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The relationship of bilateral shoulder arthroplasty timing and postoperative complications

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Background: Though several case series have described bilateral shoulder arthroplasty results with range of motion, patient-reported outcomes, and complications, little guidance exists regarding the optimal interval timing between surgeries.
Methods: All patients from 2 insurance databases who underwent staged bilateral shoulder arthroplasty between 2005 and 2016 were identified. These patients were then stratified by elapsed time between surgeries into 4 study groups: (1) less than 3 months, (2) 3-6 months, (3) 6-9 months, and (4) 9-12 months. Surgical and perioperative medical complications of these patient cohorts were compared to a control group that underwent bilateral shoulder arthroplasty with a greater than 1-year interval between surgeries.
Results: From 2005-2016, a total of 1764 patients (6.3%) underwent bilateral shoulder arthroplasty out of 27,962 shoulder arthroplasties performed in the 2 databases. Of the bilateral patients, 49.1% waited more than 1 year before their second shoulder arthroplasty. Patients waiting less than 3 months between surgeries comprised 4.9% of the total number of staged bilateral surgeries. Demographics and comorbidities were similar between the study groups. Overall, implant complications were higher in patients with surgeries less than 3 months apart compared to controls, including revision arthroplasty (11.6% vs. 5.4%, odds ratio [OR] 2.29, $P = .037$), loosening/lysis (8.1% vs. 3.5%, OR 2.46, $P = .032$), and periprosthetic fracture (4.7% vs. 1.2%, OR 4.18, $P = .010$). There were no significant increases in any implant-related complications when surgeries were staged by 3 months or more compared to controls. Venous thromboembolism (VTE; 8.1% vs. 2.2%, OR 3.95, $P = .001$) and blood transfusion (9.3% vs. 1.7%, OR 5.82, $P < .001$) occurred at a significantly higher rate in patients with less than 3 months between surgeries compared with controls. There were no differences in any medical complications when surgeries were staged by 3 months or more compared with controls.
Conclusions: Patients with staged bilateral shoulder arthroplasty who have the second arthroplasty within 3 months have significantly higher rates of revision surgery, loosening/lysis, periprosthetic fracture, VTE, and blood transfusions. Based on these lower complication rates, surgeons should consider waiting a minimum of 3 months before performing the second portion of a staged bilateral shoulder arthroplasty.
Level of evidence: Level III; Retrospective Cohort Comparison using Large Database; Treatment Study
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Keywords: Shoulder arthroplasty; bilateral shoulder arthroplasty; anatomic arthroplasty; reverse total shoulder arthroplasty; complications

Ethical approval for this study was waived by the University of Virginia Health System Research IRB because it involves the reporting of deidentified, publically reported data. This study was completed in accordance with the Helsinki Declaration as revised in 2013.

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The number of shoulder arthroplasty procedures performed in the United States for end-stage shoulder degeneration, including both anatomic and reverse shoulder arthroplasty, continue to increase dramatically.[13] Because of the significant clinical improvement patients experience following shoulder arthroplasty, patients with bilateral shoulder arthritis often desire to address both symptomatic shoulders surgically. Historically, surgeons have been concerned about the functional limitations of bilateral shoulder replacements including various combinations of anatomic total shoulder arthroplasty (TSA) and reverse total shoulder arthroplasty (RTSA) for the same patient on their left and right shoulders.[15,21] The limitations of internal rotation after RTSA to allow patients to perform activities of daily living (ADLs) such as perineal care, bra fastening, shirt tucking, etc has been cited as a reason to avoid bilateral TSA/RTSA.[2,16,21] However, multiple recent studies have demonstrated that the vast majority of patients are able to perform all ADLs and compensate without difficulty despite bilateral TSA and/or RTSA.[1,8,15-17,20] Improvements in implants over the past decade, including the use of more lateralized RTSA systems, have allowed improvements in rotational active range of motion to make ability to perform ADLs less of a concern.[22]

To date, most studies involving bilateral shoulder arthroplasty have focused on functional results in small series, such as patient-reported outcomes and range of motion.[1,21] The literature provides very little guidance regarding the optimal timing between bilateral shoulder arthroplasty, with the only study on the topic recommending performing bilateral procedures within 6 months of each other for better clinical outcomes.[10] Accordingly, the objective of this study was to better understand the influence of timing between bilateral shoulder arthroplasty surgeries on medical and surgical complications. We hypothesized that patients who had staged procedures less than 3 months apart would be at a higher risk for surgical and medical complications compared to patients with more than a year between procedures.

