JSES International 8 (2024) 152–158

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

The geriatric nutritional risk index as a strong predictor of adverse outcomes following total shoulder arthroplasty

Steven H. Liu, BS[a], Patricia Cerri-Droz, BS[a], Rachel A. Loyst, BS[a], Brandon Lung, MD[b], Kevin Kashanchi, MD[c], David E. Komatsu, PhD[d], Edward D. Wang, MD[d,*]

[a]Renaissance School of Medicine at Stony Brook University, Stony Brook, NY, USA
[b]Department of Orthopaedic Surgery, University of California Irvine, Orange, CA, USA
[c]Department of Orthopaedic Surgery, Keck School of Medicine of USC, Los Angeles, CA, USA
[d]Department of Orthopaedics, Stony Brook University, Stony Brook, NY, USA

A R T I C L E I N F O

Keywords:
Total shoulder arthroplasty
Malnutrition
Geriatric
Risk index
Complications
Postoperative

Level of Evidence: Level III; Retrospective Cohort Comparison Using Large Database; Prognosis Study

A B S T R A C T

Background: This study investigates the association between the Geriatric Nutritional Risk Index (GNRI), a simple readily available measure of malnutrition risk, and 30-day postoperative complications following total shoulder arthroplasty (TSA).

Methods: The American College of Surgeons National Surgical Quality Improvement Program database was queried for all patients who underwent TSA between 2015 and 2021. The study population was divided into 3 groups based on preoperative GNRI: normal/reference (GNRI > 98), moderate malnutrition (92 ≤ GNRI ≤ 98), and severe malnutrition (GNRI < 92). Logistic regression analysis was conducted to investigate the connection between preoperative GNRI and postoperative complications.

Results: Compared to normal nutrition, moderate malnutrition was independently significantly associated with a greater likelihood of any complications (odds ratio [OR]: 1.74, 95% confidence interval [CI]: 1.54-1.96; *P* < .001), blood transfusions (OR: 1.52, 95% CI: 1.09-2.11; *P* = .013), failure to wean off a ventilator within 48 hours (OR: 3.84, 95% CI: 1.26-11.72; *P* = .018), wound dehiscence (OR: 15.80, 95% CI: 1.61-155.28; *P* = .018), nonhome discharge (OR: 1.90, 95% CI: 1.63-2.22; *P* < .001), readmission (OR: 1.54, 95% CI: 1.19-1.99; *P* = .001), unplanned reoperation (OR: 1.87, 95% CI: 1.27-2.74; *P* = .001), length of stay > 2 days (OR: 1.85, 95% CI: 1.63-2.12; *P* < .001), and mortality (OR: 3.38, 95% CI: 1.32-8.71; *P* = .011). Severe malnutrition was independently significantly associated with a greater likelihood of any complication (OR: 3.33, 95% CI: 2.80-3.97; *P* < .001), sepsis (OR: 9.83, 95% CI: 2.94-32.85; *P* < .001), pneumonia (OR: 3.30, 95% CI: 1.71-6.38; *P* < .001), unplanned reintubation (OR: 5.77, 95% CI: 2.47-13.51; *P* < .001), urinary tract infection (OR: 2.15, 95% CI: 1.19-3.87; *P* = .011), stroke (OR: 3.57, 95% CI: 1.18-10.84; *P* = .024), blood transfusions (OR: 5.27, 95% CI: 3.86-7.20; *P* < .001), failure to wean off a ventilator within 48 hours (OR: 7.64, 95% CI: 2.29-25.55; *P* < .001), *Clostridioides difficile* infection (OR: 4.17, 95% CI: 1.21-14.32; *P* = .023), nonhome discharge (OR: 3.56, 95% CI: 2.92-4.34; *P* < .001), readmission (OR: 2.05, 95% CI: 1.46-2.89; *P* < .001), length of stay > 2 days (OR: 3.27, 95% CI: 2.73-3.92; *P* < .001), and mortality (OR: 4.61, 95% CI: 1.51-14.04; *P* = .007).

Conclusion: Malnutrition based on GNRI is a strong predictor of complications following TSA, with increasing severity related to an increased rate of complications.

As indications for total shoulder arthroplasty (TSA) broaden, technology progresses, and surgical techniques advance, an increasing number of geriatric patients will undergo the procedure.[2] TSA is effective in treating common conditions in the geriatric population such as osteoarthritis, helping restore movement and functionality, thereby improving patients' quality of life. Although postoperative complications remain relatively uncommon, they occur at a considerably higher rate in older patients and those with chronic health comorbidities such as obesity, cardiac disease, and immunosuppression.[9,25,29,40] In addition to factors related to patient history, preoperative laboratory abnormalities

Institutional review board approval was not required for this study.

*Corresponding author: Edward D. Wang, MD, Department of Orthopaedics, Stony Brook University Hospital, HSC T-18, Room 080, Stony Brook, NY 11794-8181, USA.
E-mail address: Edward.Wang@stonybrookmedicine.edu (E.D. Wang).

https://doi.org/10.1016/j.jseint.2023.08.022

such as hypoalbuminemia, anemia, thrombocytopenia, and thrombocytosis have been identified as factors associated with poorer outcomes following TSA.[6,7,11,22,24] In particular, malnutrition in the elderly has been recognized as an important predictor of increased length of stay (LOS) in the hospital and postoperative morbidity in both emergency and elective surgical procedures.[14,21,30]

