J Shoulder Elbow Surg (2016) 25, 193-200

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Malnutrition: a marker for increased complications, mortality, and length of stay after total shoulder arthroplasty

Grant H. Garcia, MD*, Michael C. Fu, MD, MHS, David M. Dines, MD, Edward V. Craig, MD, MPH, Lawrence V. Gulotta, MD

Sports and Shoulder Service, The Hospital for Special Surgery, New York, NY, USA

Background: Malnutrition is an established risk factor for postoperative complications. The purpose of this investigation was to determine the overall prevalence of malnutrition in total shoulder arthroplasty (TSA) patients, the differences in prevalence across obesity subgroups, and the overall complication risk of malnourished patients compared with normal patients.
Methods: The American College of Surgeons National Surgical Quality Improvement Program database was queried for TSA cases from 2005 to 2013 for this retrospective cohort study. Malnutrition was defined as preoperative albumin concentration of <3.5 g/dL. Rates of postoperative complications were compared between normal and malnourished patients.
Results: We identified 4,655 TSA cases, with preoperative albumin measurements available for 1681 patients (36.1%). Propensity score adjustment successfully reduced selection bias, with adjusted P values of >.05 for demographics, body mass index, and modified Charlson Comorbidity Index. Of the cohort with albumin measurements, 7.6% of patients were malnourished according to our criteria. Bivariate analysis showed malnourished patients had higher rates of pulmonary complications, anemia requiring transfusion, extended length of stay (LOS), and death (all $P < .05$). Propensity-adjusted multivariable logistic regression demonstrated that malnutrition was significantly associated (all $P < .05$) with postoperative transfusion (odds ratio, 2.49), extended LOS (odds ratio, 1.69), and death (odds ratio, 18.09).
Conclusion: The overall prevalence of malnutrition was 7.6%. Malnourished patients were at a significantly increased risk for blood transfusion, longer hospital LOS, and death within 30 days of surgery. Multivariable analysis showed TSA patients with preoperative albumin levels of <3.5 g/dL are at much higher risk for morbidity and death after surgery than patients with albumin levels within normal reference ranges.
Level of evidence: Level III, Retrospective Cohort Study using Large Database, Treatment Study.

Keywords: Albumin; shoulder arthroplasty; malnourished; obesity

This study used data from the National Surgical Quality Improvement Program, with no human identifying information, and was thus exempt from Investigational Review Board approval.

*Reprint requests: Grant H. Garcia, MD, Hospital for Special Surgery, 525 E 70th St, New York, NY 10021, USA.

E-mail address: garciagr@hss.edu (G.H. Garcia).

Malnutrition is an important medical comorbidity. The prevalence of malnutrition in surgical patients has been estimated to range from 25% to 40%, with many of these patients having complication rates as high as or higher than patients with diabetes and obesity.[11,27] The negative effect

1058-2746/$ - see front matter © 2016 Journal of Shoulder and Elbow Surgery Board of Trustees.
http://dx.doi.org/10.1016/j.jse.2015.07.034

of nutritional deficiencies on postoperative outcomes has been well documented in other surgical fields, including transplant surgery, vascular surgery, general surgery, and gynecology.[2,10,16,19,39] Initial orthopedic studies reported poor results in nutritionally deficient hip fracture patients, demonstrating significantly increased complications and longer rehabilitation times.[33,35,38] More recently, the orthopedic literature has investigated this phenomenon in spine surgery and joint arthroplasty. For spine patients with nutritional deficiency, studies demonstrate a significant increase in major postoperative medical complications, impaired wound healing, delayed postoperative recovery, and increased hospital length of stay (LOS).[17,24,37] Nutritional deficiency has been extensively investigated in hip and knee arthroplasty, with findings of up to a 5-fold increase in joint infection, wound drainage, and neurovascular and renal complications.[18,25,26,41,42]

To our knowledge, no study has evaluated the effects of nutritional status in shoulder arthroplasty, although numerous studies to date have focused on obesity rather than malnutrition.[5,22,34,36] Although it may seem counterintuitive, many obese patients are also malnourished,[41] and the adverse effects of malnutrition must be considered preoperatively in this population.[25,48] Furthermore, poor nutritional status is often subclinical, without physical manifestations until it is severe, and normal-weight patients can be malnourished without physical examination findings.

Common laboratory tests to assess nutritional status include albumin levels, transferrin levels, and total lymphocyte count.[6,21] The common standard for the total serum lymphocyte count is <1500 cells/mm^3, though the validity of this test has been questioned.[12,30] Albumin levels are more frequently used as a biomarker, with levels of <3.5 g/dL suggesting poor nutrition.[14,43] This value is used regularly in the orthopedic literature to identify malnutrition as a risk factor for poor postoperative outcomes.[14,17,42]

The purposes of the study were to (1) examine the overall prevalence of malnutrition in the total shoulder arthroplasty (TSA) population, (2) determine the overall complication risk of malnourished (albumin <3.5 g/dL) compared with nonmalnourished (albumin ≥ 3.5 g/dL) patients, and (3) evaluate the prevalence of concomitant obesity in malnourished patients.