Materials and methods

Database

The PearlDiver database (PearlDiver Technologies, West Conshohocken, PA, USA, http://www.pearldiverinc.com) was retrospectively reviewed. This national database of insurance-based administrative collection of deidentified health information is publicly available, and thus deemed exempt by our Institutional Review Board. Records include both private insurance data and Medicare data. For the present analysis, data from both the private insurance data set (Humana, 2007-2017) and the 5% Medicare data set (2005-2014) were combined in order to maximize the number of patients included. These 2 data sets index arthroplasty procedures by Current Procedural Terminology (CPT) code, which is necessary, as only CPT codes have laterality modifiers within the database to confirm laterality. The 100% Medicare Standard Analytical Files that have been used for numerous other studies from this database were not a viable option for this study because arthroplasty is indexed by the International Classification of Diseases, Ninth Revision (ICD-9), procedure code which does not include laterality modifiers. The database allows searching for patient demographic and surgical information using ICD-9 diagnoses and procedures using CPT codes. CPT codes with laterality modifiers were used to search the surgical information in order to ensure that laterality was maintained and confirm that both shoulders underwent arthroplasty instead of revision arthroplasty to the same shoulder.

Patients

Both databases were queried for all patients who underwent TSA, including both anatomic and reverse, using CPT code 23472. For the purposes of this study, as CPT codes do not allow differentiation between anatomic and reverse shoulder arthroplasty, we will refer to both as TSA. Patients with prior infection, those undergoing hemiarthroplasty, arthroplasty for a diagnosis of proximal humerus fracture, and revision shoulder arthroplasty were all excluded. Patients without laterality modifiers were also excluded from the analysis, which represented a small percentage overall (less than 5%). Although it represented a very small percentage of patients, those who underwent simultaneous (same day) bilateral shoulder arthroplasty were also excluded. Patients who underwent staged bilateral shoulder arthroplasties were identified using laterality codes for left following a right TSA and right following a left TSA. Once a cohort of patients was identified who underwent staged bilateral shoulder arthroplasty, the cohort was divided into subgroups based on the time period between procedures. The following time periods were established: less than 3 months, 3-6 months, 6-9 months, and 9-12 months. Another group consisting of patients who underwent their second shoulder arthroplasty greater than 1 year after their primary surgery was established as the control group to which comparisons were made. It was necessary to have a control group that also had bilateral shoulder arthroplasties to ensure similar arthroplasty exposure, as we assumed that the presence of 2 TSAs has a higher risk for complications than a single TSA.

Data collection

Demographic data were recorded, including age, sex, body mass index category, tobacco use, alcohol abuse, and numerous medical comorbidities. Basic demographic data are provided in the database output, and the remaining data was ascertained through ICD-9 codes. Implant-related complications were assessed for either arthroplasty from the date of the second arthroplasty. This timing was necessary to ensure that complications were not counted twice, and that the difference in complications assessed was due to the timing of bilateral TSA. The following implant-related complications at any point following either arthroplasty were assessed: (1) revision arthroplasty, (2) loosening or lysis, (3) periprosthetic fracture, (4) periprosthetic instability/dislocation, and (5) periprosthetic infection. Revision was assessed with ICD-9 procedure codes or CPT codes for revision arthroplasty for the length of the

entire database, again following the date of the second arthroplasty. The remaining implant-related complications were queried using the relevant ICD-9 diagnosis codes. The following medical complications within 90 days of the date of the second TSA were assessed using ICD-9 codes: venous thromboembolism (PE or DVT), visit to an emergency room (ER), urinary tract infection (UTI), pneumonia (PNA), myocardial infarction (MI), acute renal failure (ARF), cerebrovascular accident (CVA), and blood transfusions.

Statistical analysis

Demographics and medical comorbidities for each of the 4 study groups and control group were reported as number of patients and percentages. Overall incidence of complications were reported as numbers of patients and percentages. Comparisons of demographics and complication rates between groups were performed using chi-squared tests or Fisher exact tests for very small sample sizes. Regression analyses were not possible when combining data sets, only for individual data sets; however, the patients in each group were demographically similar (Table I). For all statistical tests, $P < .05$ was considered statistically significant. SPSS version 26 (IBM, Armonk, NY, USA) was used for all statistical analyses.