Yet, despite the known relationship of malnutrition and poorer outcomes following orthopedic surgery, malnutrition remains under-recognized and untreated in geriatric patients.[41] Traditionally, low-serum products such as albumin and prealbumin have served as indicators for poor nutritional status, as they are routinely collected values and reflect protein synthesis.[23] However, hypoalbuminemia has not been found to be exclusively correlated with malnutrition.[13] It is now thought to be the consequence of inflammatory processes, acute trauma, or chronic disease, all of which have a higher incidence in the elderly.[13] Disagreement regarding the validity of using albumin as a proxy for total body nutrition has encouraged the utilization of indices that incorporate anthropometric values. One example is the development of the Geriatric Nutritional Risk Index (GNRI), which has allowed for the determination of nutrition-related risk in geriatric patients.[5] Using weight and standing height, the score is determined by the ratio of actual to ideal weight through use of the Lorentz formula and albumin concentration.[5,14]

Although similar surgical studies in colorectal and total joint arthroplasties (TJAs) have shown that GNRI serves as an effective risk-stratification tool for elderly patients, the extent to which geriatric malnutrition affects postoperative outcomes following TSA is unexplored.[14,21,34] This study sought to investigate the association between the increasing severity of GNRI, a measure of malnutrition risk, and 30-day postoperative complications following TSA. We aim to determine whether malnutrition estimated by GNRI is an independent predictor of adverse outcomes following TSA.

Materials and methods

We queried the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database for all patients who underwent TSA between 2015 and 2021. This study was exempt from approval by our University's Institutional Review Board because the NSQIP database is fully deidentified. Data in the NSQIP database are obtained from more than 600 hospitals in the United States and are collected by trained surgical clinical reviewers. The data are periodically audited to maintain high fidelity.

The Current Procedural Terminology code 23472 was used to identify 32,866 patients who underwent TSA between 2015 and 2021. The exclusion criteria inherent to the NSQIP database exclude all cases for patients aged less than 18 years. Seventeen thousand seventy one patients with missing height, weight, or preoperative albumin were excluded, leaving 15,795 patients. Next, 4384 cases were excluded for missing discharge destination, American Society of Anesthesiologists (ASA) classification, functional health status, or age < 65 years, leaving a total of 11,411 patients to be included in this study. GNRI was then calculated for each patient using the following formula, using weight in pounds.[5,14,21]

$$GNRI = (1.489 * Albumin) + \left(41.7 * \frac{Weight}{WLo}\right)$$

WLo is the ideal weight, calculated for male and female gender using the Lorentz equations, using height in centimeters.[5,14,21]

$$WLo_{male} = (Height - 100) + \frac{Height - 150}{4}$$

$$WLo_{female} = (Height - 100) - \frac{Height - 150}{2}$$

For patients with weight exceeding their ideal weight, the ratio of Weight/WLo was capped at 1.[14,21]

The remaining study population (Fig. 1) was then indexed into 3 cohorts based on their preoperative GNRI: normal/reference (GNRI > 98), moderate malnutrition (92 ≤ GNRI ≤ 98), and severe malnutrition (GNRI < 92). Validated cutoffs for GNRI were chosen based on pre-existing research.[14]

Variables collected in this study included patient demographics, comorbidities, surgical characteristics, and 30-day postoperative complication data. Patient demographics included gender, age, body mass index, functional status, ASA classification, smoking status, and preoperative steroid use. Steroid use status was defined as patients who routinely used immunosuppressants or corticosteroids within 30 days preprocedure. Smoking status was defined as cigarette use at any point within the past year before the procedure. Preoperative comorbidities included congestive heart failure (CHF), diabetes, hypertension, severe chronic obstructive pulmonary disease (COPD), bleeding disorders, and disseminated cancer. Thirty-day complications included the following: sepsis, septic shock, pneumonia, unplanned reintubation, urinary tract infection (UTI), cardiac arrest or myocardial infarction (MI), stroke, blood transfusions, deep vein thrombosis, pulmonary embolism, on ventilator > 48 hours, surgical space infection (SSI), wound dehiscence, acute renal failure, *Clostridioides difficile* (*C. diff*) infection, nonhome discharge, readmission, unplanned reoperation, LOS > 2 days, and mortality.

All statistical analyses were conducted using SPSS Software version 26.0 (IBM Corp., Armonk, NY, USA). Patient demographics and comorbidities were compared between cohorts using bivariate logistic regression. Multivariate logistic regression, adjusted for all significantly associated patient demographics and comorbidities for the respective cohort, was used to identify associations between preoperative GNRI and postoperative complications. Odds ratios (ORs) were reported with 95% confidence intervals (CIs). The level of statistical significance was set at $P < .05$.

Results

Compared to the normal nutrition group, the moderate malnutrition group was significantly associated with female gender ($P < .001$), older age groups ($P < .001$), greater body mass index groups ($P < .001$), dependent functional status ($P = .007$), ASA classification ≥ 3 ($P < .001$), smokers ($P = .034$), comorbid CHF ($P = .001$), diabetes ($P < .001$), COPD ($P < .001$), and bleeding disorders ($P < .001$) (Table I). Compared to the normal nutrition group, the severe malnutrition group was significantly associated with female gender ($P < .001$), older age groups ($P < .001$), dependent functional status ($P < .001$), ASA classification ≥ 3 ($P < .001$), smokers ($P = .011$), chronic steroid use ($P < .001$), comorbid CHF ($P < .001$), diabetes ($P < .001$), COPD ($P < .001$), bleeding disorders ($P < .001$), and disseminated cancer ($P < .001$).

