RESEARCH ARTICLE

Does Morbid Obesity (BMI ≥40 kg/m2) Impact Operative Time, Blood Loss, Length of Stay, or Complications Following Anatomic Total Shoulder Arthroplasty?

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Abstract

Objectives: There have been conflicting reports regarding the effects of obesity on both surgical time and blood loss following anatomic shoulder arthroplasty. Varying categories of obesity has made comparison amongst existing studies difficult.

Methods: A retrospective review of consecutive anatomic shoulder arthroplasty cases (aTSA) was undertaken. Demographic data, including age, gender, body mass index (BMI), age-adjusted Charleson Comorbidity Index (ACCI), operative time, hospital length of stay (LOS), and both POD#1 and discharge visual analogue score (VAS) was collected. Intra-operative total blood volume loss (ITBVL) and need for transfusion was calculated. BMI was categorized as non-obese (<30 kg/m^2), obese (30-40 kg/m^2) and morbidly obese (≥40 kg/m^2). Unadjusted associations of BMI with operative time, ITBVL and LOS were examined using Spearman correlation coefficients. Regression analysis was used to identify factors associated with hospital LOS.

Results: There were 130 aTSA cases performed, including 45 short stem and 85 stemless implants, of which 23 (17.7%) were morbidly obese, 60 (46.2%) were obese and 47 (36.1%) were non-obese. Median operative time for the morbidly obese cohort was 119.5 minutes (IQR 93.0, 142.0) versus 116.5 minutes (IQR 99.5, 134.5) for the obese cohort versus 125.0 minutes (IQR, 99.0, 146.0) for the non-obese cohort. (*P=0.61*) The median ITBVL for the morbidly obese cohort was 235.8 ml (IQR 144.3, 329.7) versus 220.1 ml (IQR 147.7, 262.7) for the obese cohort versus 216.3 ml (IQR 139.7, 315.5) for the non-obese cohort. (*P=0.72*). BMI ≥40kg/m^2 (IRR 1.32, *P=0.038*), age (IRR 1.01, *P=0.026*), and female gender (IRR 1.54, *P<0.001*) were predictive of increased LOS. There was no difference with regards to in-hospital medical complications (*P=0.13*), surgical complications (*P=1.0*), need for re-operation (*P=0.66*) and 30-day return to the ER (*P=0.06*).

Conclusion: Morbid obesity was not associated with increased surgical time, ITBVL and perioperative medical or surgical complications following aTSA, though it was predictive of increased hospital LOS.

Level of evidence: III

Keywords: Anatomic total shoulder, Blood loss, Complications, Length of stay, Morbid obesity, Obesity, Operative time

Introduction

Projections of the incidence of shoulder arthroplasty use in the United States suggest a significant future increase relative to hip and knee arthroplasty.[1] This increased utilization has been demonstrated for both anatomic (aTSA) and reverse total shoulder arthroplasty (rTSA).[2] Concomitantly, obesity continues to evolve into an epidemic within the United States and estimates reveal that over 50% of adults will be obese by 2030.[3] Increased body mass index (BMI), in addition to male gender, has been demonstrated to be associated with prolonged operative time during shoulder arthroplasty.[4] However, in that study, the authors did not differentiate between primary rTSA and aTSA, in addition to other surgical demographics such as humeral component design (stemmed versus stemless)

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or the possible use of cement, all factors that affect surgical time. As such, the association between BMI and increased surgical time has not consistently been demonstrated in the literature. Chalmers and colleagues, in a retrospective analysis of a consecutive series of aTSA performed at a single institution, found no significant difference in operative time amongst patients categorized as BMI<25 kg/m^2, 25-35 kg/m^2 and >35 kg/m^2.[5] Similar findings have been reported by others, though the categories for obesity used differed.[6] Interestingly, a recent systematic review with pooled analysis of only rTSA demonstrated the existence of a positive relationship between increasing BMI and surgical time, potentially implicating the specific type of arthroplasty being studied.[7] Regardless, the importance of minimizing operative time during shoulder arthroplasty has been shown in order to reduce the risk for perioperative complications.[8,9]

