JSES International 8 (2024) 1215–1220

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

# Does morbid obesity negatively impact perioperative outcomes following elective reverse shoulder arthroplasty?: a propensity-matched comparative study

Suhirad Khokhar, MD[a], Cameron Smith, BA, MPH[b], Riccardo Raganato, MD[c], Robert Ades, BA[b], Yungtai Lo, PhD[d], Konrad I. Gruson, MD[a,*]

[a]Department of Orthopaedic Surgery, Montefiore Medical Center, Albert Einstein College of Medicine, Bronx, NY, USA
[b]Albert Einstein College of Medicine, Bronx, NY, USA
[c]Department of Orthopaedic Surgery, Hospital Universitario La Paz, Madrid, Spain
[d]Department of Epidemiology and Population Health, Albert Einstein College of Medicine, Bronx, NY, USA

A R T I C L E I N F O

*Keywords:*
Reverse total shoulder replacement
Return to emergency department
Readmission
Postoperative complications
Morbid obesity
Length of stay
Operative time

*Level of evidence:* Level III; Retrospective Cohort Comparison; Prognosis Study

**Background:** The incidence of primary reverse total shoulder arthroplasty (rTSA) and the prevalence of obesity have increased in the United States. Despite this, the literature assessing the effect of morbid obesity (body mass index≥40 kg/m$^2$) on perioperative surgical outcomes remains inconsistent.
**Methods:** A retrospective review of consecutive elective primary rTSA cases from January 2016 through September 2023 at a single tertiary referral center was performed. All cases involved a short-stem humeral component and screw-in glenoid baseplate from the same implant manufacturer. Surgical and patient demographic data were collected. Morbidly obese patients were propensity matched at least 1:1 with non-morbidly obese patients based on age, gender, modified 5-item frailty index score, adjusted Charlson comorbidity index score, and 12-month preoperative emergency department (ED) visit. Regression analysis was utilized to assess the relationship between morbid obesity and operative time, length of stay, intraoperative total blood volume loss, surgical postoperative complications, in-hospital medical complications, disposition, and 90-day ED return and readmission.
**Results:** There were a total of 175 short-stem rTSA cases performed with a median age of 71 years (interquartile range: 66, 76), of which 19 (10.9%) had a body mass index ≥40 kg/m$^2$. These 19 patients were propensity score matched to 41 non-morbidly obese patients (9 at 1:3, 4 at 1:2, and 6 at 1:1). There were no significant differences between the groups with regard to intraoperative total blood volume loss, operative time, need for transfusion, hospital length of stay, discharge disposition, prevalence for 90-day return to ED, or unplanned 90-day readmission.
**Conclusion:** Morbid obesity should not be considered an absolute contraindication for elective rTSA, particularly in patients who have undergone appropriate preoperative medical clearance.


The incidence of primary reverse total shoulder arthroplasty (rTSA) has steadily risen among all age groups in the United States.[5] Recent projections suggest a significant future increase relative to hip and knee arthroplasty.[30] Concurrently, obesity has become an epidemic within the United States, with projections indicating that more than half of adults will demonstrate obesity by 2030.[31] Despite this growing issue, the existing literature regarding the association between obesity and perioperative complications following rTSA remains inconsistent. A recent systematic review with pooled analysis revealed a correlation between obesity and prolonged surgical duration, increased blood loss, and a higher likelihood of discharge to a rehabilitation facility.[20] However, the various definitions for obesity within the included studies made meaningful comparisons challenging, with some authors using a cutoff of ≥30 kg/m$^2$ and others using ≥35 kg/m$^2$.[4,15,22] Pappou et al, in a 1:3 case-matched study of morbidly obese patients undergoing rTSA, found that the morbidly obese patients had a similar hospital readmission, emergency department (ED) readmission, and hospital length of stay (LOS) compared with nonobese patients.[23] However, they found that morbidly obese patients had an

This study was approved by the Albert Einstein College of Medicine IRB Board (#2022-13955).
This study was conducted at the Montefiore Medical Center, Bronx, NY, USA.
*Corresponding Author: Konrad I. Gruson, MD, Albert Einstein College of Medicine, Department of Orthopaedic Surgery, 1250 Waters Place, 11th Floor, Bronx, NY 10461, USA.
*E-mail address:* kgruson@montefiore.org (K.I. Gruson).

https://doi.org/10.1016/j.jseint.2024.06.015
2666-6383/

increased risk for nonhome discharge, higher intraoperative estimated blood loss, and longer operative time. In a study utilizing an administrative claims-based database, Cogan et al reported a significantly higher 90-day readmission, 90-day medical complication, renal insufficiency, and deep venous thrombosis/pulmonary embolus rate among morbidly obese patients compared to a cohort of nonobese patients.[9] However, the authors did not stratify the results by the use of rTSA vs. anatomic total shoulder arthroplasty (aTSA), nor were they able to provide detailed data regarding the specific implant (long-stem vs. standard length-stem, cemented vs. non-cemented) used.

