Bariatric Surgery Following Total Shoulder Arthroplasty Increases the Risk for Mechanical Complications Including Instability and Prosthetic Loosening

J. M. Cancienne, MD · Christopher L. Camp, MD · Stephen F. Brockmeier, MD · Lawrence V. Gulotta, MD · David M. Dines, MD · B. C. Werner, MD

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Abstract *Background:* While extensive literature has been published on the risks and benefits of bariatric surgery (BS) prior to and following lower-extremity arthroplasty, no similar investigations have been performed on the impact of BS prior to total shoulder arthroplasty (TSA). *Purpose:* The objective of the present study was to compare the incidence of mechanical complications in morbidly obese patients who undergo TSA: those who undergo BS following TSA compared with those who do not undergo BS, and those who undergo BS after TSA compared with those who undergo BS prior to TSA. *Methods:* A Medicare database was queried for morbidly obese patients who underwent BS either before or after TSA, as well as those who underwent TSA but no BS. Of 12,277 morbidly obese patients who underwent TSA between 2005 and 2014, 304 underwent BS (165 of them prior to TSA and 139 following TSA) and 11,923 did not undergo BS. Rates of mechanical complications were then compared between groups using a logistic regression analysis. *Results:* Patients who underwent BS after TSA had significantly higher rates of mechanical complications (12.9%) compared to controls (8.8%) or patients who underwent prior BS (7.9%). Patients who

underwent BS after TSA had higher rates of both instability (7.9%) and loosening (8.6%) than did controls (5.1 and 4.9%, respectively) or patients who underwent BS before TSA (4.8 and 4.2%, respectively). *Conclusions:* BS following TSA is associated with increased rates of mechanical complications, including instability and loosening, compared to BS prior to TSA. These findings suggest that it may be prudent to consider performing BS prior to TSA in morbidly obese patients, rather than waiting until after TSA is performed.

Keywords Total shoulder arthroplasty · bariatric surgery · mechanical complication

Introduction

The overall prevalence of obesity in the USA continues to increase, and more than a third of adults currently have a body mass index (BMI) greater than 30 kg/m² [19]. Unfortunately, the trend appears to be worsening, and by the year 2030, more than 90% of Americans are projected to be overweight and 50% obese [42]. Furthermore, these findings are particularly concerning in the aging US population, where 71% of those over 60 years of age are overweight or obese [18, 36]. Alongside the increasing prevalence of obesity is an increasing incidence of symptomatic shoulder arthritis, as patients continue to live longer, more active lives. Advances in total shoulder arthroplasty (TSA) design, surgical technique, and indications have enabled surgeons to meet the growing demand to provide patients with effective and safe arthroplasty solutions [7, 26, 27, 35, 38].

Given that older, obese patients comprise a large portion of those presenting for elective surgery, there has been increasing attention and concern surrounding the impact that obesity has on high-volume procedures such as TSA. As in

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J. M. Cancienne, MD · S. F. Brockmeier, MD ·

B. C. Werner, MD (✉)

Department of Orthopaedic Surgery,

University of Virginia Health System,

PO Box 800159 HSC, Charlottesville, VA 22908, USA

e-mail: bcw4x@virginia.edu

C. L. Camp, MD · L. V. Gulotta, MD · D. M. Dines, MD

Department of Orthopaedic Surgery, Hospital for Special Surgery,
New York, NY, USA

the lower-extremity arthroplasty literature, a plethora of evidence exists relating obesity to increased risk of both medical and surgical complications following TSA [1, 3, 16, 22, 23, 31, 44]. In light of this increased risk, many surgeons advocate restricting certain elective procedures such as TSA to patients with a BMI of 40 kg/m² or lower [32]. While nonoperative weight loss interventions are often initially tried in patients who exceed this cutoff, bariatric surgery (BS) represents an increasingly utilized procedure for obese and morbidly obese patients [13, 29]. More than 200,000 BSs are performed annually in the USA and Canada alone [6]. Furthermore, lower-extremity arthroplasty surgeons are seeing an increasing number of patients who have had BS and referring an increasing number of obese patients for bariatric evaluation prior to arthroplasty [28, 39].

While extensive literature has been published on the risks and benefits of BS prior to and following lower-extremity arthroplasty, with conflicting results, no similar investigations have been performed on the impact of BS prior to TSA [40, 41]. It is possible that a large reduction in body weight following TSA may have a significant effect on the soft-tissue envelope, leading to unintended implant-related mechanical complications. Therefore, the goal of the present study was to utilize a national database to compare the incidence of mechanical complications, such as glenoid and humeral component loosening and periprosthetic fracture, in morbidly obese patients who undergo BS following TSA and those who do not undergo BS. In addition, we sought to compare the incidence of mechanical complications in patients who undergo BS after TSA with patients who undergo BS prior to TSA.