The need for more extensive soft tissue dissection amongst morbidly obese patients, in addition to the potentially increased operative time required, have been postulated to result in increased blood loss. Malcherczk *et al.* found that elevated BMI and male gender were significantly associated with increased blood loss following primary shoulder arthroplasty, though their series included stemmed aTSA and rTSA, in addition to stemless aTSA cases.[10] Several prior studies involving only primary rTSA have similarly demonstrated the positive association between increasing BMI and higher intra-operative blood loss.[11,12] In contrast, another study demonstrated no association between BMI and intra-operative blood loss following primary aTSA.[5] Furthermore, increased BMI was previously not found to be predictive of the need for post-operative transfusion or the number of units transfused in the setting of aTSA, though standardized protocols for triggering a transfusion were not utilized.[5,8] Finally, a recent systematic review examining the relationship between obesity and clinical outcomes following aTSA reported that higher BMI was not significantly associated with intra-operative blood loss, need for transfusion, and hospital length of stay (LOS).[13]

The primary purpose of the current study was to determine whether there was a difference in operative time, intra-operative total blood volume loss (ITBVL), and hospital LOS between morbidly obese patients compared with non-morbidly obese patients treated with primary aTSA at a single tertiary referral center. The secondary purpose was to examine the relationship between morbid obesity and perioperative complications and both post-operative day #1 (POD#1) and discharge visual analogue scale (VAS) pain scores. We hypothesized that morbidly obese patients would require significantly increased surgical time, experience greater blood loss and post-operative pain, and have a longer LOS compared with obese and non-obese patients.

Materials and Methods

The demographic patient and surgical data for all consecutive primary aTSA performed by the senior author (KIG) at a single academic medical center were retrospectively reviewed and collected. All procedures were performed by a single fellowship-trained shoulder surgeon. The surgical dates spanned from January 2016 through March 2020 and then January 2021 through January 2022. The intervening time period was not included given the potential confounding effects of the COVID pandemic. Institutional Review Board (IRB) approval was obtained for this study [IRB# 2022-13955].

The inclusion criteria included any patient who underwent an elective primary aTSA for primary osteoarthritis. Exclusion criteria included anatomic arthroplasty performed for inflammatory arthritis, cases with missing or incomplete medical records and those involving a prior open surgery on the ipsilateral shoulder. Demographic data including patient age, gender, side of arthroplasty performed, history of prior ipsilateral shoulder arthroscopy, BMI and age adjusted-Charleson Comorbidity Index (ACCI) were collected. The ACCI is a validated instrument for predicting mortality based on comorbid disease and was a modification of the original CCI by adjusting risk by age.[14] Additional surgical data including the American Society of Anesthesiologists (ASA) score, use of a stemless versus uncemented short stem humeral component, use of a posteriorly augmented versus non-augmented hybrid polyethylene, type of anesthesia administered (general versus general/regional), surgical time, use of a hemovac drain, administration of tranexamic acid (TXA), hospital LOS, VAS pain score on post-operative day#1 and day of discharge, change in VAS pain score and need for transfusion (intra- or post-operatively). Operative time was defined as the time from skin incision to the initiation of incision closure to minimize the potential effect of different closure techniques and speed amongst surgeons and trainees, and has been previously used.[15] There was no defined transfusion trigger during the study period and the administration of blood products was based primarily on the presence of patient symptoms suggestive of anemia and an evaluation by the geriatric co-management service. The BMI data was categorized as ≥40 kg/m^2 (morbidly obese), 30-39.9 kg/m^2 (obese) and <30 kg/m^2 (non-obese).

Surgical data

The surgical approach was performed in a consistent fashion with use of either the Simpliciti stemless humeral component or the Ascend Flex short-stem uncemented humeral component with proximal porous coating (Wright Medical, Memphis, TN, USA). The glenoid components utilized a press-fit polyethylene central peg and 3 peripheral cemented pegs (Aequalis Perform or Perform+, Wright Medical, Memphis, TN, USA). The use of augmentation was based on pre-surgical planning and/or intra-operative assessment of posterior 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.