Compared to the normal nutrition group, the moderate malnutrition group was significantly associated with any complication ($P < .001$), unplanned reintubation ($P = .018$), cardiac arrest or MI ($P = .016$), blood transfusions ($P < .001$), failure to wean off a ventilator within 48 hours ($P = .007$), wound dehiscence ($P = .017$), nonhome discharge ($P < .001$), readmission ($P < .001$), unplanned reoperation ($P < .001$), LOS > 2 days ($P < .001$), and mortality

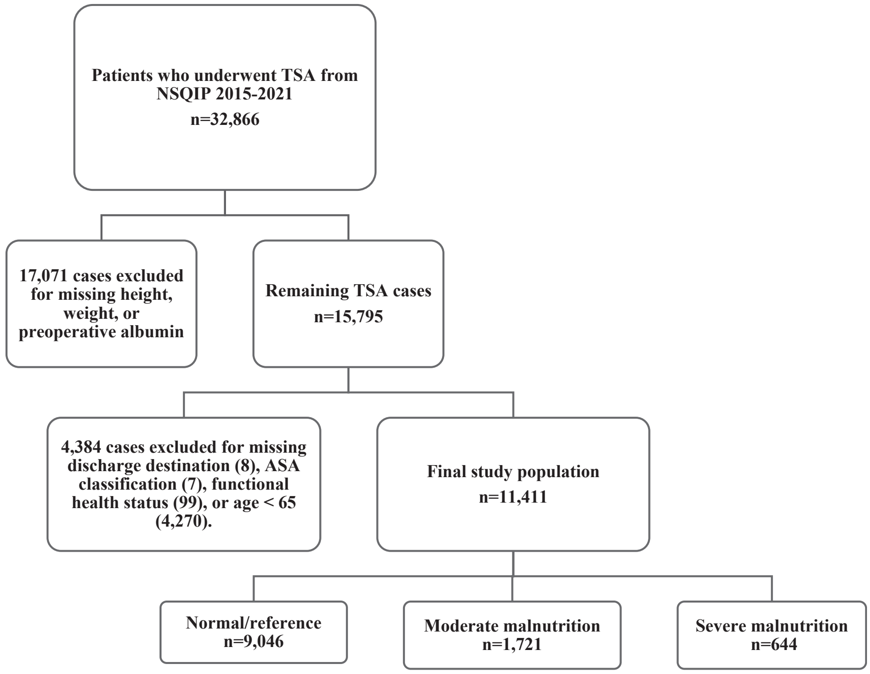

Figure 1 Case selection schematic. *TSA*, total shoulder arthroplasty; *NSQIP*, National Surgical Quality Improvement Program; *ASA*, American Society of Anesthesiologists.

Table I
Patient demographics and comorbidities for patients with preoperative normal GNRI, moderate malnutrition, and severe malnutrition.

Patient factor	Normal (GNRI > 98)	Moderate malnutrition ($92 \leq$ GNRI ≤ 98)		Severe malnutrition (GNRI < 92)	
	Number (%)	Number (%)	*P* value	Number (%)	*P* value
Overall	9046 (100.0)	1721 (100.0)		644 (100.0)	
Gender			**< .001**		**< .001**
Female	5246 (58.0)	1091 (63.4)		462 (71.7)	
Male	3800 (42.0)	630 (36.6)		182 (28.3)	
Age			**< .001**		**< .001**
65-74	2630 (29.1)	402 (23.4)		141 (21.9)	
75-84	4891 (54.1)	908 (52.8)		310 (48.1)	
≥ 85	1525 (16.9)	411 (23.9)		193 (30.0)	
BMI (kg/m^2)			**< .001**		.102
< 18.5	57 (0.6)	11 (0.6)		17 (2.6)	
18.5-29.9	4561 (50.4)	782 (45.4)		299 (46.4)	
30-34.9	2415 (26.7)	451 (26.2)		170 (26.4)	
35-39.9	1253 (13.9)	269 (15.6)		76 (11.8)	
≥ 40	760 (8.4)	208 (12.1)		82 (12.7)	
Functional status prior to surgery			**.007**		**< .001**
Dependent	209 (2.3)	59 (3.4)		67 (10.4)	
Independent	8837 (97.7)	1662 (96.6)		577 (89.6)	
ASA classification			**< .001**		**< .001**
≤ 2	3474 (38.4)	502 (29.2)		124 (19.3)	
≥ 3	5572 (61.6)	1219 (70.8)		520 (80.7)	
Smoker			**.034**		**.011**
No	8501 (94.0)	1594 (92.6)		589 (91.5)	
Yes	545 (6.0)	127 (7.4)		55 (8.5)	
Steroid use			.17		**< .001**
No	8568 (94.7)	1616 (93.9)		574 (89.1)	
Yes	478 (5.3)	105 (6.1)		70 (10.9)	
Comorbidities					
CHF	116 (1.3)	40 (2.3)	**.001**	30 (4.7)	**< .001**
Diabetes	1710 (18.9)	394 (22.9)	**< .001**	175 (27.2)	**< .001**
Hypertension	6556 (72.5)	1261 (73.3)	.497	483 (75)	.165
COPD	596 (6.6)	179 (10.4)	**< .001**	92 (14.3)	**< .001**
Bleeding disorder	246 (2.7)	80 (4.6)	**< .001**	41 (6.4)	**< .001**
Disseminated cancer	23 (0.3)	8 (0.5)	.141	8 (1.2)	**< .001**

GNRI, Geriatric Nutritional Risk Index; *BMI*, body mass index; *ASA*, American Society of Anesthesiologists; *CHF*, congestive heart failure; *COPD*, chronic obstructive pulmonary disease.
Bold *P* values indicate statistical significance with $P < .05$.