Materials and methods

This was a retrospective cohort study using the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database. TSA cases were identified from the database using Current Procedural Terminology (CPT; American Medical Association, Chicago, IL, USA) code 23472, from 2005 to 2013. This CPT code covers anatomic and reverse TSA. The study excluded patients who underwent emergency surgery, had preoperative contaminated wound classifications, and missing data including age, sex, height, and weight. An initial total of 4796 TSA patients were identified by the NSQIP database. After application of the exclusion criteria, as noted above, 4655 patients were included in the cohort.

The NSQIP database[3] is a large multicenter clinical outcomes program, with prospectively collected and risk-adjusted patient demographic and comorbidity data, preoperative laboratory results, anthropometric values, and perioperative information. Postoperative adverse events and complications are gathered up to postoperative day 30, irrespective of the date of discharge. More than 135 preoperative, intraoperative, and postoperative variables are collected prospectively from medical records, operative reports, and patient interviews.

Patient characteristics collected from the database included age, sex, height, weight, and comorbidity data. Body mass index (BMI) was calculated from height and weight. Cardiac comorbidities included myocardial infarction (within 6 months before admission), congestive heart failure (within 30 days before admission), percutaneous coronary intervention, cardiac surgery, or angina (within 1 month before admission). Pulmonary comorbidities included a history of severe chronic obstructive pulmonary disease, current pneumonia, or an assisted ventilation requirement within 48 hours before surgery. Peripheral vascular disease was defined as a history of rest pain, gangrene, or revascularization or amputation for peripheral vascular conditions. Smoking history (current smoker within the past year) and chronic steroid use (within 30 days before surgery) were also evaluated. A modified Charlson Comorbidity Index (CCI) adapted for the NSQIP was used to characterize the overall health of the patients and has been used previously in the literature.[7,8]

Patient demographics, obesity classifications, and modified CCI were compared between patients with and without preoperative serum albumin measurements. To adjust for selection bias in the patients with albumin measurements, propensity scores were determined and defined as the conditional probability of having a preoperative albumin measurement based on the observed demographic characteristics, obesity classification, and comorbidity burden. Propensity scores have been used in the literature extensively for this purpose.[4,15] Propensity-adjusted *P* values for preoperative patient characteristics were reported. The propensity adjustment successfully reduced selection bias by eliminating differences in preoperative variables (all $P > .05$). The remainder of the analysis was carried forward with propensity scores, using only patients with albumin measurements.

Patients were categorized by preoperative serum albumin concentration as normal albumin (≥ 3.5 g/dL) or hypoalbuminemic (<3.5 g/dL), the latter indicating malnutrition for the purpose of this study. Patients were also categorized based on BMI using the World Health Organization (WHO) classification[49]: underweight (BMI <18.5 kg/m^2), normal weight (BMI 18.5-24.9 kg/m^2), overweight (BMI 25.0-29.9 kg/m^2), obese I (BMI 30.0-34.9 kg/m^2), obese II (BMI 35.0-39.9 kg/m^2), and obese III (BMI ≥ 40.0 kg/m^2).

The study end points included any postoperative complication, major complications, minor complications, and extended LOS, which was defined as more than 3 days. Major complications included cardiac complications (cardiac arrest or myocardial infarction), central nervous system complications (stroke or coma), pulmonary complications (pneumonia, intubation, or ventilator requirement), renal complications (acute renal

Table I Patient demographic characteristics and comorbidities with propensity score adjustment

Variable	All patients	Preoperative albumin		*P* value	
		Yes	No	Unadjusted	Adjusted*
	(N = 4655) (%)	(n = 1681) (%)	(n = 2974) (%)		
Overall	100.0	36.1	63.9		
Male gender	43.1	41.5	44.1	.095	.984
Age, years				.295	.336
18-64	27.1	25.8	27.8		
65-79	55.2	55.7	54.9		
≥80	17.8	18.5	17.4		
Obesity classification				.071	.750
Normal weight (BMI 18.5-25 kg/m^2)	17.6	18.8	16.9		
Overweight (BMI 25-30 kg/m^2)	33.7	33.5	33.9		
Obese I (BMI 30-35 kg/m^2)	25.8	24.2	26.8		
Obese II (BMI 35-40 kg/m^2)	13.0	12.6	13.3		
Obese III (BMI >40 kg/m^2)	9.0	10.2	8.3		
Modified CCI				.105	.914
0 to 2	14.5	14.1	14.7		
3 to 4	60.6	59.2	61.4		
≥5	24.9	26.7	23.9		