Complications, Reoperations and Return to ER

Any intra- or postoperative surgical complication within 90 days of surgery was recorded and included nerve palsy, humeral and/or glenoid fracture, wound dehiscence or drainage, implant instability, or infection. Reoperations within 90 days with or without implant revision included irrigation and debridement and peri-prosthetic fracture. An in-hospital medical complication was defined as any issue requiring consultation with the Geriatric Service. Finally, any surgery-related visit to the Emergency Room

within 30 days was documented.

Blood volume loss

The pre-operative (Hct^{pre}) and post-operative (Hct^{post}) hematocrit levels was recorded. Total body volume (TBV) was calculated using the formula of Nadler and colleagues.[16] Intra-operative total blood volume loss (ITBVL) was calculated using the TBV multiplied by the change in pre-operative and post-operative hematocrit ($TBV*(Hct^{pre} - Hct^{post})$) and adding back any intra-operative blood transfusion volume administered as described by Sehat *et al.*[17], and previously utilized in clinical studies.[10,18] For the purpose of calculating ITBVL, the Hct^{pre} was compared to the Hct^{post} obtained on the evening of POD#0 for first-start cases and the Hct^{post} on the morning of POD#1 for afternoon-start cases.

Maximum Allowable Blood Loss (MABL)

The MABL provides an estimate of the maximum allowable blood volume loss based on a pre-determined transfusion threshold. The formula described by Gross and colleagues was used and MABL was calculated based on a theoretical transfusion trigger hematocrit of 10 g/dl.[19]

Statistical Analysis

Given the non-parametric nature of the data, continuous variables were presented as a median and associated inter-quartile range (IQR). The Kruskall-Wallis test was utilized to compare the medians for continuous variables and the Hodge-Lehman method was utilized to estimate the 95% confidence interval (95% CI). The standard chi-square test was utilized to evaluate categorical variables. Unadjusted associations of BMI with operative time, ITBVL, and LOS were reported using Spearman correlation coefficients: a value between 0 and 0.19, poor agreement; 0.20 to 0.39, fair agreement; 0.40 to 0.59, moderate agreement; 0.60 to 0.79, good agreement; and 0.80 to 1.00, excellent agreement. Non-parametric analysis of covariance was used to examine effects of BMI on operative time and blood loss adjusted for demographic, clinical, and surgical variables. Poisson regression analysis was used to identify factors independently associated with hospital LOS and presented as incidence rate ratio (IRR) with 95% confidence intervals (CI). Variables with p-value <0.25 in initial analyses were included in regression analysis. A P-value of P<0.05 was considered statistically significant. All statistical analyses were performed using SAS version 9.4 (SAS, Inc., Cary, North Carolina).

Results

There were 132 primary aTSA performed during the study period, though 2 (1.5%) were excluded for incomplete data. Of the remainder, 47 (36.2%) had BMI <30 kg/m^2, 60 (46.2%) had BMI 30-40 kg/m^2, and 23 (17.6%) had BMI ≥40 kg/m^2. The mean BMI for all patients was 33.2 ± 6.8 kg/m^2 (range, 20.1-54.9 kg/m^2). The median age in each of the cohorts was 64.0 years (IQR 56, 71), 61.5 years (IQR 55, 69), and 62.0 years (IQR 56, 67), respectively. (*P=0.62*) There was a significantly higher proportion of females in the morbidly obese group (91.4% versus 48.3% (obese) and 53.2% (non-obese), *P=0.001*), though the remainder of the baseline characteristics were similar [Table 1]. With regards to surgical demographics, 91.3% of the morbidly obese patients were classified as ASA ≥3 (versus 23.5% and 31.9% in the obese and non-obese groups, respectively) (*P=0.00002*). There was no significant difference in TXA use, hemovac drain use, type of anesthesia administered, or humeral component design between the groups [Table 2].