Results

A total of 1764 patients (6.3%) underwent bilateral shoulder arthroplasty out of 27,962 shoulder arthroplasties performed across both databases. Half of the staged bilateral patients waited more than 1 year before undergoing their second shoulder arthroplasty (866 patients or 49.1%). The distributions of other groups are provided in Fig. 1, with 86

Table I Patient demographics

	3 mo, n (%) (n = 86)	6 mo, n (%) (n = 294)	9 mo, n (%) (n = 272)	1 yr, n (%) (n = 246)	>1 yr, n (%) (n = 866)	Statistical comparison, *P* value			
						3 vs. 6 mo	3 vs. 9 mo	3 mo vs. 1 yr	3 mo vs. >1 yr
Demographics									
Age group									
<65 yr	9 (77)	37 (257)	26 (246)	25 (221)	65 (801)	.56	.81	.94	.33
65-69 yr	19 (67)	73 (221)	58 (214)	49 (197)	165 (701)	.60	.88	.67	.50
70-74 yr	26 (60)	93 (201)	70 (202)	81 (165)	269 (597)	.81	.41	.65	.87
75-79 yr	18 (68)	59 (235)	65 (207)	62 (184)	231 (635)	.86	.57	.43	.25
80-84 yr	12 (74)	26 (268)	48 (224)	25 (221)	119 (747)	.17	.42	.34	.96
85+ yr	2 (84)	6 (288)	5 (267)	4 (242)	17 (849)	.87	.78	.68	.82
Sex (female)	45 (41)	163 (131)	154 (118)	131 (115)	542 (324)	.61	.49	.88	.06
Obesity (BMI 30-39.9)	23 (63)	76 (218)	60 (212)	60 (186)	217 (649)	.87	.37	.66	.73
Morbid obesity (BMI 40+)	20 (66)	61 (233)	28 (244)	42 (204)	178 (688)	.62	.002	.21	.56
Tobacco use	18 (68)	71 (223)	64 (208)	53 (193)	183 (683)	.54	.62	.91	.97
Alcohol abuse	6 (80)	17 (277)	13 (259)	13 (233)	41 (825)	.68	.43	.56	.36
Comorbidities									
Diabetes mellitus	35 (51)	118 (176)	101 (171)	101 (145)	368 (498)	.93	.55	.95	.75
Hyperlipidemia	76 (10)	256 (38)	233 (39)	207 (39)	804 (62)	.75	.52	.34	.14
Hypertension	75 (11)	258 (36)	241 (31)	223 (23)	812 (54)	.89	.73	.37	.06
Peripheral vascular disease	16 (70)	39 (255)	61 (211)	48 (198)	204 (662)	.22	.45	.85	.30
Congestive heart failure	23 (63)	70 (224)	56 (216)	68 (178)	212 (654)	.58	.23	.87	.64
Coronary artery disease	34 (52)	104 (190)	112 (160)	112 (134)	410 (456)	.48	.79	.34	.17
Chronic kidney disease	20 (66)	71 (223)	61 (211)	58 (188)	224 (642)	.86	.87	.95	.60
Chronic lung disease	30 (56)	79 (215)	88 (184)	81 (165)	318 (548)	.15	.66	.74	.74
Chronic liver disease	10 (76)	29 (265)	22 (250)	23 (223)	93 (773)	.64	.32	.54	.80
Thyroid disease	28 (58)	106 (188)	93 (179)	82 (164)	334 (532)	.55	.78	.90	.27
Depression	33 (53)	111 (183)	104 (168)	82 (164)	351 (515)	.92	.98	.40	.70

BMI, body mass index.

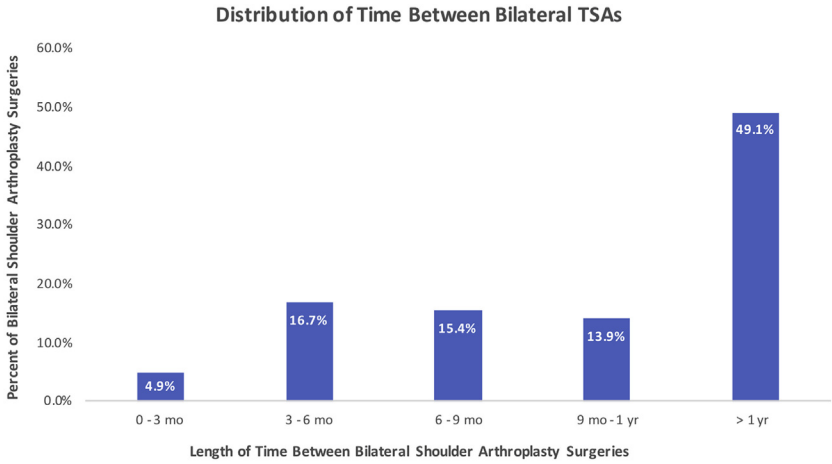

Figure 1 Distribution of patients into time periods describing the interval waiting period between first and second shoulder arthroplasties. *TSAs*, total shoulder arthroplasties.