BMI, body mass index; *CCI*, Charlson Comorbidity Index.
* To control for selection bias between the groups with and without preoperative serum albumin measurements, propensity scores were used, with the propensity score defined as the conditional probability of having a preoperative albumin measurement based on the observed patient characteristics. Propensity-adjusted *P* values for demographics, obesity classification, and modified CCI are reported. The model successfully reduced selection bias by eliminating significant differences in preoperative variables (adjusted *P* all > 0.05).

insufficiency or failure), sepsis or septic shock, pulmonary embolism, deep vein thrombosis, return to the operating room, and death. Minor complications consisted of wound complications (superficial wound infection, deep incisional surgical site infection, organ space surgical site infection, or wound dehiscence), urinary tract infection, and postoperative anemia requiring transfusion.

Demographic and comorbidity variables were compared between the normal albumin and hypoalbuminemic cohorts, using the Pearson χ^2 test for categoric variables and Student *t* test for continuous variables. Patients in the cohorts with normal albumin and hypoalbuminemia were further categorized by BMI. The rates of postoperative complications and extended LOS were then compared between the albumin groups as unadjusted bivariate analyses.

Complications with a *P* value of <.2 were carried forward into a propensity-adjusted multivariable logistic regression model to determine the effect of preoperative hypoalbuminemia on the likelihood of developing a postoperative complication. The multivariable models were adjusted for age, sex, diabetes, hypertension, cardiac comorbidities, pulmonary comorbidities, peripheral vascular disease, history of transient ischemic attack or cerebrovascular accident, smoking history, chronic steroid use, BMI, American Society of Anesthesiologists Physical Status Classification, and the propensity scores predicting the presence of preoperative albumin data. The modified CCI was not included in the model because of the high covariance with age. BMI was adjusted for as a continuous variable. Odds ratios (ORs) with 95% confidence intervals (CI) were calculated. A *P* value of <.05, or if the 95% CI did not include 1.0, was deemed to be statistically significant. All statistical tests were 2-tailed.

Results

We identified 4,655 TSA patients, of whom 1681 (36.1%) had preoperative albumin measurements. Compared with those without preoperative albumin measurements, patients with albumin data were more likely to be female, older in age, and have a higher obesity classification and higher modified CCI (Table I). The unadjusted *P* values trended toward statistical significance, particularly for the differences in sex (*P* = .095) and obesity classification (*P* = .071). To adjust for selection bias between the albumin measurement groups, propensity scores were determined from patient demographics, BMI, and the modified CCI for each patient. This adjusts for the conditional probability of a patient having a preoperative albumin measurement in a nonrandomized sample. Table I also reports the propensity-adjusted *P* values for comparisons between the groups, and they indicate a successful reduction in selection bias, with all adjusted *P* values well higher than .05. The remainder of the analysis was performed with the 1681 patients with albumin measurements, while carrying forward the propensity scores.

The overall prevalence of preoperative malnutrition was 7.6%. Compared with patients with normal albumin, malnourished patients were older, more likely to be female, have a modified CCI ≥5, American Society of Anesthesiologists Physical Status Classification ≥3, have pulmonary comorbidities, diabetes, a history of transient ischemic

Table II Patient demographics by albumin category

Variable*	Normal albumin (≥3.5 g/dL)	Hypoalbuminemic (<3.5 g/dL)	*P* value
Patients	1553 (92.4)	128 (7.6)	
Age, y	69.7 ± 10.3	73.0 ± 10.7	.001
Female	57.1	75.8	<.001
BMI, kg/m^2	30.7 ± 6.7	31.2 ± 8.4	.390
Modified CCI ≥5	24.8	50.0	<.001
ASA ≥3	52.2	74.2	<.001
Hypertension	68.3	75.8	.077
Cardiac comorbidity	4.8	10.2	.008
Pulmonary comorbidity	12.6	28.9	<.001
Diabetes	17.3	29.7	<.001
Smoking history	9.7	11.7	.452
Peripheral vascular disease	0.2	0.8	.190
TIA/CVA	2.7	6.3	.023
Chronic steroid use	5.6	15.6	<.001

ASA, American Society of Anesthesiologists; *BMI*, body mass index, *CCI*, Charlson Comorbidity Index; *CVA*, cerebrovascular accident; *TIA*, transient ischemic attack.

* Categoric data are expressed as number (%) or as percentage and continuous data as mean ± standard deviation.

attack or cerebrovascular accident, and to have a history of chronic steroid use (all $P < .05$). These results are further delineated in Table II.