Table II
Bivariate analysis of 30-day postoperative complications in patients with preoperative normal GNRI, moderate malnutrition, and severe malnutrition.

Complication	Normal (GNRI > 98)	Moderate malnutrition (92 ≤ GNRI ≤ 98)		Severe malnutrition (GNRI < 92)	
	Number (%)	Number (%)	*P* value	Number (%)	*P* value
Any complication	1698 (18.8)	552 (32.1)	**< .001**	337 (52.3)	**< .001**
Sepsis	8 (0.1)	1 (0.1)	.692	5 (0.8)	**< .001**
Septic shock	7 (0.1)	3 (0.2)	.239	2 (0.3)	.083
Pneumonia	49 (0.5)	14 (0.8)	.178	13 (2.0)	**< .001**
Unplanned reintubation	18 (0.2)	9 (0.5)	**.018**	8 (1.2)	**< .001**
UTI	67 (0.7)	16 (0.9)	.412	16 (2.5)	**< .001**
Cardiac arrest or MI	24 (0.3)	11 (0.6)	**.016**	6 (0.9)	**.006**
Stroke	12 (0.1)	0 (0.0)	.999	5 (0.8)	**< .001**
Blood transfusions	148 (1.6)	52 (3.0)	**< .001**	73 (11.3)	**< .001**
DVT	26 (0.3)	7 (0.4)	.414	3 (0.5)	.428
PE	18 (0.2)	6 (0.3)	.234	2 (0.3)	.550
On ventilator > 48 hours	7 (0.1)	6 (0.3)	**.007**	5 (0.8)	**< .001**
SSI	32 (0.4)	8 (0.5)	.489	2 (0.3)	.858
Wound dehiscence	1 (0.0)	3 (0.2)	**.017**	1 (0.2)	.062
Acute renal failure	5 (0.1)	1 (0.1)	.964	0 (0.0)	.999
Clostridioides difficile infection	10 (0.1)	4 (0.2)	.209	4 (0.6)	**.004**
Nonhome discharge	763 (8.4)	304 (17.7)	**< .001**	214 (33.2)	**< .001**
Readmission	248 (2.7)	83 (4.8)	**< .001**	46 (7.1)	**< .001**
Unplanned reoperation	100 (1.1)	38 (2.2)	**< .001**	14 (2.2)	**.017**
LOS > 2 days	1178 (13.0)	425 (24.7)	**< .001**	268 (41.6)	**< .001**
Mortality	10 (0.1)	8 (0.5)	**.002**	5 (0.8)	**< .001**

GNRI, Geriatric Nutritional Risk Index; *UTI*, urinary tract infection; *MI*, myocardial infarction; *DVT*, deep vein thrombosis; *PE*, pulmonary embolism; *SSI*, surgical space infection; *LOS*, length of stay.
Bold *P* values indicate statistical significance with *P* < .05.

(*P* = .002) (Table II). Compared to the normal nutrition group, the severe malnutrition group was significantly associated with any complication (*P* < .001), sepsis (*P* < .001), pneumonia (*P* < .001), unplanned reintubation (*P* < .001), UTI (*P* < .001), cardiac arrest or MI (*P* = .006), stroke (*P* < .001), blood transfusions (*P* < .001), failure to wean off a ventilator within 48 hours (*P* < .001), *C. diff* infection (*P* = .004), nonhome discharge (*P* < .001), readmission (*P* < .001), unplanned reoperation (*P* = .017), LOS > 2 days (*P* < .001), and mortality (*P* < .001).

After controlling for all significant patient demographic and comorbidity factors, an adjusted multivariate regression analysis was conducted (Table III). Compared to the normal nutrition group, the moderate malnutrition group was independently significantly associated with a greater likelihood of any complications (OR: 1.74, 95% CI: 1.54-1.96; *P* < .001), blood transfusions (OR: 1.52, 95% CI: 1.09-2.11; *P* = .013), failure to wean off a ventilator within 48 hours (OR: 3.84, 95% CI: 1.26-11.72; *P* = .018), wound dehiscence (OR: 15.80, 95% CI: 1.61-155.28; *P* = .018), nonhome discharge (OR: 1.90, 95% CI: 1.63-2.22; *P* < .001), readmission (OR: 1.54, 95% CI: 1.19-1.99; *P* = .001), unplanned reoperation (OR: 1.87, 95% CI: 1.27-2.74; *P* = .001), LOS > 2 days (OR: 1.85, 95% CI: 1.63-2.12; *P* < .001), and mortality (OR: 3.38, 95% CI: 1.32-8.71; *P* = .011). The severe malnutrition group was independently significantly associated with a greater likelihood of any complication (OR: 3.33, 95% CI: 2.80-3.97; *P* < .001), sepsis (OR: 9.83, 95% CI: 2.94-32.85; *P* < .001), pneumonia (OR: 3.30, 95% CI: 1.71-6.38; *P* < .001), unplanned reintubation (OR: 5.77, 95% CI: 2.47-13.51; *P* < .001), UTI (OR: 2.15, 95% CI: 1.19-3.87; *P* = .011), stroke (OR: 3.57, 95% CI: 1.18-10.84; *P* = .024), blood transfusions (OR: 5.27, 95% CI: 3.86-7.20; *P* < .001), failure to wean off a ventilator within 48 hours (OR: 7.64, 95% CI: 2.29-25.55; *P* < .001), *C. diff* infection (OR: 4.17, 95% CI: 1.21-14.32; *P* = .023), nonhome discharge (OR: 3.56, 95% CI: 2.92-4.34; *P* < .001), readmission (OR: 2.05, 95% CI: 1.46-2.89; *P* < .001), LOS > 2 days (OR: 3.27, 95% CI: 2.73-3.92; *P* < .001), and mortality (OR: 4.61, 95% CI: 1.51-14.04; *P* = .007).