patients (4.9%) undergoing their second shoulder arthroplasty less than 3 months after the first surgery and the remaining groups being between 14% and 17% each. There were no statistically significant differences in demographics between the groups, with the exception of the rate of morbid obesity between the 3- and 9-month groups ($P = .002$) (Table I). Medical comorbidities were also similar between the groups ($P > .05$ for all comparisons).

Implant-related complications

Patients who underwent bilateral shoulder arthroplasties within less than 3 months of each other were roughly twice as likely as patients who waited more than 1 year between surgeries to require revision of either prosthesis (11.6% vs. 5.4%, odds ratio [OR] 2.29, 95% confidence interval [CI] 1.21-4.71, $P = .037$) (Fig. 2). Additionally, patients with less than 3 months between their arthroplasties had higher rates of loosening/lysis (8.1% vs. 3.5%, OR 2.46, 95% CI 1.15-5.80, $P = .032$) and periprosthetic fracture (4.7% vs. 1.2%, OR 4.18, 95% CI 1.28-13.61, $P = .010$) compared to those with more than 1 year in between. There were no significant differences in the rates of periprosthetic dislocation ($P = .618$) or infection ($P = .157$) between 3-month patients and controls (Fig. 2). There were no significant differences in any implant-related complications between patients in the 3-6-month, 6-9-month, and 9-12-month groups and the controls ($P > .05$ for all comparisons).

Medical complications

Patients who underwent bilateral shoulder arthroplasty with less than 3 months between surgeries had a higher incidence of venous thromboembolism (8.1% vs. 2.2%, OR 3.95, 95% CI 1.61-9.68, $P = .001$) and blood transfusions (9.3% vs. 1.7%, OR 5.82, 95% CI 2.39-14.15, $P < .001$) compared to patients with greater than 1 year between surgeries (Fig. 3). There were no differences in the risk of any of the other assessed medical complications between the <3-month patients and controls ($P > .05$ for all comparisons). There were no significant differences in any medical complications between patients in the 3-6-month, 6-9-month, and 9-12-month groups and the controls ($P > .05$ for all comparisons) (Fig. 3).

Discussion

The important findings of this study are that patients who undergo a contralateral shoulder arthroplasty less than 3 months following their first shoulder arthroplasty are at a higher risk for several implant-related and medical complications compared with patients who wait longer than a year between surgeries. This risk appears to be mitigated by waiting 3 or more months between bilateral shoulder arthroplasty as there was no increased complications beyond that threshold.

There are several reports that describe postoperative function, range of motion, and complications after bilateral shoulder arthroplasty, which are mostly limited by low patient numbers as case reports[7,19] and single-center case series.[8-10,16,20] These existing studies have been important to demonstrate that improvements in technology have made good functional outcomes and range of motion possible with bilateral shoulder arthroplasty.

Concern exists about loss of functional range of motion resulting from bilateral shoulder arthroplasty.[21] Namdari et al[18] reported that although obtaining full range of motion was the goal of all shoulder treatment, significantly less range of motion was necessary to complete ADLs, making it feasible that the active motion losses from bilateral shoulder arthroplasty would be tolerated. Despite concern that patients with bilateral RTSA would not be able to accomplish basic ADLs, Stevens et al demonstrated in their cohort of 15 patients that all were

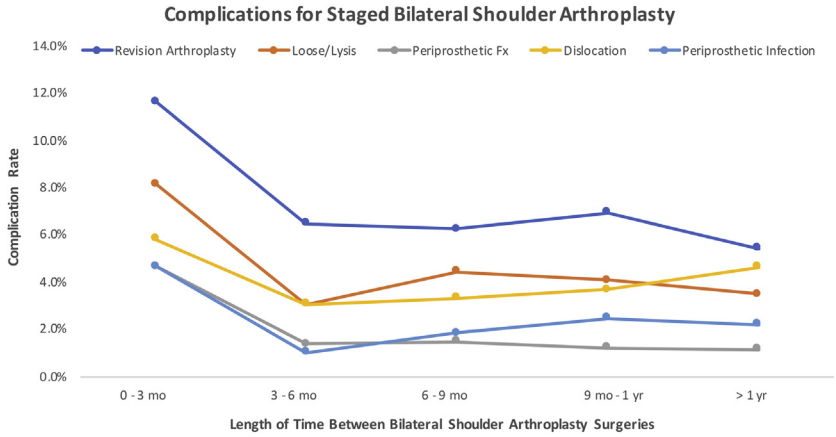

Figure 2 Complication rates according to the interval period between first and second shoulder arthroplasties. *Fx*, fracture.