To further investigate the relationship between BMI and malnutrition, additional analysis of the distribution across obesity classes was performed (Fig. 1). There was a significantly increased proportion of normal weight and obese III patients among hypoalbuminemic patients compared with controls (all $P < .05$). The small number of underweight patients in the study (12 of 1681) obviated further analysis of this subgroup. (Table III)

Complications and LOS were evaluated in the unadjusted bivariate analyses (Table IV). Malnourished patients were at higher risk of requiring a blood transfusion (all $P < .001$). Considering major complications, hypoalbuminemic patients were more likely to develop postoperative pulmonary complications or death (all $P < .05$). There was a trend toward an increased risk of any major complication in this cohort as well, but significance was not reached ($P = .063$). Malnourished patients were also more likely to have extended LOS than controls ($P < .001$).

The results of the multivariable logistic regressions are reported in Table V. Adjustments were made for demographics, comorbidities, and BMI. Preoperatively, malnourished patients were at significantly increased risk for death within 30 days (OR, 18.09; 95% CI, 1.88-173.98), postoperative anemia requiring transfusion (OR, 2.49; 95% CI, 1.43-4.33), and extended LOS (OR, 1.69; 95% CI, 1.02-2.78).

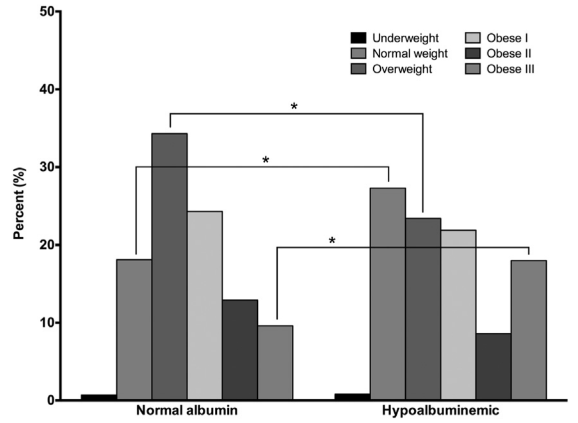

Figure 1 Proportions of patients in each obesity class among patients with normal albumin and hypoalbuminemia. *$P < .05$ indicating statistically significant differences.

Discussion

The clinical implications of malnutrition are significant in orthopedic surgery patients. Numerous spine and arthroplasty studies have reported increased complications and LOS in these patients,[14,17,25,29,31,41] but there is a paucity of research on malnutrition in shoulder arthroplasty. Our study found hypoalbuminemia, as a marker of malnutrition, was present in 7.6% of all shoulder arthroplasty patients. These malnourished patients had a propensity-adjusted increased risk of anemia requiring blood transfusion, extended LOS, and death compared with well-nourished patients.

Overall, 7.6% of our study patients had preoperative albumin levels of <3.5 g/dL, whereas previous joint replacement studies have reported rates ranging from 8% to 50%.[21,25,27,41] Although the prevalence of malnutrition in this study cohort was lower than the prevalence reported in the lower extremity arthroplasty literature, the results for LOS were similar. We found that shoulder patients with low albumin had a significantly increased incidence of extended LOS compared with well-nourished controls in propensity-adjusted and unadjusted bivariate analyses. This is consistent with historic data demonstrating increased LOS in malnourished patients.[18,21,27] Further analysis of the economic effect of extended LOS after shoulder arthroplasty should be considered.

The increased risk of complications in malnourished patients has been previously described in the surgical literature. Our investigation found patients with albumin levels of <3.5 g/dL were at significantly higher risk anemia requiring a transfusion compared with patients with normal albumin levels. This level of significance was maintained in unadjusted bivariate and in propensity-adjusted analysis. With regards to the other minor complications, wound complications and urinary tract infections among malnourished and control patients were not statistically different. This is of interest, because these findings differ

Table III Proportion of patients in each obesity class by preoperative albumin

BMI group	Normal albumin (≥3.5 g/dL) (n = 1553) No. (%)	Hypoalbuminemic (<3.5 g/dL) (n = 128) No. (%)	*P* value
Underweight (<18.5 kg/m^2)	11 (0.7)	1 (0.8)	.615
Normal weight (18.5-25 kg/m^2)	281 (18.1)	35 (27.3)	.013
Overweight (25-30 kg/m^2)	533 (34.3)	30 (23.4)	.011
Obese I (30-35 kg/m^2)	378 (24.3)	28 (21.9)	.592
Obese II (35-40 kg/m^2)	201 (12.9)	11 (8.6)	.168
Obese III (>40 kg/m^2)	149 (9.6)	23 (18.0)	.006

BMI, body mass index.