Table 1. Patient baseline demographic data

Clinical Parameters	BMI <30 kg/m^2 (median (IQR)) (n=47)	BMI 30-40 kg/m^2 (median(IQR)) (n=60)	BMI ≥40 kg/m^2 (median(IQR)) (n=23)	P-value
Age, yrs	64.0 (56,71)	61.5 (55,69)	62.0 (56,67)	0.62
Gender, n (%)				0.001
Male	22 (46.8%)	31 (51.7%)	2 (8.6%)	
Female	25 (53.2%)	29 (48.3%)	21 (91.4%)	
BMI, kg/m^2	26.8 (24.9,28.2)	33.9 (32.4,36.5)	42.7 (41.3,45.4)	<0.00001
Surgical side				0.39
Right	25 (53.2%)	36 (60.0%)	10 (43.4%)	
Left	22 (46.8%)	24 (40.0%)	13 (56.6%)	
Age-adjusted Charleson Comorbidity Index (ACCI)	3.0 (2.0,4.0)	2.5 (1.5,4.0)	2.0 (2.0,3.0)	0.66

Table 1. continued				
Prior ipsilateral arthroscopy				
Yes	7 (14.8%)	12 (20.0%)	1 (4.3%)	0.21
No	40 (75.2%)	48 (80.0%)	22 (95.7%)	

IQR: inter-quartile range; BMI: body mass index; Age-adjusted Charleson Comorbidity Index (ACCI)

Table 2 .Patient surgical and hospitalization data				
Surgical Parameters	**BMI <30 kg/m² (median (IQR)) (n=47)**	**BMI 30-40 kg/m² (median(IQR)) (n=60)**	**BMI ≥40 kg/m² (median(IQR)) (n=23)**	**P-value**
Operative time (minutes)	125.0 (99.0,146.0)	116.5 (99.5,134.5)	119.0 (93.0,142.0)	0.61
Use of augmented polyethylene				0.54
Yes	11 (23.4%)	11 (18.3%)	4 (17.4%)	
No	36 (76.6%)	49 (81.7%)	19 (83.6%)	
ASA				*0.00002*
1,2	32 (68.1%)	26 (76.5%)	2 (8.7%)	
≥3	15 (31.9%)	34 (23.5%)	21 (91.3%)	
Hemovac use				
Yes	35 (74.5%)	43 (71.7%)	17 (73.9%)	0.94
No	12 (25.5%)	17 (28.3%)	6 (26.1%)	
Transexamic acid use				
Yes	44 (93.6%)	55 (91.7%)	21 (91.3%)	0.91
No	3 (6.4%)	5 (8.3%)	2 (8.7%)	
Anesthesia, n (%)				
General alone	3 (6.4%)	1 (1.7%)	2 (8.7%)	0.30
General/regional	44 (93.6%)	59 (98.3%)	21 (91.3%)	
Humeral component design				0.35
Stemless	29 (61.7%)	43 (71.7%)	13 (56.5%)	
Short stem	18 (38.3%)	17 (28.3%)	10 (43.5%)	
Intra-operative total volume loss (ITBVL), ml	216.3 (139.7,315.5)	220.1 (147.7,262.7)	235.8 (144.3,329.7)	0.72
Total blood volume loss (TBVL), ml	359.7 (300.4,519.5)	372.4 (294.0,451.7)	409.6 (267.3,456.5)	0.95
Maximum allowable blood loss (MABL), ml exceeded				
Yes	1 (2.2%)	1 (1.7%)	0 (0.0%)	1.00
No	46 (97.8%)	59 (98.3%)	23 (100.0%)	
Transfusion (# of patients)				
Yes	0 (0.0%)	2 (3.3%)	0 (0.0%)	0.66
No	47 (100.0%)	58 (96.7%)	23 (100.0%)	
Length of stay	2 (1,2)	2 (1,3)	2 (2,4)	0.10
VAS pain score				
Post-op day #1	3 (0,7)	4.5 (0,7)	6 (2,7)	0.43
Day of discharge	2 (0,4)	2 (0,4.5)	2 (0,7)	0.88
Change	0 (-1,4)	0.5 (0,4)	2 (-1,5)	0.67

BMI: body mass index; ASA: American Society of Anesthesiologists classification; VAS: visual analogue scale
IQR: inter-quartile range