The implementation of strict body mass index (BMI) cutoffs above which patients would be denied access to a joint arthroplasty with the goal of minimizing the risk of complications to this challenging patient population and reducing the potential for increased healthcare expenditures could certainly result in limited access to a pain-relieving procedure.[11,17,26] Saini and colleagues, in a study utilizing a national database, found that 14 complication-free TSA procedures would need to be denied in patients with a BMI ≥40 kg/m$^2$ in order to prevent a major complication. Furthermore, they reported that 20 complication-free procedures would need to be denied among this patient group to avoid a single clinically significant medical complication.[26] Interestingly, Kulkarni et al reported that adherence to strict BMI cutoffs for TSA could inadvertently result in worsening healthcare disparities.[17] Understanding the association between morbid obesity and both perioperative complications and outcomes following rTSA could provide further evidence as to the clinical utility for instituting formal preoperative BMI cutoffs.

Therefore, the purpose of the current study was to: 1) define the baseline demographic differences between morbidly obese patients undergoing primary rTSA from non-morbidly obese patients; 2) identify the reasons for 90-day postoperative ED return and readmission; and 3) investigate the effect of morbid obesity on operative duration, intraoperative total blood volume loss (ITBVL), need for transfusion, hospital LOS, perioperative medical and surgical complications, discharge disposition, 90-day return to ED, and unplanned 90-day readmission in patients undergoing primary elective rTSA using a consistent short-stem implant. Our hypothesis was that morbidly obese patients would exhibit prolonged surgical duration, higher blood loss, and a longer hospital stay compared to non-morbidly obese patients.

## Materials and methods

We conducted a retrospective analysis of all primary elective rTSAs performed by a single fellowship-trained orthopedic surgeon at a tertiary referral teaching hospital from January 2016 to September 2023. Institutional review board approval was obtained for this study [#2022-13955]. Inclusion criteria comprised patients undergoing elective primary rTSA with a minimum 90-day follow-up, while exclusion criteria encompassed patients undergoing revision rTSA, arthroplasty for acute fracture, or arthroplasty following prior fracture fixation.

Patient demographic data, including age, gender, BMI, marital status, insurance type (commercial vs. Medicare vs. Medicaid), self-reported race, smoking status (current vs. former vs. never smoked), age-adjusted Charlson comorbidity index (ACCI), modified 5-item frailty index (mFI-5), distance from home-to-clinic, 90-day postoperative visits to the ED with presentation diagnoses, and 90-day unplanned postoperative readmissions, were collected through electronic health records. The ACCI is a reliable tool for predicting mortality based on comorbid diseases,[8] while the mFI-5 serves as a marker of physiologic decline and anticipates adverse outcomes and readmission following total shoulder arthroplasty.[16,29] Surgical data included preoperative diagnosis, history of prior non-arthroplasty ipsilateral shoulder surgery (none vs. open vs. arthroscopic vs. combined), hospital LOS, intraoperative complications, postsurgical complications within 4 weeks, in-hospital medical complications, operative time, ITBVL, and the need for intraoperative or postoperative transfusion. The BMI data were stratified into 2 categories: ≥40 kg/m$^2$ (morbidly obese) vs. <40 kg/m$^2$ (non-morbidly obese). The mFI-5 was categorized as <2 vs. ≥2, as has previously been described in the literature.[16] Similarly, the ACCI was categorized as <5 or ≥5 based on prior publications.[1]

Operative time was defined as the duration from skin incision to the commencement of incision closure to standardize for potential variations in closure techniques and speed among surgeons and trainees, a method previously employed.[14] ITBVL was calculated as described by Sehat et al[28] and previously utilized with regard to shoulder arthroplasty.[14] No specific trigger for transfusion was defined during the study period. The decision to administer blood products was based primarily on the presence of patient symptoms suggestive of anemia and an assessment by the geriatric comanagement service providers. Finally, medically and surgically related 90-day ED visits and readmission data were combined due to the low number of cases, with surgically related reasons including wound complications, intractable surgical site pain, or periprosthetic fractures/dislocations.

### *Surgical technique*

The surgical approach was performed in a consistent fashion through a standard deltopectoral approach. All cases involved the use of the Ascend Flex short-stem humeral component with proximal porous coating and the Aequalis Perform Reverse glenoid component (Wright Medical, Memphis, TN, USA). High-viscosity bone cement was utilized based on the proximal humeral bone quality. The use of baseplate augmentation was based on presurgical computerized planning of the glenoid bone deformity. A single loading dose of intravenous tranexamic acid (TXA) was administered at a dose of 10 mg/kg over 10 minutes prior to incision. All cases were performed with a combination of regional and general anesthesia.