Table IV Unadjusted postoperative adverse events by preoperative albumin level

Variable	Normal albumin (≥3.5 g/dL)	Hypoalbuminemic (<3.5 g/dL)	*P* value
Patients, No. (%)	1,553 (92.4)	128 (7.6)	
Any postoperative complication, %	4.4	7.0	.168
Major complication, %	3.2	6.3	.063
Pulmonary	0.7	3.1	.005
Cardiac	0.3	0.8	.403
Renal	0.1	0.0	.685
DVT/PE	0.8	0.8	.992
Sepsis/septic shock	0.2	0.8	.190
Return to operating room	1.1	1.6	.631
Death	0.1	2.3	<.001
Minor complication, %	7.2	18.0	<.001
Urinary tract infection	1.3	0.8	.620
Wound complication	0.6	0.8	.776
Anemia requiring transfusion	5.5	16.4	<.001
Extended length of stay, %	9.0	20.3	<.001

DVT, deep vein thrombosis, *PE*, pulmonary embolism.

from the previous lower extremity arthroplasty literature.[18,44,45] This lack of significance may be due to differential risks for infection between upper and lower extremity surgical sites as well as the inability to capture late wound complications after postoperative day 30 using the NSQIP database.

Finally, our incidence of increased transfusion requirements in malnourished patients is similar to previous reports.[46] Transfusion risk may be a relatively minor complication but could also signify a more difficult operation or increased blood loss during the procedure. Overall, hypoalbuminemic patients had more than double the risk of requiring a blood transfusion, and this is an important preoperative consideration in this patient population.

The unadjusted analysis of malnourished patients showed significantly increased risks of major complications, including pulmonary complications and death, compared with controls. After adjusting for major risk factors and propensity scores for having an albumin measurement, only the risk of death remained significant among the malnourished patients. A recent study by Huang et al[25] found an increased risk of any major complication, including neurovascular and renal complications, in malnourished spine patients. Unadjusted analysis of pulmonary complications in their study also trended towards significance ($P < .094$); however, similar to our results, multivariable analysis failed to show a significant difference. Others have reported other major complications, such as periprosthetic joint infections, in malnourished patients.[21,26,41]

Even after adjusting for all major identifiable demographics, comorbidities, and propensity scores, hypoalbuminemic patients were at significantly increased risk of death postoperatively. To the best of our knowledge, no arthroplasty study has identified increased mortality in malnourished patients, although this variable has rarely been analyzed as a postoperative complication.[14,21,25] Beyond arthroplasty patients, several studies of hip fracture patients and some nonorthopedic cohorts have found that malnourished patients are at increased risk of death in the postoperative period.[13,19,40,47] Although these patients were identified as hypoalbuminemic preoperatively,

Table V Multivariable propensity-adjusted logistic regression results for hypoalbuminemia*

Variable	Adjusted OR	95% CI	P value
Any postoperative complication	1.15	0.53-2.51	.721
Major complication	1.41	0.61-3.26	.423
Pulmonary complication	2.25	0.61-8.29	.221
Death	18.09	1.88-173.98	.012
Minor complication	2.09	1.23-3.54	.006
Anemia requiring transfusion	2.49	1.43-4.33	.001
Extended length of stay	1.69	1.02-2.78	.041

CI, confidence interval; *OR*, odds ratio.

* Adjusted for age, sex, diabetes, hypertension, cardiac comorbidity, pulmonary comorbidity, peripheral vascular disease, transient ischemic attack/cerebrovascular accident, smoking history, chronic steroid use, body mass index, American Society of Anesthesiologists classification, and propensity score for having a preoperative albumin measurement.

whether more extensive risk stratification and medical optimization was performed was unclear. Furthermore, these patients might have had subclinical end-organ dysfunction from poor nutrition, and the added insult of surgery could have contributed to increased postoperative mortality.

A recent trend in the shoulder arthroplasty literature has been a focus on the effects of obesity on postoperative outcomes.[22,34,36] That obese patients would be adequately nourished seems logical, but current data show the opposite is true. This study's results demonstrate that obese patients had a higher prevalence of malnutrition (7.8%) than nonobese patients (7.4%), which is consistent with previous observations.[25,28,41] Further stratification by WHO obesity classifications showed that a significantly higher number of these nutritionally deficient patients were morbidly obese (obese III). Surgeons may therefore want to strongly consider preoperative nutritional screening in this high-risk group of patients through the use of serum biomarkers such as albumin concentration.

To reduce the effect of complications from malnutrition, various efforts have been directed at improving the nutritional status of surgical patients. Hu et al[24] studied the effects of postoperative total parenteral nutrition on patients undergoing spinal reconstruction surgery and found a decreased incidence of pneumonia and urinary tract infection. Lawson et al[32] studied the effect of routine postoperative nutritional supplementation in orthopedic wards and found fewer overall complications as well as lower cost per stay compared with controls. In contrast, Cross et al[14] recommended a preoperative approach to address malnutrition without finding definitive improvement. Overall, studies have demonstrated improved outcomes after postoperative nutritional supplementation, but further research is required to determine if preoperative nutritional supplementation results in fewer complications.