In general, compared to the normal nutrition group, severe malnutrition was independently significantly associated with a greater number of complications than moderate malnutrition. Moreover, for complications independently significantly associated with both moderate and severe malnutrition, severe malnutrition was generally found to have stronger associations: any complication (OR: 3.33 in severe malnutrition vs. 1.74 in moderate malnutrition), blood transfusions (OR: 5.27 vs. 1.52), failure to wean off a ventilator within 48 hours (OR: 7.64 vs. 3.84), nonhome discharge (OR: 3.56 vs. 1.90), readmission (OR: 2.05 vs. 1.54), LOS > 2 days (OR: 3.27 vs. 1.85), and mortality (OR: 4.61 vs. 3.38).

Discussion

It is understood that undetected and misdiagnosed abnormalities within the elderly increase morbidity and mortality.[32,37] In the setting of TSA, advanced age, health comorbidities such as obesity, cardiac disease, and immunosuppression, and preoperative laboratory abnormalities such as hypoalbuminemia, anemia, thrombocytopenia, and thrombocytosis are factors associated with poorer outcomes postoperatively.[6,7,9,11,22,24,25,29,40] In this study, we investigated patients' degree of malnutrition based on GNRI as a risk factor for postoperative complications in geriatric patients undergoing TSA. We found that several complications associated with malnutrition were moderate to life-threatening postoperative complications, including sepsis, pneumonia, unplanned reintubation, UTI, cardiac arrest or MI, stroke, blood transfusions, failure to wean off a ventilator within 48 hours, C. *diff* infection, nonhome discharge, readmission, unplanned reoperation, LOS > 2 days, and mortality. Admission for elective surgeries, such as TSA, exposes the patients to postoperative risks associated with surgery and hospitalization. This study emphasizes the utility of GNRI in older adults as a strong predictor of outcomes following TSA.

Malnutrition is a pertinent comorbidity in the geriatric adult that may negatively affect postoperative outcomes, increase recurrence of hospitalization, and reduce the overall quality of life.

Table III
Multivariate analysis of 30-day postoperative complications in patients with preoperative normal GNRI, moderate malnutrition, and severe malnutrition. Dashes represent associations not significant in bivariate analysis and were not included in multivariate analysis.

Complication	Moderate malnutrition (92 ≤ GNRI ≤ 98)	Severe malnutrition (GNRI < 92)
	OR, *P* value (95% CI)	OR, *P* value (95% CI)
Any complication	1.74, < **.001** (1.54-1.96)	3.33, < **.001** (2.80-3.97)
Sepsis	.81, .844 (.10-6.53)	9.83, < **.001** (2.94-32.85)
Pneumonia	–	3.30, < **.001** (1.71-6.38)
Unplanned reintubation	2.25, .050 (1.00-5.06)	5.77, < **.001** (2.47-13.51)
UTI	–	2.15, **.011** (1.19-3.87)
Cardiac arrest or MI	2.05, .052 (0.99-4.23)	–
Stroke	–	3.57, **.024** (1.18-10.84)
Blood transfusions	1.52, **.013** (1.09-2.11)	5.27, < **.001** (3.86-7.20)
On ventilator > 48 hours	3.84, **.018** (1.26-11.72)	7.64, < **.001** (2.29-25.55)
Wound dehiscence	15.80, **.018** (1.61-155.28)	5.94, .246 (.29-120.12)
Clostridioides difficile infection	–	4.17, **.023** (1.21-14.32)
Nonhome discharge	1.90, < **.001** (1.63-2.22)	3.56, < **.001** (2.92-4.34)
Readmission	1.54, **.001** (1.19-1.99)	2.05, < **.001** (1.46-2.89)
Unplanned reoperation	1.87, **.001** (1.27-2.74)	1.58, .142 (.86-2.89)
LOS > 2 days	1.85, < **.001** (1.63-2.12)	3.27, < **.001** (2.73-3.92)
Mortality	3.38, **.011** (1.32-8.71)	4.61, **.007** (1.51-14.04)

GNRI, Geriatric Nutritional Risk Index; *OR*, odds ratio; *CI*, confidence interval; *UTI*, urinary tract infection; *MI*, myocardial infarction; *LOS*, length of stay.
Bold *P* values indicate statistical significance with *P* < .05.

The impact of malnutrition on postoperative morbidity and mortality in older adults is well defined, highlighting the greater need for reliable preoperative indices that can encourage informed choices and suitable postoperative outcomes in geriatric patients. Serum albumin level < 3.5 g/dL has often been used to classify malnutrition in geriatric patients.[5] Studies in TJA have successfully used low albumin levels as a predictor for adverse outcomes.[3,4] However, when stratifying their cohort of 181 patients based on albumin levels, an early study on GNRI found that if malnutrition had been determined by albumin, only 65% of the patients identified by GNRI would have been classified.[5] It was further postulated that hydration status of the patient can confound the predictive capacity of albumin.[5] In addition, levels of albumin are often influenced heavily by conditions unrelated to malnutrition, such as end-stage renal disease and severe proteinuria.[15] As a result, malnutrition risk questionnaires such as the Mini Nutritional Assessment (MNA) emerged. MNA is frequently used for those aged more than 70 years; however, it does not incorporate patient-derived serological values.[18] Although MNA has been efficacious in geriatric nutrition evaluation studies, its dependence on neuropsychiatric stability and consciousness and lack of serum data has proven to be a weakness for the assessment, particularly in its short form.[17,18,39] The development of GNRI aimed to consider both serum and anthropometric values and is an objective measurement unaffected by the consciousness level of elderly adults.[5] GNRI has displayed reliability and validity comparable to established nutritional assessments; notably, poor prognosis following orthopedic surgeries was most effectively predicted by GNRI scores.[16] Furthermore, studies support the use of GNRI in cases where questionnaires such as MNA cannot be performed, even encouraging the use of both assessments to allow for more accurate results.[12]