### *Statistical analysis*

Propensity score matching was undertaken with the involvement of a biostatistician to create comparable groups of morbidly obese and non-morbidly obese patients. Each morbidly obese patient was matched to at least 1 non-morbidly obese patient based on age (±2 years), gender, mFI-5 (<2 or ≥2), ACCI (<5 or ≥5), and 12-month preoperative ED visit (yes/no). A group was defined as a morbidly obese patient with up to 3 matched controls. LeBrun et al reviewed 83 matched case-control studies published in the top orthopedic journals according to impact factor from 2007 to 2016 and found a median of 3 matching factors and 1 control were used per case.[18] Austin et al found that utilization of 1:1 or 2:1 matching would be optimal with propensity score matching.[3] Medians and interquartile ranges (IQRs) were used to describe continuous variables. Differences in demographic and medical characteristics between patients with and without morbid obesity were compared using the Wilcoxon rank-sum or Kruskal-Wallis tests for continuous variables and chi-squared or Fisher's exact tests for categorical variables. Logistic regression with a group-specific random effect was utilized to assess the differences between the matched cohort groups. A $P$ value <.05 was considered statistically significant. Where a $P$ value could not be calculated given the absence of an outcome in either group, the result was listed as "n/a." All statistical analyses were performed using SAS, version 9.4 (SAS Institute, Cary, NC, USA). Post hoc sample size calculations were performed to determine the number of patients required to achieve significance in the ITBVL and operative time when the two groups did not differ significantly. This demonstrated that 472 morbidly obese:non-morbidly obese matched pairs would be required to demonstrate significance in ITBVL with $P = .05$ and 80% power and 319 morbidly obese:non-morbidly obese matched pairs would be required to demonstrate significance in operative time with $P = .05$ and 80% power. The current study was thus underpowered for the detection of these outcome measures.

## Results

There were 175 total cases included in this study, with 19 (10.9%) morbidly obese patients with a median age of 68 (IQR: 64, 73) years and a range from 58 to 81 years. The remaining 156 non-morbidly obese patients had a median age of 71 (IQR: 66.5, 77) years. There were no significant differences between the groups with regard to age, gender, history of prior ipsilateral shoulder surgery, and ACCI [Table 1]. There were significantly more diagnoses of rotator cuff-deficient arthritis among the morbidly obese group compared to the non-morbidly obese group (63% vs. 35%, $P = .015$).

Following propensity score matching, a group of 41 case-matched controls with a median age of 69 (IQR: 65.5, 75) years with a range from 56 to 81 years was identified. There were 37 (90%) females with 14 (34%) having an mFI-5<2 [Table 2]. There was no statistically significant difference between the propensity-matched cohorts with regard to self-identified race, insurance status, ACCI, distance from home-to-clinic, clinical diagnosis, smoking status, or a history of a prior ipsilateral shoulder surgery. There was no significant difference with regard to the use of bone cement for humeral component fixation between the two groups ($P = .15$). With regard to surgical implants, an augmented glenoid baseplate was used in 3 (16%) of the morbidly obese patients and 14 (34%) of the non-morbidly obese patients ($P = .22$). A median of 3 peripheral screws were used in both groups ($P = .24$).

With regard to outcome differences between the matched cohorts, there was no significant difference between the non-morbidly obese and morbidly obese cohorts with regard to median ITBVL (218.6 ml vs. 213.9 ml, $P = .620$), median hospital stay (2 days vs. 2 days, $P = .654$), operative time (114 min vs. 114 min, $P = .423$), 90-day return to ED (21% vs. 19%, $P = .890$), in-hospital medical complication (24% vs. 21%, $P = .888$), and disposition to nonhome (8% vs. 19%, $P = .281$) [Table 3].

There were no cases of 4-week surgical postoperative complications and a single (5.2%) 90-day unplanned readmission among the morbidly obese cohort. There was no difference in postoperative day 1 visual analogue scale pain levels ($P = .36$), discharge VAS pain levels ($P = .62$), or the difference in postoperative day 1 and discharge VAS pain levels ($P = .18$) between the matched groups. For the morbidly obese patients, there were 3 patients with 5 visits to the ED within 90 days, all of which were medically related. The specific reasons for the visits included dizziness, chest pain, new-onset atrial fibrillation, hyperglycemia, and knee pain. One ED visit occurred at <7 days postsurgically and the remainder from 30-90 days. For the non-morbidly obese patients, there were 7 patients with ten 90-day ED visits, 2 of which were surgically related. The remaining medically related visits included: fall (2), musculoskeletal pain (1), vertigo (1), chest pain (1), abdominal pain (1), acute mental status change (1), and social support (1). Two ED visits occurred at <7 days postsurgically, 3 visits from 7-30 days and 5 visits from 30-90 days.