This study is subject to several important limitations, the most important being that of a total of 4655 TSA cases identified, just 1681 (36.1%) had preoperative albumin measurements. Given the multicenter nature of this clinical outcomes database, there is likely to be heterogeneity across multiple preoperative risk stratification protocols, patient characteristics, clinician preferences, and data collection practices. Although patients with and without albumin measurements did not have any statistically significant differences in this analysis, several characteristics trended toward statistical significance, indicating the presence of selection bias. A propensity score-adjustment model was used to account for this bias, which successfully reduced the differences to well above the threshold for significance. The subsequent multivariable analysis with only patients with albumin data was performed while adjusting for the same propensity scores, accounting for any selection bias in the cohort.

In addition, analysis using the NSQIP database has several important limitations. First, complications beyond postoperative day 30 are not captured, and orthopedic-specific outcomes, such as functional scores and range of motion data, were not available. Furthermore, albumin was the only nutritional marker available in the database; other common biomarkers, such as serum transferrin and total absolute lymphocyte count, were not measured. Despite this potential limitation, recent studies have suggested albumin is the preferred biomarker for poor nutrition.[14,42]

Finally, because TSA patients were identified from the NSQIP using CPT rather than ICD-9, patients with reverse TSA and anatomic TSA implants could not be differentiated. Although this is a disadvantage inherent to NSQIP, the benefits of having accurate, prospectively collected demographic, anthropometric, and comorbidity data outweighed the benefit of using a database based on ICD-9 codes, such as a Nationwide Inpatient Sample. The shortcomings of clinical outcomes research based on ICD-9-coded databases are well documented.[9,20] Interestingly, there is little disparity in short-term postoperative outcomes between reverse and anatomic TSA patients.[1,23]

Conclusion

Malnutrition is an important preoperative comorbidity to consider before shoulder arthroplasty, with an overall incidence of 7.6% in this shoulder arthroplasty cohort. Malnourished patients were at a significantly increased risk of anemia requiring transfusion (2.49), extended LOS (1.69), and death (OR, 1.88-173.98) within 30 days of surgery. In addition the prevalence of morbid obesity was greater in malnourished patients than in controls. Overall, shoulder arthroplasty patients with preoperative albumin levels <3.5 g/dL are at significantly higher risk for morbidity and death after surgery. Preoperative screening should be considered to identify this high-risk population.