The mechanism of malnutrition in the elderly population is multifactorial in nature.[35] An older adult's ability to properly access, consume, and absorb nutrients may be limited by malignancy, chronic disease, psychological disturbances, cognitive deterioration, and socioeconomic factors.[33] Accordingly, the present study found that along with greater age, comorbid disease, including CHF, COPD, diabetes, cancer, and bleeding disorders were significantly associated with malnutrition. In addition, females were more susceptible to malnutrition, comprising 63.4% and 71.7% of moderate and severe GNRI scores, respectively. A study of GNRI as a predictive tool before TJA found that 64.7% of severe GNRI scores belonged to females.[14] Another study of hospitalized elderly females found that 63.9% were at risk of malnutrition or were experiencing malnutrition, proposing the negative influence of socioeconomic differences and increased depressive states.[28] Outside of disease, greater age in general exerts gradual yet dramatic effects on nutrition. Poor physical functionality hinders the ability for elderly individuals to maintain muscle mass, leading to progressive muscle catabolism, a common process in aging.[19]

Malnutrition may lead to impaired immune function, promoting persistent infection and inflammation, as well as disrupting the wound healing process. In particular, protein-energy malnutrition leads to disfunction in cell-mediated defense.[8] This may explain many infectious complications following TSA, including sepsis, pneumonia, *C. diff* infection, and UTI. A similar study of GNRI in TJA supported these findings, reporting severe malnutrition to be associated with pneumonia, UTI, SSI, and sepsis.[14] Similar infection-related complications were also described in geriatric patients with severe GNRI following emergency surgery, including SSI, UTI, pneumonia, and sepsis.[21] Although rates of infection-associated complications remain low following TSA, infection may complicate wound healing, surgical success, and increase risk of reoperation in orthopedic surgery.[10,38]

We found that any degree of predicted malnutrition was associated with cardiovascular complications such as blood transfusion, cardiac arrest or MI, and stroke following TSA. Elderly adults are more likely to suffer from cardiovascular conditions that may alter nutritional status, including cardiac cachexia.[1] In a study of geriatric patients with stable coronary artery disease, GNRI detected malnutrition in 31.2% of the population.[27] In orthopedic literature, a study of patients undergoing TJA using serum albumin to detect malnutrition found that patients with malnutrition had increased risk of developing postoperative cardiovascular complications.[20,36]

Moreover, we found respiratory complications, including failing to wean off the ventilator and unplanned reintubation, to be significantly associated with malnutrition. Other surgery literature has similarly reported that malnutrition increases the likelihood of respiratory complications following operation in geriatric patients.[21,26] This may be explained by established evidence that malnutrition is linked to respiratory decline, secondary to respiratory muscular weakness and susceptibility to infection.

The significantly associated complications described in this study all hold the potential to increase LOS and promote readmission. Moreover, they may lead to mortality in elderly patients. Although mortality was found to be associated with malnutrition within this study, it is important to highlight that it remains extremely uncommon in TSA, occurring at rates as low as 0.09% in admitted patients.[31]

To our knowledge, this is the first study to describe the relationship between GNRI and complications following TSA. There are several limitations encountered by this study. The American College of Surgeons National Surgical Quality Improvement Program database is constrained by a 30-day postoperative period, hindering consideration of long-term complications, readmission, and mortality. Furthermore, a proportion of cases were excluded for missing albumin or weight values required to calculate GNRI. Serum albumin may not always be routinely obtained preoperatively, particularly if a patient is considered clinically low risk. Therefore, there may exist some degree of selection bias in our study.

GNRI is a simple measure that has the potential to allow orthopedic surgeons to detect otherwise undetected cases of malnutrition, accurately assess nutritional status, and anticipate potential complications following surgical procedures. Most importantly, the presence of malnutrition can encourage the implementation of corrective and preventative actions to improve outcomes. Based on the degree of malnutrition and other associated comorbidities, individualized responses such as improvement of diet and greater supplementation can promote better chances for a successful operation.

Conclusion

Among geriatric patients with predicted malnutrition based on GNRI, the overall rate of complication following TSA was found to increase with increasing severity of malnutrition. Compared to normal nutrition, moderate malnutrition was independently significantly associated with a greater likelihood of any complications, blood transfusions, failure to wean off a ventilator within 48 hours, wound dehiscence, nonhome discharge, readmission, unplanned reoperation, LOS > 2 days, and mortality. Severe malnutrition was independently significantly associated with a greater likelihood of any complication, sepsis, pneumonia, unplanned reintubation, UTI, stroke, blood transfusions, failure to wean off a ventilator within 48 hours, *C. diff* infection, nonhome discharge, readmission, LOS > 2 days, and mortality. These findings suggest that GNRI is a powerful predictor of 30-day postoperative complications following TSA in geriatric patients. Our study supports the utility of GNRI as an adjunctive tool in the risk stratification of geriatric patients undergoing TSA to reduce postoperative adverse events, minimize hospital stay, and promote favorable patient outcomes.