**Table I**
Overall patient cohort baseline demographic data.

| Clinical parameters | BMI ≥ 40 kg/m$^2$ (median [IQR]) (n = 19) | BMI < 40 kg/m$^2$ (median[IQR]) (n = 156) | *P* value |
|---|---|---|---|
| Age, y | 68 (64, 73) | 71 (66.5, 77) | .12 |
| Gender, n (%) | | | .32 |
| Male | 3 (16%) | 41 (26%) | |
| Female | 16 (84%) | 115 (74%) | |
| Self-identified race | | | |
| White | 5 (28%) | 22 (14%) | .51 |
| Hispanic | 10 (50%) | 85 (54%) | |
| Black | 4 (22%) | 46 (20%) | |
| Asian | 0 | 3 (2%) | |
| Insurance type | | | |
| Medicare | 15 (78%) | 122 (78%) | .60 |
| Medicaid | 2 (11%) | 25 (16%) | |
| Commercial | 2 (11%) | 9 (6%) | |
| BMI, kg/m$^2$ | 42.4 (41.0, 45.1) | 30.3 (27.2, 33.1) | *<.00001* |
| Surgical side | | | .68 |
| Right | 11 (58%) | 98 (63%) | |
| Left | 8 (42%) | 58 (37%) | |
| Distance from home-to-clinic | 2.6 (1.3, 3.0) | 3.0 (2.4, 4.3) | .07 |
| Diagnosis | | | |
| RTC-deficient arthritis | 12 (63%) | 54 (35%) | *.03* |
| GH OA | 4 (21%) | 23 (15%) | |
| Chronic RTC tear | 2 (11%) | 47 (30%) | |
| Other | 1 (5%) | 32 (20%) | |
| mFI-5 | | | |
| 0,1 | 8 (42%) | 76 (49%) | .59 |
| ≥2 | 11 (58%) | 80 (51%) | |
| Smoking status | | | |
| Never | 6 (32%) | 87 (56%) | .10 |
| Former | 11 (58%) | 53 (34%) | |
| Current | 2 (10%) | 16 (10%) | |
| Age-adjusted Charlson comorbidity index (ACCI) | 4 (3,5) | 4 (3,5) | .88 |
| Prior ipsilateral surgery | | | .85 |
| None | 16 (84%) | 112 (72%) | |
| Arthroscopy | 3 (16%) | 35 (22%) | |
| Open surgery | 0 (0%) | 5 (3%) | |
| Open surgery/ arthroscopy | 0 (0%) | 4 (3%) | |

*IQR*, interquartile range; *BMI*, body mass index; *mFI-5*, 5-item modified fragility index; *GH OA*, glenohumeral osteoarthritis; *RTC*, rotator cuff.
A *P*-value < .05 is given in italics.

## Discussion

A retrospective, single institution study was performed utilizing propensity score matching based on age, gender, mFI-5 score, ACCI, and 12-month preoperative ED visit to assess the association between morbid obesity and perioperative complications and outcome measures. The main findings from the current study were that patients with morbid obesity undergoing elective rTSA using a single implant design did not demonstrate a longer hospital LOS, operative time, increased in-hospital medical complications, increased risk for transfusion, increased disposition to nonhome, increased risk for 90-day ED return, or unplanned 90-day readmission.

We found that the risk for 90-day ED return and all-cause unplanned readmission was not significantly increased for morbidly obese patients undergoing elective rTSA. Interestingly, Werner et al, in a Medicare database study evaluating only aTSA, found that a preoperative ED visit within 12 months of surgery was an independent risk factor for a 90-day postoperative ED visit.[33] Based on their findings, we included the 12-month preoperative ED visit in

**Table II**
Demographic data following propensity score case matching.

| Clinical parameters | BMI ≥ 40 kg/m$^2$ (median [IQR]) (n = 19) | BMI < 40 kg/m$^2$ (median[IQR]) (n = 41) | *P* value |
|---|---|---|---|
| Age, y | 68 (64, 73) | 68 (65, 73) | .80 |
| Gender, n (%) | | | .50 |
| Male | 3 (16%) | 4 (10%) | |
| Female | 16 (84%) | 37 (90%) | |
| Self-identified race | | | .35 |
| White | 5 (28%) | 6 (15%) | |
| Hispanic | 10 (50%) | 20 (49%) | |
| Black | 4 (22%) | 15 (37%) | |
| Asian | 0 | 0 (0%) | |
| Insurance type | | | .33 |
| Medicare | 15 (78%) | 32 (78%) | |
| Medicaid | 2 (11%) | 8 (20%) | |
| Commercial | 2 (11%) | 1 (2%) | |
| BMI, kg/m$^2$ | 42.4 (41.0, 45.1) | 30.6 (26.4, 32.7) | *<.00001* |
| Surgical side | | | .90 |
| Right | 11 (58%) | 23 (56%) | |
| Left | 8 (42%) | 18 (44%) | |
| Distance from home-to-clinic | 2.6 (1.3, 3.0) | 2.8 (2.4, 3.7) | .19 |
| Diagnosis | | | .16 |
| RTC-deficient arthritis | 12 (63%) | 16 (39%) | |
| GH OA | 4 (21%) | 6 (15%) | |
| Chronic RTC tear | 2 (11%) | 10 (24%) | |
| Other | 1 (5%) | 9 (22%) | |
| mFI-5 | | | .55 |
| 0,1 | 8 (42%) | 14 (34%) | |
| ≥2 | 11 (58%) | 27 (56%) | |
| Smoking status | | | .19 |
| Never | 6 (32%) | 23 (56%) | |
| Former | 11 (58%) | 14 (34%) | |
| Current | 2 (10%) | 4 (10%) | |
| Age-adjusted Charlson comorbidity index (ACCI) | 4 (3,5) | 4 (3,6) | .75 |
| Prior ipsilateral surgery | | | .25 |
| None | 16 (84%) | 24 (59%) | |
| Arthroscopy | 3 (16%) | 12 (29%) | |
| Open surgery | 0 (0%) | 3 (7%) | |
| Open surgery/ arthroscopy | 0 (0%) | 2 (5%) | |