Operative time

The median operative time for the morbidly obese group was 119 minutes (IQR 93,142) versus 116.5 minutes (IQR 99.5 134.5) for the obese group and 125 minutes (IQR 99,146) in the non-obese group [Table 2]. (P=0.61) The estimated median difference in operative time comparing patients with BMI ≥40 kg/m^2 versus <40 kg/m^2 was -4 minutes (95% CI, -18 – 12 minutes, P=0.64) BMI was not associated with operative time when evaluated as a continuous variable. (r= -0.067, P=0.45) The use of stemless humeral implants (P<0.001), female gender (P=0.003), and higher aCCI (P=0.022) were associated with shorter surgical time. Regression analysis demonstrated that morbid obesity, adjusted for humeral component type, gender, and aCCI, was not significantly associated with operative time. (r= -0.084, P=0.99)

Intra-operative total blood volume loss

The median ITBVL for the morbidly obese cohort was 235.8 ml (IQR 144.3, 329.7) versus 220.1 ml (IQR 147.7, 262.7) for the obese group and 216.3 ml (IQR 139.7, 315.5) in the non-obese group. (P=0.72) The estimated median difference in ITBVL comparing patients with BMI ≥40 kg/m^2 versus <40 kg/m^2 was 13.0 ml (95% CI, -45.0 – 71.8, P=0.64) [Table 2]. BMI was not associated with ITBVL when evaluated as a continuous variable. (r= -0.022, P=0.8) Humeral component design (P=0.005) and gender (P=0.001) were significantly associated with blood volume loss. However, BMI ≥40 kg/m^2, when adjusted for humeral component type and gender, was not significantly associated with ITBVL. (P=0.61)

Transfusion and Maximum Allowable Blood Loss (MABL)

There were 2 transfusions administered during the study, both in the obese cohort. One transfusion was given intra-operatively and one post-operatively. There was no significant difference in transfusion risk between groups (P=0.66) There was no significant difference in the number of patients exceeding the MABL between the groups [Table 2].

Length of stay and post-operative pain

The median LOS for cases performed prior to the COVID pandemic in March 2020 was 1.5 days (IQR 1, 2) versus 1 day (IQR 2, 3) for those performed after elective surgery resumed. (P=0.0009) There was no significant difference in median hospital LOS between the groups based on BMI [Table 2]. (P=0.10) BMI was associated with hospital LOS. (r=0.171, P=0.05) Morbid obesity was significantly associated with increased hospital LOS relative to non-obese patients (IRR 1.316, 95% CI 1.015-1.705, P=0.038), though this association was not found for obese patients. (IRR 1.157, 95% CI 0.936-1.431, P=0.18) When BMI was analyzed continuously, there was a significantly increased LOS for each unit of BMI. (IRR 1.017, 95% CI 1.004-1.030, P=0.007) Female gender, older age, and the use of a hemovac drain were independently associated with increased hospital LOS [Table 3].

Table 3. Factors associated with hospital stay after TSA on Poisson regression

	Incidence rate ratio (IRR)	95% C.I.	P-value
BMI ≥ 40	1.316	1.015 – 1.705	0.038
30 ≤ BMI < 40	1.157	0.936 – 1.431	0.177
BMI < 30 (reference)	1		
Age, (per year)	1.012	1.001 – 1.023	0.026
Female gender	1.538	1.247 – 1.897	< 0.001
Hemovac use	1.392	1.105 – 1.754	0.005

There was no significant difference in VAS pain scores on POD#1 (P=0.43), day of discharge (P=0.88), or in the change in VAS score between POD#1 and the day of discharge (P=0.67) between the cohorts. When evaluated continuously, BMI was not associated with POD#1 pain, discharge day pain and change in pain level. (r= 0.085, -0.030 and 0.122, P=0.33, P=0.73 and P=0.16, respectively)

Perioperative complications and Return to ER

Amongst patients with BMI ≥40 kg/m2, there were 2 (8.7%) returns to the ER postoperatively, one for shortness of breath (SOB) and one for lower extremity swelling [Table 4]. There were no significant differences between the groups with regards to in-hospital medical complications (P=0.13), postoperative surgical complications (P=1.0), need for reoperation (P=0.66) or visits to the ER within 30 days (P=0.06).