Disclaimers:

Funding: No funding was disclosed by the authors.
Conflicts of interest: The authors, their immediate families, and any research foundation 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. Bergstrom J, Lindholm B. Malnutrition, cardiac disease, and mortality: an integrated point of view. Am J Kidney Dis 1998;32:834-41.
2. 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/j.jse.2020.08.010.
3. Black CS, Goltz DE, Ryan SP, Fletcher AN, Wellman SS, Bolognesi MP, et al. The role of malnutrition in ninety-day outcomes after total joint arthroplasty. J Arthroplasty 2019;34:2594-600. https://doi.org/10.1016/j.arth.2019.05.060.
4. Bohl DD, Shen MR, Kayupov E, Cvetanovich GL, Della Valle CJ. Is hypoalbuminemia associated with septic failure and acute infection after Revision total joint arthroplasty? A study of 4517 patients from the National Surgical Quality Improvement Program. J Arthroplasty 2016;31:963-7. https://doi.org/10.1016/j.arth.2015.11.025.
5. Bouillanne O, Morineau G, Dupont C, Coulombel I, Vincent JP, Nicolis I, et al. Geriatric Nutritional Risk index: a new index for evaluating at-risk elderly medical patients. Am J Clin Nutr 2005;82:777-83. https://doi.org/10.1093/ajcn/82.4.777.
6. Burns KA, Robbins LM, LeMarr AR, Fortune K, Morton DJ, Wilson ML. Modifiable risk factors increase length of stay and 90-day cost of care after shoulder arthroplasty. J Shoulder Elbow Surg 2022;31:2-7. https://doi.org/10.1016/j.jse.2021.08.010.
7. Buzney CD, Zhong H, Gulotta LV, Memtsoudis SG, Liu J. Is there synergistic effect between obesity and hypoalbuminemia on postoperative outcomes among primary total shoulder arthroplasty recipients? HSS J 2022;18:504-11. https://doi.org/10.1177/15563316221083251.
8. Chandra RK. Nutrition and the immune system: an introduction. Am J Clin Nutr 1997;66:460S-3S.
9. Devana SK, Shah AA, Lee C, Gudapati V, Jensen AR, Cheung E, et al. Development of a machine learning algorithm for prediction of complications and unplanned readmission following reverse total shoulder arthroplasty. J Shoulder Elb Arthroplast 2021;5:24715492211038172. https://doi.org/10.1177/24715492211038172.
10. Dickhaut SC, DeLee JC, Page CP. Nutritional status: importance in predicting wound-healing after amputation. J Bone Joint Surg Am 1984;66:71-5.
11. Doan MK, Pollock JR, Moore ML, Hassebrock JD, Makovicka JL, Tokish JM, et al. Increasing severity of anemia is associated with poorer 30-day outcomes for total shoulder arthroplasty. JSES Int 2021;5:360-4. https://doi.org/10.1016/j.jseint.2021.02.001.
12. Duran Alert P, Mila Villarroel R, Formiga F, Virgili Casas N, Vilarasau Farre C. Assessing risk screening methods of malnutrition in geriatric patients: Mini Nutritional Assessment (MNA) versus geriatric nutritional risk index (GNRI). Nutr Hosp 2012;27:590-8. https://doi.org/10.1590/S0212-16112012000200036.
13. Evans DC, Corkins MR, Malone A, Miller S, Mogensen KM, Guenter P, et al. The use of visceral proteins as nutrition markers: an ASPEN position paper. Nutr Clin Pract 2021;36:22-8. https://doi.org/10.1002/ncp.10588.
14. Fang CJ, Saadat GH, Butler BA, Bokhari F. The geriatric nutritional risk index is an independent predictor of adverse outcomes for total joint arthroplasty patients. J Arthroplasty 2022;37:S836-41. https://doi.org/10.1016/j.arth.2022.01.049.
15. Gama-Axelsson T, Heimburger O, Stenvinkel P, Barany P, Lindholm B, Qureshi AR. Serum albumin as predictor of nutritional status in patients with ESRD. Clin J Am Soc Nephrol 2012;7:1446-53. https://doi.org/10.2215/CJN.10251011.
16. Gong J, Zuo S, Zhang J, Li L, Yin J, Li X, et al. Comparison of four nutritional screening tools in perioperative elderly patients: taking orthopedic and neurosurgical patients as examples. Front Nutr 2023;10:1081956. https://doi.org/10.3389/fnut.2023.1081956.
17. Griep MI, Mets TF, Collys K, Ponjaert-Kristoffersen I, Massart DL. Risk of malnutrition in retirement homes elderly persons measured by the “mini-nutritional assessment”. J Gerontol A Biol Sci Med Sci 2000;55:M57-63.
18. Guigoz Y, Lauque S, Vellas BJ. Identifying the elderly at risk for malnutrition. The Mini Nutritional Assessment. Clin Geriatr Med 2002;18:737-57. https://doi.org/10.1016/s0749-0690(02)00059-9.
19. Hickson M. Malnutrition and ageing. Postgrad Med J 2006;82:2-8. https://doi.org/10.1136/pgmj.2005.037564.
20. 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. https://doi.org/10.1016/j.arth.2013.05.038.
21. Jia Z, El Moheb M, Nordestgaard A, Lee JM, Meier K, Kongkaewpaisan N, et al. The geriatric nutritional risk index is a powerful predictor of adverse outcome in the elderly emergency surgery patient. J Trauma Acute Care Surg 2020;89:397-404. https://doi.org/10.1097/TA.0000000000002741.
22. Kashanchi KI, Nazemi AK, Komatsu DE, Wang ED. The impact of preoperative anemia on complications after total shoulder arthroplasty. J Am Acad Orthop Surg Glob Res Rev 2021;5. https://doi.org/10.5435/JAAOSGlobal-D-20-00136.
23. Keller U. Nutritional laboratory markers in malnutrition. J Clin Med 2019;8:775. https://doi.org/10.3390/jcm8060775.
24. Kim M, Ling K, Nazemi A, Tantone R, Kashanchi K, Lung B, et al. Abnormal preoperative platelet count may predict postoperative complications following shoulder arthroplasty. JSES Int 2022;6:935-41. https://doi.org/10.1016/j.jseint.2022.06.008.
25. Koh J, Galvin JW, Sing DC, Curry EJ, Li X. Thirty-day complications and readmission rates in elderly patients after shoulder arthroplasty. J Am Acad Orthop Surg Glob Res Rev 2018;2:e068. https://doi.org/10.5435/JAAOSGlobal-D-18-00068.