*IQR*, interquartile range; *BMI*, body mass index; *mFI-5*, 5-item modified fragility index; *GH OA*, glenohumeral osteoarthritis; *RTC*, rotator cuff.
A *P*-value < .05 is given in italics.

the propensity matching. Our results are consistent with those of Pappou et al who reported that the 90-day ED and hospital readmission rate were not significantly increased among morbidly obese patients undergoing rTSA compared to nonobese-matched controls.[23] Similarly, Anakwenze et al, in a retrospective analysis of an institutional database comprised of 44 morbidly obese patients undergoing rTSA, found no association between increasing BMI and the likelihood of 90-day readmission.[2] Overall, 11% of the morbidly obese patients experienced a 90-day readmission, approximately twice the rate of the current study. Our results contrast with those of Cogan et al who reported a >2-fold increase in 90-day readmission among morbidly obese patients compared to nonobese patients, though that study did not stratify by the nature of the TSA performed and the fact that their analysis controlled only for age, gender, and comorbidity.[9] Our findings that morbidly obese patients undergoing rTSA do not have a significantly higher 90-day ED return or readmission is particularly important given the introduction of alternative payment models that center on single payments to institutions for all services provided during an episode of care, including the 90-day postdischarge period.[7,32] The average cost for readmission following TSA has been calculated at nearly $14000, representing a significant burden to the healthcare system should it occur.[12,24,27] Finally, the reasons for the 90-day return to ED among the morbidly obese patients in this study were all medically related, suggesting that these complex patients could benefit from being comanaged by their primary care physicians in the early postoperative period to further reduce the risk of ED return.

We found no significant difference in operative time between the morbidly obese patients and the propensity-matched non-morbidly obese cohort. This underscores the importance of experience and consistency in surgical approach by the entire orthopedic and anesthesia team to manage these complex cases efficiently. Our results are concordant with those of Pappou et al who reported that although the total procedural time was 13 minutes longer among the morbidly obese cohort undergoing rTSA, there was no significant difference in the actual surgical time between the groups.[23] In contrast, Linberg et al, in a retrospective case series including 41 morbidly obese patients undergoing unconstrained shoulder arthroplasty, found a longer operative time in morbidly obese patients compared to historical nonobese controls, which the authors attributed to a more challenging surgical exposure and soft tissue management due to large body habitus.[19] However, the conclusions were limited by a lack of a true control group. Our analysis revealed that ITBVL and the need for perioperative transfusion did not significantly differ between morbidly obese and non-morbidly obese patients. Our findings differ from those of Pappou et al who reported a 40 cc increased estimated blood loss among the morbidly obese patients.[23] However, the authors in that study do not discuss specifically how blood loss was determined, whereas the ITBVL was calculated in the current study and has been used previously within the orthopedic literature.[14] Furthermore, the blood loss that they reported may not be considered clinically significant. Similar to our findings, Cogan and colleagues did not find a significant increase in transfusion risk for morbidly obese patients undergoing TSA.[9] Using a national database, Bixby et al demonstrated a trend toward decreased perioperative transfusion following TSA, which the authors surmised was a result of widespread use of TXA.[6] The primary reason for the lack of significant difference in blood loss and need for transfusion in our study likely includes the routine use of a single dose of TXA prior to incision in all cases.[10]

We found no increase in postoperative LOS for the morbidly obese patients undergoing rTSA. Our findings stand in contrast with those of Griffin et al who reported that morbidly obese patients experienced a longer LOS compared to both obese and nonobese patients undergoing TSA.[13] Their study, however, did not differentiate between rTSA and aTSA. Our results are consistent with those of Pappou et al who similarly reported no significant increase in hospital LOS among morbidly obese patients.[23] It is certainly possible that the comparable LOS between the cohorts noted in our study was a result of the general trend toward decreasing LOS following TSA despite an increase in comorbidities including morbid obesity.[6] In the current study, we found no difference in disposition to home among morbidly obese patients vs. non-morbidly obese patients with >80% of the morbidly obese patients being discharged home. Our findings stand in discordance to Pappou et al who found that morbidly obese patients were significantly more likely to be discharged to a skilled nursing facility or rehabilitation facility than controls.[23] A recent study, however, demonstrated a national trend toward discharge home following TSA and significantly higher 90-day costs related to nonhome disposition to skilled nursing facility or inpatient rehabilitation facilities, though patients with higher CCI were still more likely to be discharged to an inpatient facility.[25] This trend has been demonstrated by others.[6] At our institution, patients are evaluated