Materials and Methods

An insurance-based database of patient records, the PearlDiver Patient Records Database (www.pearliverinc.com, Fort Wayne, IN, USA), was utilized for the present study. It contains data from several different insurers, including both Medicare and private insurers. The patients from the present study were all taken from the Medicare database within PearlDiver.

The PearlDiver Medicare database contains procedural volumes, basic patient demographics, and laboratory data, among numerous other data for patients with International Classification of Diseases, 9th Revision (ICD-9), diagnoses and procedures or Current Procedural Terminology (CPT) codes. The database covers patients insured from the years 2005 to 2014, containing approximately 20 million patients with orthopedic diagnoses. All data is deidentified and anonymous and was thus exempt from institutional review board approval.

The Standard Analytic Files (SAF) 100% Medicare database was used for the present study. It was first queried for patients who underwent TSA using ICD-9 procedure code 81.80. Patients undergoing revision surgery (or any procedure) for a diagnosis of infection were excluded, in addition to any patients without 1-year pre-TSA database exposure and a minimum 1-year postoperative database follow up. Morbidly obese patients were then identified from this

patient population using the ICD-9 codes for morbid obesity (278.01) or BMI > 40 kg/m² (V85.4, V85.41–V85.45). The database was then queried for patients who underwent BS for weight loss, including laparoscopic banding and gastric bypass, using CPT and ICD-9 coding (ICD-9 procedure codes 44.68, 44.69, 44.39, 43.89 and CPTs 43842, 43843, 43845, 43846, 43847, 43644, 43645, 43770, 43775). Two separate study cohorts were then formed: (1) BS before TSA and (2) BS following TSA. The remaining morbidly obese patients who underwent TSA but did not undergo BS were used as a control group for comparison purposes.

A total of 304 unique patients who underwent BS and TSA met inclusion criteria and were identified in the database. This included 165 patients who underwent BS at an average of 2.6 years prior to TSA and 139 patients who underwent BS at an average of 2.2 years following TSA. These study groups were compared to a control of 11,923 morbidly obese patients who underwent TSA without any history of BS recorded in the database (Fig. 1).

The outcome of interest was postoperative mechanical complications within 1 year following the TSA if BS was performed before the TSA or within 1 year of the BS if it was performed following the TSA. This included periprosthetic instability and dislocation and periprosthetic loosening. Periprosthetic instability and dislocation were identified using ICD-9 codes 718.31, 831.00, 831.01, 831.02, 831.03, 831.09, and 996.42 and/or CPT codes 23650, 23655, and 23660. The ICD-9 and CPT codes selected for periprosthetic instability are specific for prosthetic shoulder dislocation, subluxation events, and the treatment of these with closed and/or open procedures. Periprosthetic loosening was identified using ICD-9 codes 996.41, 996.43, and 996.45 and are specific for loosening of the prosthetic joint as seen on imaging, a broken prosthesis, and/or osteolysis surrounding the humeral or glenoid component. The diagnosis and capture of these events is dependent on the accuracy and quality of procedural coding within the database, and there may be variability with which more subjective diagnoses, such as prosthetic subluxation, are defined and coded for among surgeons.

Fig. 1. Flow chart depicting the breakdown of patients included in the study *TSA* total shoulder arthroplasty, *BS* bariatric surgery

Rates of mechanical complications were then compared between groups using a logistic regression analysis in which patient demographics (age, sex, BMI, tobacco use, and alcohol use), diagnosis for TSA (osteoarthritis, avascular necrosis, acute proximal humerus fracture, malunion or nonunion of fracture, or rotator cuff tear), and medical comorbidities (including hypertension, hyperlipidemia, coronary artery disease, congestive heart failure, peripheral vascular disease, chronic kidney disease, chronic lung disease, chronic liver disease, inflammatory arthritis, depression, hypercoagulability disorders, thyroid disease, and current hemodialysis use) were analyzed.

Results

Patients who underwent BS prior to TSA experienced a 7.9% overall combined mechanical complication rate within 1 year, including a 4.8% instability rate (prosthetic shoulder dislocation, subluxation events, and the treatment of these with closed and/or open procedures) and a 4.2% loosening rate (loosening of the prosthetic joint, a broken prosthesis, and/or osteolysis surrounding the humeral or glenoid component) (Table 1). There were no statistically significant differences in the overall complication ($p = 0.872$), instability ($p = 0.943$), or loosening ($p = 0.655$) rates when compared to the control group (Table 2).

Patients who underwent BS after TSA experienced a 12.9% overall mechanical complication rate within 1 year, including a 7.9% instability rate and an 8.6% loosening rate (Table 1). Compared to the control group, these patients had significantly higher overall rates of mechanical complication (OR, 1.62; 95% CI, 1.12–2.34; $p = 0.039$), instability (OR, 1.80; 95% CI, 1.38–2.34; $p = 0.008$), and periprosthetic loosening (OR, 1.72; 95% CI, 1.08–2.73; $p = 0.035$) (Table 2).

