and their rates are displayed in Table IV.

RSA cohort

The overall PJI rate at 1 year after primary RSA was 0.73%. Patients who underwent aseptic reoperation within 90 days of the primary

Table III
Total shoulder arthroplasty univariate and multivariate regression analysis of risk factors for prosthetic joint infection.

Parameter	Univariate analysis				Multivariate analysis			
	OR	95% CI		*P* value	OR	95% CI		*P* value
		Low	High			Low	High	
Age (continuous)	0.95	0.94	0.96	<.001*	0.95	0.94	0.96	<.001*
CCI	0.99	0.94	1.04	.784	1.00	0.95	1.06	.876
Male gender	1.24	1.03	1.50	.0234*	1.12	0.93	1.36	.238
Diabetes diagnosis	1.08	0.90	1.30	.412	1.10	0.89	1.34	.381
Obesity diagnosis	1.26	1.05	1.52	.0148*	1.16	0.96	1.41	.133
Reoperation <90 ds	15.23	10.77	21.01	<.001*	14.19	9.99	19.69	<.001*

CCI, Charlson comorbidity index; *CI*, confidence interval; *OR*, odds ratio.
*Indicates significance ($P < .05$).

surgery had a subsequent PJI rate of 3.08% ($P < .001$) at 1 year, while those who had no reoperation (aseptic or PJI related) within 90 days of surgery had a 1-year PJI rate of 0.37% ($P < .001$) (Table V). Univariate analysis of risk factors found that patients who underwent aseptic reoperation within 90 days had an elevated risk of PJI at 1 year (OR, 10.28; 95% CI 7.95-13.13; $P < .001$). Additional factors that reached significance in univariate model included age (OR, 0.94; 95% CI 0.93-0.95; $P < .001$), male gender (OR, 1.83; 95% CI 1.53-2.18; $P < .001$), and obesity (OR, 1.35; 95% CI 1.13-1.61; $P < .001$). Diabetes and CCI did not reach significance (Table VI). Aseptic reoperation within 90 days remained significant on multivariate analysis (OR, 8.38; 95% CI 6.45-10.77; $P < .001$), as did age (OR, 0.94; 95% CI 0.93-0.95; $P < .001$), male gender (OR, 1.54; 95% CI 1.29-1.84; $P < .001$), and CCI (OR, 1.04; 95% CI 1.00-1.08; $P = .038$) (Table VI).

The most common indication for reoperation after primary RSA was prosthetic dislocation (49%) followed by implant loosening or mechanical complication (18%) and fracture (13%). All indications for reoperation can be viewed in Table IV.

Table IV
Indication for aseptic reoperation within 90 days after primary shoulder arthroplasty.

Indication for reoperation	TSA, n (%)	RSA, n (%)
Periprosthetic Fracture	33 (10)	95 (13)
Prosthetic joint instability	105 (31)	366 (49)
Mechanical complication of implant	53 (16)	136 (18)
Prosthetic stiffness	30 (9)	64 (9)
Rotator cuff tear	89 (26)	0 (0)
Scapula fracture	0 (0)	14 (2)
Hematoma	25 (7)	47 (6)
Other	4 (1)	25 (3)

RSA, reverse shoulder arthroplasty; *TSA*, total shoulder arthroplasty (anatomic).

Table V
Prosthetic joint infection rates at 1 year, reverse shoulder arthroplasty.

Cohort	n (%)	PJI at 1 yr (%)	*P* value
All patients withRSA	49838	0.73	-
PJI within 90 d	160 (0.32)	-	-
Reoperation within 90 d	747 (1.50)	3.08	<.0001
No surgery or PJI within 90 d	48,931 (98.2)	0.37	<.0001

PJI, prosthetic joint infection; *RSA*, reverse shoulder arthroplasty.

Discussion

This study demonstrated a 4.2- and 4.7-fold increase in risk of subsequent deep PJI after aseptic reoperation within 90 days after primary RSA and TSA, respectively. The risk associated with early reoperation remained significant on multivariate regression analysis in both cohorts. This finding highlights the importance of preventing avoidable complications and emphasizing patient compliance, in the acute postoperative period after shoulder arthroplasty to minimize risk of future PJI.

The rate of PJI requiring a reoperation in the first 90 days was low at 0.23% for TSA and 0.32% for RSA. Notably, patients who at 90 days after index procedure had not undergone a reoperation for any indication had 1-year PJI rates of 0.49% and 0.38% in the TSA and RSA cohorts, respectively. Comparing patients who had an early aseptic reoperation to those who had no reoperation in the first 90 days, the aseptic reoperation cohort had a 7.2- to 8.3-fold increase in risk of subsequent PJI. This further highlights the importance of the acute postoperative period and is reassuring for patients who do not suffer an early complication after shoulder arthroplasty.

The rate of reoperation within 90 days of index procedure was higher in the RSA cohort at 1.50% compared with the TSA cohort at 0.72%. Previous studies have shown this relationship of increased reoperation rates in the 90-day period after RSA compared with TSA.[18,22] The etiology of the increased complication rate is likely multifactorial and related to host factors, surgical technique, implant design, and other factors associated with RSA procedures.