Disclaimer

The 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. Aldinger PR, Raiss P, Rickert M, Loew M. Complications in shoulder arthroplasty: an analysis of 485 cases. Int Orthop 2010;34:517-24. http://dx.doi.org/10.1007/s00264-009-0780-7
2. Alphs HH, Zahurak ML, Bristow RE, Díaz-Montes TP. Predictors of surgical outcome and survival among elderly women diagnosed with ovarian and primary peritoneal cancer. Gynecol Oncol 2006;103:1048-53. http://dx.doi.org/10.1016/j.ygyno.2006.06.019
3. American College of Surgeons National Surgical Quality Improvement Program. User guide for the 2013 participant use data file; 2014. Available at: https://www.facs.org/quality-programs/acs-nsqip
4. Basques BA, Toy JO, Bohl DD, Golinvaux NS, Grauer JN. General compared with spinal anesthesia for total hip arthroplasty. J Bone Joint Surg Am 2015;97:455-61. http://dx.doi.org/10.2106/JBJS.N.00662
5. Beck JD, Irgit KS, Andreychik CM, Maloney PJ, Tang X, Harter GD. Reverse total shoulder arthroplasty in obese patients. J Hand Surg 2013;38:965-70. http://dx.doi.org/10.1016/j.jhsa.2013.02.025
6. Beiner JM, Grauer J, Kwon BK, Vaccaro AR. Postoperative wound infections of the spine. Neurosurg Focus 2003;15:1-5. http://dx.doi.org/10.3171/foc.2003.15.3.14
7. Bohl DD, Fu MC, Golinvaux NS, Basques BA, Gruskay JA, Grauer JN. The "July effect" in primary total hip and knee arthroplasty: analysis of 21,434 cases from the ACS-NSQIP database. J Arthroplasty 2014;29:1332-8. http://dx.doi.org/10.1016/j.arth.2014.02.008
8. Bohl DD, Basques BA, Golinvaux NS, Miller CP, Baumgaertner MR, Grauer JN. Extramedullary compared with intramedullary implants for intertrochanteric hip fractures: thirty-day outcomes of 4432 procedures from the ACS NSQIP database. J Bone Joint Surg Am 2014;96:1871-7. http://dx.doi.org/10.2106/JBJS.N.00041
9. Bohl DD, Russo GS, Basques BA, Golinvaux BA, Fu MC, Long WD 3rd, et al. Variations in data collection methods between national databases affect study results: a comparison of the Nationwide Inpatient Sample and National Surgical Quality Improvement Program databases for lumbar spine fusion procedures. J Bone Joint Surg Am 2014;96:e193. http://dx.doi.org/10.2106/JBJS.M.01490
10. Boitano LT, Wang EC, Kibbe MR. Differential effect of nutritional status on vascular surgery outcomes in a Veterans Affairs versus private hospital setting. Am J Surg 2012;204:e27-37. http://dx.doi.org/10.1016/j.amjsurg.2012.07.023
11. Bruun L, Bosaeus I, Bergstad L, Nygaard K. Prevalence of malnutrition in surgical patients: evaluation of nutritional support and documentation. Clin Nutr 1999;18:141-7. http://dx.doi.org/10.1016/S0261-5614(99)80003-X
12. Cereda E, Pusani C, Limonta D, Vanotti A. The association of geriatric nutritional risk index and total lymphocyte count with short-term nutrition-related complications in institutionalised elderly. J Am Coll Nutr 2008;27:406-13. http://dx.doi.org/10.1080/07315724.2008.10719718
13. Correia MITD, Waitzberg DL. The impact of malnutrition on morbidity, mortality, length of hospital stay and costs evaluated through a multivariate model analysis. Clin Nutr 2003;22:235-9. http://dx.doi.org/10.1016/S0261-5614(02)00215-7
14. Cross MB, Yi PH, Thomas CF, Garcia J, Della Valle CJ. Evaluation of malnutrition in orthopaedic surgery. J Am Acad Orthop Surg 2014;22:193-9. http://dx.doi.org/10.5435/JAAOS-22-03-193
15. d'Agostino RB. Tutorial in biostatistics: propensity score methods for bias reduction in the comparison of a treatment to a non-randomized control group. Stat Med 1998;17:2265-81.
16. Delgado-Rodriguez M, Medina-Cuadros M, Gómez-Ortega A, Martinez-Gallego G, Mariscal-Ortiz M, Martinez-Gonzalez MA, et al. Cholesterol and serum albumin levels as predictors of cross infection, death, and length of hospital stay. Arch Surg 2002;137:805-12. http://dx.doi.org/10.1001/archsurg.137.7.805
17. Fu MC, Buerba RA, Grauer JN. Preoperative nutritional status as an adjunct predictor of major postoperative complications following anterior cervical discectomy and fusion. J Spinal Disord Tech 2014; http://dx.doi.org/10.1097/BSD.0000000000000181. [Epub ahead of print].
18. Gherini S, Vaughn BK, Lombardi AV Jr, Mallory TH. Delayed wound healing and nutritional deficiencies after total hip arthroplasty. Clin Orthop Relat Res 1993;293:188.
19. Gibbs J, Cull W, Henderson W, Daley J, Hur K, Khuri SF. Preoperative serum albumin level as a predictor of operative mortality and morbidity: results from the national VA surgical risk study. Arch Surg 1999;134:36-42.
20. Golinvaux NS, Bohl DD, Basques BA, Fu MC, Gardner EC, Grauer JN. Limitations of administrative databases in spine research: a study in obesity. Spine J 2014;14:2923-8. http://dx.doi.org/10.1016/j.spinee.2014.04.025
21. Greene KA, Wilde AH, Stulberg BN. Preoperative nutritional status of total joint patients: relationship to postoperative wound complications. J Arthroplasty 1991;6:321-5.
22. 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. http://dx.doi.org/10.1016/j.jse.2013.12.027
23. Groh GI, Groh GM. Complications rates, reoperation rates, and the learning curve in reverse shoulder arthroplasty. J Shoulder Elbow Surg 2014;23:388-94. http://dx.doi.org/10.1016/j.jse.2013.06.002
24. Hu SS, Fontaine F, Kelly B, Bradford DS. Nutritional depletion in staged spinal reconstructive surgery: the effect of total parenteral nutrition. Spine 1998;23:1401-5.
25. Huang R, Greenky M, Kerr GJ, Austin MS, Parvizi J. The effect of malnutrition on patients undergoing elective joint arthroplasty. J Arthroplasty 2013;28:21-4. http://dx.doi.org/10.1016/j.arth.2013.05.038
26. Jaberi FM, Parvizi J, Haytmanek CT, Joshi A, Purtill J. Procrastination of wound drainage and malnutrition affect the outcome of joint arthroplasty. Clin Orthop Relat Res 2008;466:1368-71. http://dx.doi.org/10.1007/s11999-008-0214-7
27. Jensen JE, Jensen TG, Smith TK, Johnston DA, Dudrick SJ. Nutrition in orthopaedic surgery. J Bone Joint Surg Am 1982;64:1263-72.
28. Kaidar-Person O, Person B, Szomstein S, Rosenthal RJ. Nutritional deficiencies in morbidly obese patients: a new form of malnutrition? Obes Surg 2008;18:1028-34. http://dx.doi.org/10.1007/s11695-007-9350-5
29. Klein JD, Hey LA, Yu CS, Barbi KB, Coufal FJ, Young EP, et al. Perioperative nutrition and postoperative complications in patients undergoing spinal surgery. Spine 1996;21:2676-82.
30. Kuzuya M, Kanda S, Koike T, Suzuki Y, Iguchi A. Lack of correlation between total lymphocyte count and nutritional status in the elderly. Clin Nutr 2005;24:427-32. http://dx.doi.org/10.1016/j.clnu.2005.01.003