When comparing patients who had BS after TSA to those who had it prior to TSA, there was a significantly higher incidence of overall mechanical complications in BS after the TSA group (OR, 2.61; 95% CI, 1.36–5.0; $p = 0.004$) in addition to a significantly higher rate of periprosthetic loosening (OR, 2.69; 95% CI, 1.37–5.28; $p = 0.013$). There was no statistically significant difference in the rate of instability between the 2 cohorts ($p = 0.166$) (Table 2).

Discussion

The aims of the present study were to evaluate the effect of the timing of BS on TSA by measuring the incidence of

mechanical complications, such as glenoid and humeral component loosening and periprosthetic fracture. The present study suggests that BS after TSA is associated with a higher rate of mechanical complications in morbidly obese patients compared to those who do not undergo BS following TSA. Furthermore, this association was not noted in patients who underwent BS prior to TSA. These findings are likely due to multifactorial causes; however, a large, rapid reduction in body weight following TSA likely has a significant effect on the soft-tissue envelope, possibly leading to increased prosthetic instability.

The present study has several limitations, the majority of which are inherent to all studies utilizing large, administrative databases [8, 9]. First and most important, the power of our analysis and conclusions are dependent on the quality of the available data. Thus, miscoding or noncoding by physicians could represent a source of error. A Centers for Medicare and Medicaid Services improper payments report from 2012 cited an overall coding error rate of 1.3% [10]. Therefore, although this is a major potential limitation when using administrative databases such as PearlDiver, the overall coding error rate is low. Furthermore, while it is expected that the majority of the patients in the present study underwent anatomic TSA, we are unable to differentiate those patients who may have undergone a reverse TSA due to a lack of specific coding during the time period studied. Thus, the conclusions must be considered in this context and with the knowledge that mechanical complications have been reported to be slightly higher in reverse TSA than in anatomic TSA in some studies [12, 15, 20, 21]. Second, risk factors for mechanical complications following TSA are likely multifactorial, and several factors that might contribute to this risk are unable to be characterized within the database. These factors include soft-tissue handling, component positioning, preoperative deformity, surgical technique, surgical approach, surgeon experience, and postoperative rehabilitation. Additionally, while we attempted to stratify patients based on the time interval between the TSA and BS to make our results more clinically impactful, limited patient numbers prevented this. Third, while we attempted to accurately represent a large American population of interest, we cannot be certain that our cohorts represent true cross-sections of morbidly obese patients, because only Medicare data was used in this analysis. Fourth, the database indexes only an 8-year increment of data; thus, patients who had outcomes of interest or underwent BS outside of this time period may not have been captured as such. Finally, we limited our outcomes of interest to 1 year in an attempt to increase the likelihood that complications were related to the

Table 1 Incidence of mechanical complications after total shoulder arthroplasty (TSA)

Study group	Overall mechanical		Instability/dislocation		Loosening	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Control (<i>n</i> = 11,619)	1025	8.8%	587	5.1%	564	4.9%
Bariatric surgery <i>before</i> TSA (<i>n</i> = 165)	13	7.9%	8	4.8%	7	4.2%
Bariatric surgery <i>after</i> TSA (<i>n</i> = 139)	18	12.9%	11	7.9%	12	8.6%

Table 2 Comparison of mechanical complications after total shoulder arthroplasty (TSA)

Variable	Adj. odds ratio	95% CI	<i>p</i>
Bariatric surgery <i>after</i> TSA (<i>n</i> = 139) compared to controls (<i>n</i> = 11,619)			
Overall mechanical complications	1.62	(1.12–2.34)	0.039
Instability/dislocation	1.80	(1.38–2.34)	0.008
Periprosthetic loosening	1.72	(1.08–2.73)	0.035
Bariatric surgery <i>before</i> TSA (<i>n</i> = 165) compared to controls (<i>n</i> = 11,619)			
Overall mechanical complications	0.96	(0.59–1.58)	0.872
Instability/dislocation	1.02	(0.55–1.90)	0.943
Periprosthetic loosening	0.84	(0.41–1.72)	0.655
Bariatric surgery <i>after</i> TSA (<i>n</i> = 139) compared to <i>before</i> TSA (<i>n</i> = 165)			
Overall mechanical complications	2.61	(1.36–5.00)	0.004
Instability/dislocation	2.11	(0.84–5.29)	0.166
Periprosthetic loosening	2.69	(1.37–5.28)	0.013

variables studied and not another condition or medical or surgical issue. Therefore, complications outside of this window would not be captured in our study.