In an institutional database study, Streubel et al[22] reported shoulder instability as the most common indication for reoperation within 90 days of index shoulder arthroplasty. Our study supports this finding as shoulder instability accounted for 31% and 49% of the aseptic reoperations in the first 90 days after TSA and RSA, respectively. Proper component positioning and restoration of soft-tissue tensions intraoperatively are critical for prevention of postoperative instability.[2,18,19] Patients who may be at increased risk for postoperative instability should be identified preoperatively to optimize outcomes. Postoperative hematoma has been reported as a common complication after index shoulder arthroplasty procedures, particularly in the RSA literature.[9,11,25] Hematoma was a relatively rare indication for reoperation in this study, accounting for 7% in the TSA group and 6% in the RSA group. This discrepancy is likely owing to the present study only accounting for hematomas which require an operation, excluding those treated conservatively or joint aspiration performed in clinic.

Numerous prior studies have indicated male gender and younger age as risk factors for subsequent PJI after TSA and RSA.[4,6,13,14,16,20] In the present study, male gender, younger age, and CCI were significant risk factors in multivariate analysis of the RSA cohort. Analysis of the TSA cohort showed male gender and younger age to be significant factors on univariate analysis; however, only younger age remained significant on multivariate analysis. This discrepancy may be explained by the fact our study is the first to include early aseptic reoperations in the multivariate analysis and only reports serious infections requiring reoperation within the first year.

While this is the first study to address infection-risk associated with early aseptic reoperation after shoulder arthroplasty,

Table VI
Reverse shoulder arthroplasty univariate and multivariate regression analysis of risk factors for prosthetic joint infection.

Parameter	Univariate analysis				Multivariate analysis			
	OR	95% CI		*P* value	OR	95% CI		*P* value
		Low	High			Low	High	
Age (continuous)	0.94	0.93	0.95	<.001*	0.94	0.93	0.95	<.001*
CCI	1.03	0.99	1.07	.102	1.04	1.00	1.08	.038*
Male gender	1.83	1.53	2.18	<.001*	1.54	1.29	1.84	<.001*
Diabetes diagnosis	1.01	0.85	1.21	.896	0.90	0.75	1.09	.302
Obesity diagnosis	1.35	1.13	1.61	<.001*	1.16	0.96	1.39	.115
Reoperation <90 days	10.28	7.95	13.13	<.001*	8.38	6.45	10.77	<.001*

CCI, Charlson comorbidity index; *CI*, confidence interval; *OR*, odds ratio.
*Indicates significance ($P < .05$).

literature from other fields has reported similar findings. Goldman et al published on a series of patients with total hip arthroplasty requiring aseptic reoperation within the first year of primary arthroplasty reporting an 8- to 13-fold increased risk of PJI.[8] The group reported similar findings on a series of patient with total knee arthroplasty with an associated 4- to 9-fold increased risk of subsequent PJI.[7] At a cellular level, wound healing is a carefully orchestrated process which requires tight control of oxygen tension and pH levels for appropriate healing response and infection prevention.[1,3,10,12,17,21] The disruption of a healing wounds oxygen tension level and pH level with the early insult of a reoperation may in part explain the relationship between early reoperation and subsequent infection. In addition, there may be host factors that increase a patient's risk of experiencing early reoperation that may independently increase a patient's risk of developing PJI.

The retrospective design of this study is a limitation as we can by definition only establish association, not causation. There are also inherent limitations to any national database study. Patient charts cannot be directly reviewed, thus the scope of the investigation is limited to information captured in billing codes. Given this, we are unable to comment on relevant information such as species of pathogens, rate of perioperative culture collection during reoperation, or possible interventions to mitigate the increased risk of infection after reoperation. In addition, accurate billing codes, miscoding, and noncoding by physicians are all potential sources of error. The study included patients before and after the introduction of ICD-10 codes, thus ICD-9 and ICD-10 codes were used to query patients. A code translator was used to identify corresponding codes and maximize accuracy. To limit the effect of coding error and exclude superficial infections, the definition of PJI was restricted to patients with a significant deep infection requiring a surgical intervention. Similarly, PJI outcomes were restricted to 1 year postoperatively to avoid confounding patients that subsequently had a contralateral shoulder arthroplasty. This restriction limits our ability to comment on the effect of early reoperation on development of late PJI. Finally, national database studies can potentially miss patients not captured by the registry affecting the outcome of the clinical question analyzed.

The congruence of our findings with those available in the literature speaks to the validity of this national database study. The 1-year PJI rates for TSA (0.75%) and RSA (0.73%) reported in this study are within the range of expected PJI rates based on current literature.[11,15,18,24] The combined 90-day aseptic reoperation rate after shoulder arthroplasty observed in this study was 1.12% which does not significantly differ from the 0.91% reported in the institutional database study by Streubel et al.[22] Use of the PearlDiver database allowed us to query 96,648 shoulder arthroplasty patients across multiple payer-types and geographic locations. Early aseptic reoperations and PJIs are each relatively uncommon events after shoulder arthroplasty, thus access to a large, heterogenous population was a major strength of this study and makes these results generalizable.

Conclusion

Patients who underwent an aseptic reoperation within 90 days of index shoulder arthroplasty surgery experienced a 4.2- to 4.7-fold increase in risk of prosthetic joint infection at 1-year. The rates of 90-day reoperation were 0.72% in the TSA cohort and 1.50% in the RSA cohort.

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Supplementary data

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