**Table III**
Comparison of outcomes between matched cohorts.

| Clinical outcome measures | Non-morbid obese (BMI < 40) N = 41 | Morbid obese (BMI ≥ 40) N = 19 | Not morbid obese − morbid obese (within pair difference) | *P* value |
|---|---|---|---|---|
| ITBVL, median (IQR) | 218.6 (139.8, 305.0) | 213.9 (106.3, 434.5) | 7.0 (−127.7, 114.1) | .620 |
| Hospital stay, median (IQR) | 2 (2, 3) | 2 (1, 3) | 0 (−1, 1) | .654 |
| Operative time, median (IQR) | 114 (96, 126) | 114 (103, 137) | 0 (−35, 22) | .423 |
| 90-day return to ED | | | | .890 |
| No | 34 | 16 | | |
| Yes | 7 | 3 | | |
| Intraoperative complications | | | | n/a |
| No | 41 | 17 | | |
| Yes | 0 | 2 | | |
| Surgical postoperative complications | | | | n/a |
| No | 38 | 19 | | |
| Yes | 3 | 0 | | |
| In-hospital medical complication | | | | .888 |
| No | 33 | 15 | | |
| Yes | 8 | 4 | | |
| 90-day readmission | | | | .321 |
| No | 35 | 18 | | |
| Yes | 6 | 1 | | |
| Disposition | | | | .281 |
| Home | 38 | 16 | | |
| Nonhome | 3 | 3 | | |
| Transfusion | | | | .950 |
| No | 39 | 18 | | |
| Yes | 2 | 1 | | |

*IQR*, interquartile range; *ED*, emergency department; *BMI*, body mass index; *ITBVL*, intraoperative total blood volume loss.

postoperatively by a multidisciplinary team including physiatrists and social workers to determine the most appropriate pathway for discharge and the need for skilled home-based outpatient services including home therapy and visiting nurses when discharged home. Interestingly, the use of home health services following TSA has recently been demonstrated not to reduce the rate of 90-day readmission despite increased costs, suggesting that they should be implemented on a case-by-case basis.[34]

We found that the risk for in-hospital medical complications requiring an evaluation by our geriatric comanagement service was not significantly increased among patients with morbid obesity. This finding may be the result of efforts at medical optimization performed prior to surgery. Bixby et al found that the risk for 30-day urinary tract infections and sepsis following TSA has decreased significantly from 2005 through 2018.[6] Saini and colleagues, in a retrospective study using the National Surgical Quality Improvement Program database, found that morbid obesity was not significantly associated with total complications, all major complications and all minor complications, but was independently predictive of 30-day renal complications, pulmonary emboli, and prolonged ventilator use after controlling for modified CCI and age.[26] Some of the discrepancy between these findings and the current study may be related to the nature of their study design. Monroe and colleagues, in a review assessing the association between obesity and rTSA, found that while larger database studies demonstrated elevated risks of infection, revision surgery, and other medical complications among obese patients, smaller single-surgeon studies often revealed no significant differences in these parameters.[21] The authors opined that the published differences could be the result of multiple factors, including inconsistencies with procedure and complication coding, in addition to the inclusion of surgeons irrespective of volume and experience in the database studies.

While the current study offers valuable insights, it is certainly not without limitations. The retrospective study design, the small sample size of morbidly obese patients, and the focus on a single institution may limit the generalizability of our reported findings. Performing a multicenter study could certainly increase patient numbers, but would also add inhomogeneity with regard to surgeon volume and implant type utilized. Finally, it is not clear whether further categorization of the patients into another group of superobese (BMI $\geq$50 kg/m$^2$) would yield different results for our outcome measures, though this was not possible in the current studies given the numbers available. A strength of the current study includes the multiple baseline patient and surgical demographics examined. Specifically, we were able to examine the potential confounding effect of both socioeconomic and racial factors on perioperative outcomes such as hospital LOS and readmissions. Furthermore, all of the cases were performed with a standardized surgical approach and using short-stem rTSA implants from a single manufacturer. We believe that this approach removes some of the confounders inherent in national database studies wherein the specifics of the implant and surgical technique are unknown. Finally, the use of propensity-score matching based on multiple demographic parameters certainly enhanced the robustness of the analysis.

## Conclusions

Morbid obesity did not significantly impact ITBVL, hospital LOS, operative time, risk of in-hospital medical complications, and 90-day return to the ED or unplanned readmission among patients undergoing elective rTSA. We believe that the findings of the current study have several implications for clinical practice. These findings suggest that morbid obesity should not be considered an absolute contraindication to the utilization of rTSA and that rTSA can be performed safely in this patient population using a standardized surgical technique following medical optimization. Further research involving patients with higher categories of obesity (BMI$\geq$50 kg/m$^2$) may shed more light into the true effect of increasing BMI on complications and outcomes following rTSA.

**Disclaimers:**

Funding: This study was supported by the Montefiore Orthopaedic Seed Grant—Montefiore Department of Orthopaedic Surgery. Grant number 0008 was used to support the open-access payment and the medical student involved in the project.

Conflicts of interest: Konrad I. Gruson, MD, is a paid consultant and reports stock ownership for Stryker. The other 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.