able to perform all ADLs with at least 1 shoulder, most with minimal difficulty.[20] Another group reported that although patients who undergo anatomic followed by anatomic TSA (TSA/TSA) ultimately reach higher forward elevation, internal rotation, and external rotation levels than those who undergo reverse followed by reverse TSA (RTSA/RTSA), both groups experience similar amounts of improvement and ultimately satisfactory levels.[14] Conflicting data exist for rotational range of motion, as some studies have reported no rotational range of motion improvements for bilateral RTSA, whereas others have found satisfactory and even improved range of motion after bilateral shoulder arthroplasty.[2,15,24,25] Although we cannot comment specifically on range of motion for the patients in our administrative data set, the evidence from the majority of these prior case series supports that living with bilateral arthroplasty is feasible and that the majority of patients will regain sufficient functional range of motion to perform ADLs.

Several prior case series have described the incidence of various complications after staged bilateral shoulder arthroplasty, but given the limited number of patients in any existing reports, no study has been able to correlate complications with timing between surgeries. One study of 50 patients undergoing bilateral RTSA average 22 months apart showed 2 postoperative complications, 1 with bilateral scapular spine fractures and 1 a periprosthetic humeral fracture.[20] Another study of 19 patients with bilateral RTSA staged on average 18 months apart reported 2 patients who suffered traumatic scapular spine fractures after falls.[15] Morris et al[17] had 1 patient of 11 who had 2 complications. Gerber et al[11] compared 6 patients with simultaneous bilateral shoulder arthroplasty to 8 patients with staged shoulder arthroplasty (mean surgical interval of 18 months, range 6-43 months) and found a significantly higher rate of transfusions in the simultaneous group. No venous thromboembolism events were found in either group in that study. However, 2 additional series have

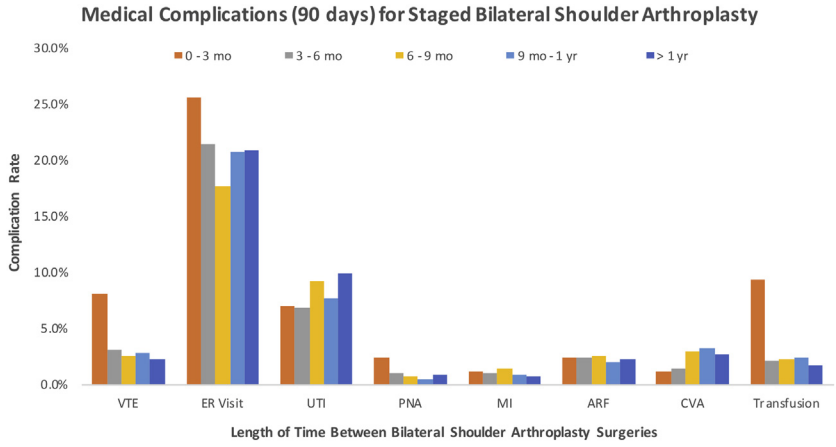

Figure 3 Medical complications within 90 days according to period of time between shoulder arthroplasties. *VTE*, venous thromboembolism; *ER*, emergency room; *UTI*, urinary tract infection; *PNA*, pneumonia; *MI*, myocardial infarction; *ARF*, acute renal failure; *CVA*, cerebrovascular accident.

reported much higher complication rates nearing 30% in groups of 16 and 57 patients, with mean 14 months between arthroplasties in both studies, who underwent bilateral RTSA.[24,25] Five of 50 patients (10%) in another staged RTSA/RTSA study with 15 months between sides developed acromial fractures.[16] Although the numbers are small, the rate of acromial stress fracture is higher than the 1%-4% reported in the literature and is important to consider. It is possible that the primary prosthesis shoulder experiences an increase in stress from the higher workload once the second shoulder is immobilized in the postoperative period from the second surgery. This could account for the acromial stress fractures in these studies. Moreover, regardless of implant type, this increased stress may account for the higher rates of surgical complications noted in our analysis, such as loosening/lysis, periprosthetic fractures, and resulting revision surgery. This assertion is further supported by single-photon emission computed tomography/computed tomography data demonstrating that osseointegrative metabolic activity around TSA implants is completed by 3 months postoperatively, which may explain the finding of a 3-month threshold in our study.[3]