31. Lalueza M, Colomina M, Bago J, Clemente S, Godet C. Analysis of nutritional parameters in idiopathic scoliosis patients after major spinal surgery. Eur J Clin Nutr 2005;59:720-2. http://dx.doi.org/10.1038/sj.ejcn.1602126
32. Lawson R, Doshi M, Barton J, Cobden I. The effect of unselected post-operative nutritional supplementation on nutritional status and clinical outcome of orthopaedic patients. Clin Nutr 2003;22:39-46. http://dx.doi.org/10.1054/clnu.2002.0588
33. Lee H, Chang Y, Jean Y, Wang H. Importance of serum albumin level in the preoperative tests conducted in elderly patients with hip fracture. Injury 2009;40:756-9. http://dx.doi.org/10.1016/j.injury.2009.01.008
34. Li X, Williams PN, Nguyen JT, Craig EV, Warren RF, Gulotta LV. Functional outcomes after total shoulder arthroplasty in obese patients. J Bone Joint Surg Am 2013;95:e160. http://dx.doi.org/10.2106/JBJS.L.01145
35. Lieberman D, Friger M, Lieberman D. Inpatient rehabilitation outcome after hip fracture surgery in elderly patients: a prospective cohort study of 946 patients. Arch Phys Med Rehabil 2006;87:167-71. http://dx.doi.org/10.1016/j.apmr.2005.10.002
36. Linberg CJ, Sperling JW, Schleck CD, Cofield RH. Shoulder arthroplasty in morbidly obese patients. J Shoulder Elbow Surg 2009;18:903-6. http://dx.doi.org/10.1016/j.jse.2009.02.006
37. Mandelbaum BR, Tolo VT, McAfee PC, Burest P. Nutritional deficiencies after staged anterior and posterior spinal reconstructive surgery. Clin Orthop Relat Res 1988;234:5-11.
38. Miyanishi K, Jingushi S, Torisu T. Mortality after hip fracture in japan: the role of nutritional status. J Orthop Surg (Hong Kong) 2010;18:265-70.
39. Molnar MZ, Kovesdy CP, Bunnapradist S, Streja E, Mehrotra R, Krishnan M, et al. Associations of pretransplant serum albumin with post-transplant outcomes in kidney transplant recipients. Am J Transplant 2011;11:1006-15. http://dx.doi.org/10.1111/j.1600-6143.2011.03480.x
40. Mullen JO, Mullen NL. Hip fracture mortality: a prospective, multifactorial study to predict and minimize death risk. Clin Orthop Relat Res 1992;280:214-22.
41. Yi PH, Frank RM, Vann E, Sonn KA, Moric M, Della Valle CJ. Is potential malnutrition associated with septic failure and acute infection after revision total joint arthroplasty? Clin Orthop Relat Res 2015;473:175-82. http://dx.doi.org/10.1007/s11999-014-3685-8
42. Pruzansky JS, Bronson MJ, Grelsamer RP, Strauss E, Moucha CS. Prevalence of modifiable surgical site infection risk factors in hip and knee joint arthroplasty patients at an urban academic hospital. J Arthroplasty 2014;29:272-6. http://dx.doi.org/10.1016/j.arth.2013.06.019
43. Puskarich CL, Nelson CL, Nusbickel FR, Stroope HF. The use of two nutritional indicators in identifying long bone fracture patients who do and do not develop infections. J Orthop Res 1990;8:799-803.
44. Rai J, Gill SS, Kumar BR. The influence of preoperative nutritional status in wound healing after replacement arthroplasty. Orthopedics 2002;25:417-21.
45. Smith TK. Nutrition: Its relationship to orthopedic infections. Orthop Clin North Am 1991;22:373-7.
46. Stephenson GR, Moretti EW, El-Moalem H, Clavien PA, Tuttle-Newhall JE. Malnutrition in liver transplant patients: preoperative subjective global assessment is predictive of outcome after liver transplantation. Transplantation 2001;72:666-70.
47. Symeonidis PD, Clark D. Assessment of malnutrition in hip fracture patients: effects on surgical delay, hospital stay and mortality. Acta Orthop Belg 2006;72:420.
48. Via M. The malnutrition of obesity: micronutrient deficiencies that promote diabetes. ISRN Endocrinol 2012;2012:103472. http://dx.doi.org/10.5402/2012/103472
49. World Health Organization. 10 Facts on obesity. BMI classification. Available at: http://www.who.int/features/factfiles/obesity/facts/en/index.html. Accessed Jan 20, 2015.