## References

1. Amit P, Marya SKS. Age-adjusted Charlson comorbidity index as a novel guideline for patient selection between unilateral versus bilateral simultaneous total knee arthroplasty. Arch Orthop Trauma Surg 2022;142:657-63. https://doi.org/10.1007/s00402-021-03841-z.
2. Anakwenze O, Fokin A, Chocas M, Dillon MT, Navarro RA, Yian EH, et al. Complications in total shoulder and reverse total shoulder arthroplasty by body mass index. J Shoulder Elbow Surg 2017;26:1230-7. https://doi.org/10.1016/j.jse.2016.11.055.
3. Austin PC. Statistical criteria for selecting the optimal number of untreated subjects matched to each treated subject when using many-to-one matching on the propensity score. Am J Epidemiol 2010;172:1092-7. https://doi.org/10.1093/aje/kwq224.
4. Beck JD, Irgit KS, Andreychik CM, Maloney PJ, Tang X, Harter GD. Reverse total shoulder arthroplasty in obese patients. J Hand Surg Am 2013;38:965-70. https://doi.org/10.1016/j.jhsa.2013.02.025.
5. Best MJ, Aziz KT, Wilckens JH, McFarland EG, Srikumaran U. Increasing incidence of primary reverse and anatomic total shoulder arthroplasty in the United States. J Shoulder Elbow Surg 2021;30:1159-66. https://doi.org/10.1016/Jse.2020.08.010.
6. Bixby EC, Boddapati V, Anderson MJJ, Mueller JD, Jobin CM, Levine WN. Trends in total shoulder arthroplasty from 2005 to 2018: lower complications rates and shorter lengths of stay despite patients with more comorbidities. JSES Int 2020;4:657-61. https://doi.org/10.1016/j.jseint.2020.04.024.
7. Bosco JA, Harty JH, Iorio R. Bundled payment arrangements: keys to success. J Am Acad Orthop Surg 2018;26:817-22. https://doi.org/10.5435/JAAOS-D-17-00022.
8. Charlson M, Szatrowski TP, Peterson J, Gold J. Validation of a combined comorbidity index. J Clin Epidemiol 1994;47:1245-51.
9. Cogan CJ, Flores SE, Freshman RD, Chi HM, Feeley BT. Effect of obesity on short- and long-term complications of shoulder arthroplasty. J Shoulder Elbow Surg 2023;32:253-9. https://doi.org/10.1016/j.jse.2022.07.028.
10. Cunningham G, Hughes J, Borner B, Mattern O, Taha ME, Smith MM, et al. A single dose of tranexamic acid reduces blood loss after reverse and anatomic shoulder arthroplasty: a randomized controlled trial. J Shoulder Elbow Surg 2021;30:1553-60. https://doi.org/10.1016/j.jse.2020.11.022.
11. Giori NJ, Amanatullah DF, Gupta S, Bowe T, Harris AHS. Risk Reduction compared with access to care: quantifying the trade-off of enforcing a body mass index eligibility criterion for joint replacement. J Bone Joint Surg Am 2018;100:539-45. https://doi.org/10.2106/JBJS.17.00120.
12. Gowd AK, Agarwalla A, Beck EC, Rosas S, Waterman BR, Romeo AA, et al. Prediction of total healthcare cost following total shoulder arthroplasty utilizing machine learning. J Shoulder Elbow Surg 2022;31:2449-56. https://doi.org/10.1016/j.jse.2022.07.013.
13. Griffin JW, Novicoff WM, Browne JA, Brockmeier SF. Morbid obesity in total shoulder arthroplasty: risk, outcomes, and cost analysis. J Shoulder Elbow Surg 2014;23:1444-8. https://doi.org/10.1016/j.jse.2013.12.027.
14. Gruson KI, Lo Y, Stallone S, Qawasmi F, Lee S, Shah P. A comparison of operative time and intraoperative blood volume loss between Stemless and short-stem anatomic total shoulder arthroplasty: a single Institution's experience. J Am Acad Orthop Surg Glob Res Rev 2022;6:e22.00141. https://doi.org/10.5435/JAAOSGlobal-D-22-00141.
15. Gupta AK, Chalmers PN, Rahman Z, Bruce B, Harris JD, McCormick F, et al. Reverse total shoulder arthroplasty in patients of varying body mass index. J Shoulder Elbow Surg 2014;23:35-42. https://doi.org/10.1016/j.jse.2013.07.043.
16. Holzgrefe RE, Wilson JM, Staley CA, Anderson TL, Wagner ER, Gottschalk MB. Modified frailty index is an effective risk-stratification tool for patients undergoing total shoulder arthroplasty. J Shoulder Elbow Surg 2019;28:1232-40. https://doi.org/10.1016/j.jse.2018.12.004.
17. Kulkarni R, Guareschi AS, Eichinger JK, Friedman RJ. How using body mass index cutoffs to determine eligibility for total shoulder arthroplasty affects health care disparities. J Shoulder Elbow Surg 2023;32:2239-44. https://doi.org/10.1016/j.jse.2023.04.019.