26. Kregel HR, Murphy PB, Attia M, Meyer DE, Morris RS, Onyema EC, et al. The Geriatric Nutritional Risk Index as a predictor of complications in geriatric trauma patients. J Trauma Acute Care Surg 2022;93:195-9. https://doi.org/10.1097/TA.0000000000003588.
27. Kunimura A, Ishii H, Uetani T, Aoki T, Harada K, Hirayama K, et al. Impact of Geriatric Nutritional Risk Index on cardiovascular outcomes in patients with stable coronary artery disease. J Cardiol 2017;69:383-8. https://doi.org/10.1016/j.jjcc.2016.09.004.
28. Larburu N, Artola G, Kerexeta J, Caballero M, Ollo B, Lando CM. Key factors and AI-based risk prediction of malnutrition in hospitalized older women. Geriatrics (Basel) 2022;7. https://doi.org/10.3390/geriatrics7050105.
29. Ling K, Kim M, Nazemi A, Smolev E, Komatsu DE, Wang ED. Chronic steroid use and readmission following total shoulder arthroplasty. JSES Int 2022;6:775-80. https://doi.org/10.1016/j.jseint.2022.06.006.
30. Martinez-Escribano C, Arteaga Moreno F, Perez-Lopez M, Cunha-Perez C, Belenguer-Varea A, Cuesta Peredo D, et al. Malnutrition and increased risk of adverse outcomes in elderly patients undergoing elective colorectal cancer surgery: a case-control study nested in a cohort. Nutrients 2022;14:207. https://doi.org/10.3390/nu14010207.
31. McCormick F, Nwachukwu BU, Kiriakopoulos EB, Schairer WW, Provencher MT, Levy J. In-hospital mortality risk for total shoulder arthroplasty: a comprehensive review of the medicare database from 2005 to 2011. Int J Shoulder Surg 2015;9:110-3. https://doi.org/10.4103/0973-6042.167938.
32. Partridge JS, Dhesi JK, Cross JD, Lo JW, Taylor PR, Bell R, et al. The prevalence and impact of undiagnosed cognitive impairment in older vascular surgical patients. J Vasc Surg 2014;60:1002-1011.e3. https://doi.org/10.1016/j.jvs.2014.04.041.
33. Saka B, Kaya O, Ozturk GB, Erten N, Karan MA. Malnutrition in the elderly and its relationship with other geriatric syndromes. Clin Nutr 2010;29:745-8. https://doi.org/10.1016/j.clnu.2010.04.006.
34. Sasaki M, Miyoshi N, Fujino S, Ogino T, Takahashi H, Uemura M, et al. The Geriatric Nutritional Risk Index predicts postoperative complications and prognosis in elderly patients with colorectal cancer after curative surgery. Sci Rep 2020;10, 10744. https://doi.org/10.1038/s41598-020-67285-y.
35. Saunders J, Smith T. Malnutrition: causes and consequences. Clin Med (Lond) 2010;10:624-7. https://doi.org/10.7861/clinmedicine.10-6-624.
36. Schwartz AM, Wilson JM, Farley KX, Bradbury TL Jr, Guild GN 3rd. Concomitant malnutrition and frailty are uncommon, but significant risk factors for mortality and complication following primary total knee arthroplasty. J Arthroplasty 2020;35:2878-85. https://doi.org/10.1016/j.arth.2020.05.062.
37. Skinner TR, Scott IA, Martin JH. Diagnostic errors in older patients: a systematic review of incidence and potential causes in seven prevalent diseases. Int J Gen Med 2016;9:137-46. https://doi.org/10.2147/IJGM.S96741.
38. Smith TK. Prevention of complications in orthopedic surgery secondary to nutritional depletion. Clin Orthop Relat Res 1987:91-7.
39. Trampisch US, Pourhassan M, Daubert D, Volkert D, Wirth R. Interrater reliability of routine screening for risk of malnutrition with the Mini Nutritional Assessment short-form in hospital. Eur J Clin Nutr 2022;76:1111-6. https://doi.org/10.1038/s41430-022-01080-y.
40. White CA, Duey A, Zaidat B, Li T, Quinones A, Cho SK, et al. Does age at surgery influence short-term outcomes and readmissions following anatomic total shoulder arthroplasty? J Orthop 2023;37:69-74. https://doi.org/10.1016/j.jor.2023.02.007.
41. Zhang Z, Pereira SL, Luo M, Matheson EM. Evaluation of blood biomarkers associated with risk of malnutrition in older adults: a systematic review and meta-analysis. Nutrients 2017;9. https://doi.org/10.3390/nu9080829.