Mechanical complications, such as periprosthetic loosening and instability, are among the most frequently reported complications following TSA in the literature [4, 12, 38]. Several studies have reported no association between obesity and postoperative mechanical complications, while other studies have shown significantly higher rates in obese patients following TSA [3, 22–24, 31, 43]. In the present study, an overall mechanical complication rate of 8.2% was noted in the morbidly obese control group, including a 4.8% dislocation rate and a 4.4% periprosthetic loosening rate within 1 year, each of which are consistent with reports in the broader TSA literature [43]. While some studies suggest higher rates of mechanical complications in obese patients undergoing TSA, the effects of rapid weight loss induced by BS, either before or after TSA, on mechanical complications following TSA are currently unknown. The present study suggests that the rapid weight loss seen with BS following TSA places patients at a significantly increased risk for mechanical complications following surgery. It is well established that BS causes bone mineral metabolism disturbances, including reduced bone mineral density and alterations in the biomechanical markers of bone turnover up to 7 years following the surgical procedure [14, 33, 45]. These changes in bone metabolism and density may result in an increased risk of periprosthetic fracture and/or implant ingrowth, resulting in the increased incidence of complications presented in this study. Furthermore, we believe the rapid weight loss has a significant effect on the soft-tissue envelope. It is known that BS can result in protein deficiency, causing loss of muscle mass and subsequent muscle weakness and edema, among other integumentary system changes [5, 34, 37]. Thus, in a morbidly obese patient undergoing BS following TSA, the soft-tissue balancing and tension present at the time of surgery is likely altered with extreme and rapid weight loss. With changing soft-tissue tension and muscle tone, unbalanced forces are placed across the implant, possibly leading to increased loosening and a higher risk for

instability. In addition, increased soft-tissue laxity may simply be the result of decreased fat surrounding the shoulder joint. Further biomechanical studies are needed to analyze shoulder mechanics following TSA in patients who undergo BS both before and after surgery.

In the broader orthopedic literature, obesity has been cited as a significant risk factor for postoperative instability following total hip arthroplasty (THA) [2, 11, 17, 25]. Similar to TSA, BS prior to or following THA can affect soft-tissue tension and component balancing, possibly leading to an increased risk of instability [25]. Hernigou et al. recently reviewed 670 THAs within a minimum 5-year follow up, including 85 THA patients who had prior BS. The group noted a significantly increased risk of postoperative instability in patients who underwent BS prior to surgery. The authors proposed that the mechanical soft-tissue distortion results in increased soft-tissue laxity as a result of decreased fat surrounding the hip, leading to an increased risk of instability [25]. The results of this study are consistent with another study by Kulkarni et al., who also reported a significantly increased rate of instability in patients who underwent BS prior to THA [30].

In conclusion, while obesity has been identified as a possible risk factor for increased mechanical complications following TSA, there is a lack of literature evaluating the effect of bariatric surgery, either pre- or postoperatively, on this complication after surgery. Given an increasing incidence of obesity within the TSA population, alongside increasing use of BS for weight loss, it is critical that this relationship be assessed. The present study suggests that in morbidly obese patients, BS after TSA is associated with a higher rate of mechanical complications than no BS after TSA. Furthermore, this association was not noted in patients who underwent BS prior to TSA. These findings are likely multifactorial in nature, although a large, rapid reduction in body weight following TSA likely has a significant effect on the soft-tissue envelope, possibly leading to increased prosthetic instability. Given the results of the present study, we suggest that morbidly obese patients being evaluated for BS for weight control be encouraged to undergo this procedure prior to pursuing TSA.

Compliance with Ethical Standards

Conflict of Interest: J. M. Cancienne, MD, Christopher L. Camp, MD, B. C. Werner, MD, declare that they have no conflicts of interest. Stephen F. Brockmeier, MD, reports board or committee membership in American Orthopaedic Society for Sports Medicine, International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine, and MidAtlantic Shoulder and Elbow Society; editorial or governing board membership at Journal of Bone and Joint Surgery American, Orthopaedic Journal of Sports Medicine, Techniques in Shoulder and Elbow Surgery; research support and/or payment as presenter or speaker from Arthrex, Biomet, DePuy (A Johnson & Johnson Company), Tornier; publishing royalties or financial or material support from Springer; fees as a consultant from MicroAire Surgical Instruments LLC, Zimmer. Lawrence V. Gulotta, MD, reports receiving fees as a consultant and a presenter or speaker from Biomet and board membership at HSS Journal. David M. Dines, MD, reports board or committee membership in American Association of Orthopaedic Surgeons, American Shoulder and Elbow Surgeons; financial or material support from Biomet; publishing royalties from Saunders/Mosby-Elsevier; editorial or governing board membership from Springer; fees as a consultant from Wright Medical Technology, Inc.; intellectual property royalties from Zimmer.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2013.

Informed Consent: Informed consent was waived from all patients for being included in this study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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