18. LeBrun DG, Tran T, Wypij D, Kocher MS. How often do orthopaedic matched case-control studies use matched methods? A review of methodological quality. Clin Orthop Relat Res 2019;477:655-62. https://doi.org/10.1097/CORR.0000000000000612.
19. Linberg CJ, Sperling JW, Schleck CD, Cofield RH. Shoulder arthroplasty in morbidly obese patients. J Shoulder Elbow Surg 2009;18:903-6. https://doi.org/10.1016/j.jse.2009.02.006.
20. Mahmoud S, Dong Y, Loloi J, Gruson KI. Are perioperative complications and clinical outcomes following reverse shoulder arthroplasty adversely affected by obesity? A systematic review. Semin Arthroplasty: JSES 2021;31:147-58. https://doi.org/10.1053/j.sart.2020.11.006.
21. Monroe EJ, Hardy R, Holmquist J, Brand JC. Obesity and reverse total shoulder arthroplasty. Curr Rev Musculoskelet Med 2022;15:180-6. https://doi.org/10.1007/s12178-022-09753-8.
22. Morris BJ, O'Connor DP, Torres D, Elkousy HA, Gartsman GM, Edwards TB. Risk factors for periprosthetic infection after reverse shoulder arthroplasty. J Shoulder Elbow Surg 2015;24:161-6. https://doi.org/10.1016/j.jse.2014.05.020.
23. Pappou I, Virani NA, Clark R, Cottrell BJ, Frankle MA. Outcomes and costs of reverse shoulder arthroplasty in the morbidly obese: a case control study. J Bone Joint Surg Am 2014;96:1169-76. https://doi.org/10.2106/JBJS.M.00735.
24. Pezzulo JD, Farronato DM, Rondon AJ, Sherman MB, Getz CL, Davis DE. Predicting hospital readmissions after total shoulder arthroplasty within a bundled payment cohort. J Am Acad Orthop Surg 2023;31:199-204. https://doi.org/10.5435/JAAOS-D-22-00449.
25. Rosas S, Kurowicki J, Triplet JJ, Berglund DD, Horn B, Levy JC. Discharge disposition costs following total shoulder arthroplasty: a comprehensive national analysis. J Shoulder Elb Arthroplast 2017;1. https://doi.org/10.1177/2471549217740242.
26. Saini S, Bono O, Li L, MacAskill M, Chilton M, Ross G, et al. Investigating a potential limit to access to care: preoperative cutoff values for body mass index for shoulder arthroplasty. J Am Acad Orthop Surg 2022;30:e67-73. https://doi.org/10.5435/JAAOS-D-21-00476.
27. Scott KL, Chung AS, Makovicka JL, Pena AJ, Arvind V, Hattrup SJ. Ninety-day readmissions following reverse total shoulder arthroplasty. JSES Open Access 2019;3:54-8. https://doi.org/10.1016/j.jses.2018.11.002.
28. Sehat KR, Evans RL, Newman JH. Hidden blood loss following hip and knee arthroplasty. Correct management of blood loss should take hidden loss into account. J Bone Joint Surg Br 2004;86:561-5. https://doi.org/10.1302/0301-620X.86B4.14508.
29. Traven SA, McGurk KM, Reeves RA, Walton ZJ, Woolf SK, Slone HS. Modified frailty index predicts medical complications, length of stay, readmission, and mortality following total shoulder arthroplasty. J Shoulder Elbow Surg 2019;28:1854-60. https://doi.org/10.1016/j.jse.2019.03.009.
30. Wagner ER, Farley KX, Higgins I, Wilson JM, Daly CA, Gottschalk MB. The incidence of shoulder arthroplasty: rise and future projections compared with hip and knee arthroplasty. J Shoulder Elbow Surg 2020;29:2601-9. https://doi.org/10.1016/j.jse.2020.03.049.
31. Wang YC, McPherson K, Marsh T, Gortmaker SL, Brown M. Health and economic burden of the projected obesity trends in the USA and the UK. Lancet 2011;378:815-25. https://doi.org/10.1016/S0140-6736(11)60814-3.
32. Walters JD, Walsh RN, Smith RA, Brolin TJ, Azar FM, Throckmorton TW. Bundled payment plans are associated with notable cost savings for ambulatory outpatient total shoulder arthroplasty. J Am Acad Orthop Surg 2020;28:795-801. https://doi.org/10.5435/JAAOS-D-19-00441.
33. Werner BC, Bustos FP, Gean RP, Deasey MJ. Emergency department visits in the year prior to total shoulder arthroplasty as a risk factor for postoperative emergency department visits. HSS J 2021;17:200-6. https://doi.org/10.1177/1556331621995775.
34. Wieland MD, Sequeira SB, Imbergamo C, Murthi AM, Wright MA. Home health care is associated with an increased risk of readmission and cost of care without reducing risk of complication following shoulder arthroplasty: a propensity-score analysis. J Shoulder Elbow Surg 2023;S1058-2746:00881-9. https://doi.org/10.1016/j.jse.2023.10.034.