Table 4. Perioperative medical and surgical complications

Clinical Parameters	BMI <30 kg/m^2 (no. (%)) (n=47)	BMI 30-40 kg/m^2 (no. (%)) (n=60)	BMI ≥40 kg/m^2 (no. (%)) (n=23)	P-value
In-hospital medical complication				**0.13**
Yes	3 (6.4%)	11 (18.3%)	5 (21.7%)	
No	44 (93.6%)	49 (71.7%)	18 (78.3%)	

Table 4. continued

Return to ER w/in 30 days				
Yes	3 (6.4%)	0 (0.0%)	2 (8.7%)	**0.06**
No	44 (93.6%)	60 (100.0%)	21 (91.3%)	
Intra-operative surgical complication				
Yes	1 (2.1%)	0 (0.0%)	0 (0.0%)	**0.54**
No	46 (97.9%)	60 (100.0%)	23 (100.0%)	
Post-operative surgical complication				
Yes	2 (4.2%)	3 (5.0%)	1 (4.3%)	**1.00**
No	45 (95.8%)	57 (95.0%)	22 (95.7%)	
Any complication (medical and/or surgical)				**0.16**
Yes	7 (14.9%)	13 (21.7%)	8 (34.8%)	
No	40 (85.1%)	47 (88.3%)	15 (65.2%)	
Re-operation				**0.66**
Yes	1 (2.1%)	3 (5.0%)	0 (0.0%)	
No	46 (97.9%)	57 (95.0%)	23 (100.0%)	

IQR: inter-quartile range; BMI: body mass index; Age-adjusted Charleson Comorbidity Index (ACCI)

Discussion

The main findings of this study were that morbid obesity, when compared to patients with BMI<40 kg/m^2, did not experience increased surgical time, intra-operative TBVL, or VAS pain scores on POD#1 or at discharge. The presence of morbid obesity was associated with a significantly increased hospital LOS.

We found that patients with morbid obesity did not experience increased surgical times when compared to obese and non-obese patients undergoing aTSA. This result was unexpected given the perceived more extensive dissection required during the surgical exposure with the increased surrounding soft tissue envelope. Our findings were consistent with prior studies on primary aTSA, though lower thresholds for the highest BMI category were utilized in those studies.[5,6] Furthermore, when assessing BMI and adjusting for gender, humeral component design (stemless versus short-stem) and aCCI, we did not find an association with surgical time. In contrast, a recent national database study reported a higher risk for prolonged surgical time, defined as ≥150 minutes, in patients with increasing BMI undergoing shoulder arthroplasty.[4] The mean surgical time in our cohort was 123 ± 32 minutes and only 18% had a surgical time >150 minutes, both of which likely contributed to the discordant findings. Furthermore, the authors did not elucidate between aTSA and rTSA, the length of the humeral stem, the specific implant manufacturer utilized or whether cement was used for then humerus, all factors which may have led to the different results. Specifically, Wiater et al. reported no difference in operative time between stemless and short stem implants from a single manufacturer, [20] a finding that differs from others using different implants.[15] This emphasizes the importance of reporting on humeral component design when assessing potential risk factors for increasing surgical time. In fact, while several studies have not found an association between BMI and surgical time following aTSA, [5, 6] others have demonstrated this relationship amongst patients undergoing rTSA.[7]