The timing between staged shoulder arthroplasty has been less adequately defined. The best existing study on the topic evaluated 82 patients who undergo bilateral TSA.[10] The authors reported that having the second surgery within 6 months of the first resulted in improved patient-reported outcomes (University of California–Los Angeles shoulder scores, Constant scores, and Simple Shoulder Test scores) than those who wait longer between surgeries.[10] Given that only 2 complications occurred in the entire study, no temporal conclusions could be drawn regarding complication rates, and the authors could not define a minimum safe interval between staged surgeries. It is important to note that the study involved only anatomic prostheses, is a single-center study, and had a 28% loss to follow-up, all of which may affect the reported complication rates. Several other studies have reported the timing of the second shoulder arthroplasty but have not made any conclusions regarding a safe interval.[2,15-17,22] One series had a mean time interval between the first and second RTSA of 8 months (range 2-21 months).[17] Another group reported a mean staging interval of 18 months (range 3-46 months).[15] Berglund et al[2] described a mean interval of 21 months (range 2-64 months) in their study of 73 patients who underwent a combination of TSA/TSA, TSA/RTSA, and RTSA/RTSA. Another group of 50 patients with bilateral RTSA had a mean interval period of 15 months (range 2-63 months).[16] Another 26-patient study of bilateral TSA and bilateral RTSA had mean intervals of 25 months and 28 months for these surgeries, respectively.[22] Simultaneous arthroplasties have been rarely reported, with only 1 study involving 6 patients describing simultaneous bilateral shoulder arthroplasty for degenerative causes.[11] Several case reports have described RTSA/RTSA for bilateral traumatic fracture/dislocations performed within the same hospitalization either simultaneously or several days apart.[6,23] Using implant and medical complications as endpoints in a large nationwide series of patients undergoing staged bilateral arthroplasty, we recommend a minimum of 3 months between staged arthroplasty procedures.

In addition to reducing complications, there are functional reasons to consider a delay between bilateral shoulder arthroplasties. Multiple authors have recommended waiting at least 3 months after the primary arthroplasty to allow for internal rotation motion and function to improve to allow the patient to care for themselves with that side while recovering from the second surgery.[17,20] Gerber et al[11] found improved outcomes with simultaneous shoulder arthroplasty compared with staged arthroplasty, but this small case series is the only study to support this approach. Others state that an interval as short as 6 weeks could be considered for patients recovering quickly from their first procedure.[12,15]

As a retrospective database review, this study is subject to intrinsic limitations understood to complicate administrative database research. Precise and accurate documentation is required for the PearlDiver database to be reliable. Fortunately, the Centers for Medicare & Medicaid Services found a 1.3% general coding error rate in 2012, minimizing the concern that documentation errors could have distorted these findings.[5] Numerous surgeons of variable skill and experience and numerous implant systems, including both TSA and RTSA, were involved in the patient care represented by this data. This represents the reality of today's health care environment and was necessary in order to gain the high enough volume to analyze relatively rare complications of an atypical patient population for common orthopedic practice. We could not distinguish between TSA and RTSA and still determine surgical laterality because of the constraints of CPT and ICD-9 procedural coding. Historically, RTSA has been associated with a higher complication rate.[4] However, the current literature of bilateral shoulder arthroplasty regardless of whether cohorts included TSA, RTSA, or both has shown consistently low complication rates with good functional outcomes.[2,8,9] Lastly, the etiology of specific complications cannot be determined based on this administrative data, as we only have access to diagnostic and procedural codes, but the correlations between complications and surgical timing aid in advancing our understanding and safe practices for staged bilateral shoulder arthroplasty. It is possible that the necessary time period between arthroplasties varies based on patient age and comorbidities for instance.

Conclusions

Patients with staged bilateral shoulder arthroplasty who have the second arthroplasty within 3 months have significantly higher rates of revision surgery, loosening/

lysis, periprosthetic fracture, venous thromboembolism, and blood transfusions. Based on these lower complication rates, surgeons should consider waiting a minimum of 3 months before performing the second portion of a staged bilateral shoulder arthroplasty.

Disclaimer

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