In the current study, morbid obesity was not significantly associated with ITBVL when compared with patients with BMI <40 kg/m^2. Furthermore, there was no difference in the need for transfusion or the number of patients exceeding the MABL using a hemoglobin level of 10 g/dl as a theoretical threshold for transfusion. Our results are consistent with those of Chalmers and colleagues who found no association between BMI and both estimated blood loss or need for transfusion.[5] Using a BMI cutoff of >30 kg/m^2 for obesity, Li et al. reported a similar lack of association between the need for transfusion and BMI.[6] Our results differ from those of Malcherczyk et al. who found that lower BMI was associated with the need for transfusion amongst patients undergoing rTSA, stemmed aTSA and stemless aTSA using an actual transfusion cutoff of <8 g/dl in most of their cases.[10] Only a single intra-operative blood transfusion and one post-operative blood transfusion were administered to 2 individual patients in the current study, both in the obese group, for an overall prevalence of 1.5%. In contrast, Malcherczyk et al. reported a 14.4% transfusion rate amongst the rTSA and aTSA stemmed implant cohort and a 0% transfusion rate amongst the stemless cohort, and reported that patients with an elevated BMI had a 6-fold increased blood loss following TSA.[10] The difference from our study may have resulted from the higher mean BMI for our patients (33.2 kg/m^2) compared with their patients (28.7 kg/m^2), our specific focus on the morbidly obese patient, and

the use of tranexamic acid in 92.3% of cases. Given the variable transfusion triggers amongst institutions, utilization of MABL may serve as a more relevant assessment of blood loss following aTSA in future research.

We found that patients with morbid obesity had a 32% increased hospital LOS compared to non-obese patients. For each unit of increased BMI, hospital LOS was increased by 1.7%. Of interest, patients with BMI 30-39.9 kg/m^2 did not demonstrate an increased LOS compared to non-obese patients suggesting that future research be focused on the morbidly obese and superobese categories. In a prior database study, Menendez et al. found that BMI was independently predictive of increased extended LOS following aTSA.[21] Griffin and colleagues found that morbidly obese patients had a significantly increased LOS compared to both obese and non-obese patients undergoing TSA.[22] The relationship between morbid obesity and LOS is all the more striking given that the overall LOS following TSA has been decreasing with time.[23] In the current study, we also found a significantly decreased LOS following the resumption of surgery after the COVID pandemic onset. In contrast, King et al. reported no relationship between BMI and length of hospitalization, though the average BMI fell within the overweight category and the study involved multiple preoperative diagnoses including inflammatory arthritis.[24] Female gender and advanced age were both significantly associated with prolonged LOS, with a nearly 54% increased LOS amongst females. The relationship between female gender and older age with increased LOS has previously been reported.[25] The gender association has been postulated to occur as a result of women undergoing shoulder arthroplasty at an older age, have a higher risk for thromboembolic events and need for blood transfusion, all of which may result in longer LOS.[26] Finally, we found that VAS pain scores on POD#1, as well as upon discharge, were not significantly different between morbidly obese patients and the other patients in this study. The use of multimodal pain management strategies following shoulder arthroplasty with a focus on non-opioid medications and regional anesthetics likely played a role in this outcome.[27] We found no association between BMI and in-hospital medical and perioperative surgical complications, postoperative visits to the ER and need for reoperation. These findings are consistent with those reported by others.[5] Werner and colleagues demonstrated increased complications amongst superobese patients (BMI>50 kg/m^2) compared with obese and morbidly obese patients undergoing TSA,[28] suggesting that future ongoing be focused on patients with morbid obesity and higher.

There are certainly limitations to this study. All of the procedures were performed by a single surgeon at a tertiary care referral center, which may limit the generalizability of the reported findings. However, this may reduce the confounding effect of varying surgical techniques and experience, and likely minimized the reported discordant relationship between low-volume surgeons and hospital LOS.[29] Furthermore, the estimation of surgical blood loss has been described using multiple published formulas relying either on hemoglobin or hematocrit. We utilized a commonly described method and calculating blood loss has generally demonstrated higher accuracy than intra-operative direct measurements. We did not take into account the hidden blood volume loss into the surrounding soft tissues of the surgical site as has been described by Sehat et al. for lower extremity arthroplasty.[17] finally, all of the implants in this study were from one manufacturer and it is possible that the results would be different if other implants were used. Strengths of this study include the consistent surgical technique and post-operative protocols utilized.

Conclusion

Amongst patients undergoing aTSA, morbid obesity was not associated with increased operative time, ITBVL and discharge VAS pain scores. Morbid obesity, female gender and increasing patient age resulted in a significantly increased hospital LOS. In light of recent efforts to decrease inpatient stay following TSA, further study will help ascertain which patients will successfully experience a safe and timely discharge.

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