The Geriatric Nutritional Risk Index is a powerful predictor of adverse outcome in the elderly emergency surgery patient

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BACKGROUND: The degree to which malnutrition impacts perioperative outcomes in the elderly emergency surgery (ES) patient remains unknown. We aimed to study the relationship between malnutrition, as measured by the Geriatric Nutritional Risk Index (GNRI), and postoperative outcomes in elderly patients undergoing ES.

METHODS: Using the 2007 to 2016 American College of Surgeons National Surgical Quality Improvement Program database, all patients 65 years or older undergoing ES were included in our study. The GNRI, defined as (1.489 × albumin [g/L]) + (41.7 × [weight/ideal weight]) was calculated for each patient in the database. Patients with missing height, weight, or preoperative albumin data were excluded. Patients were divided into four malnutrition groups: very severe (GNRI < 73), severe (GNRI, 73–82), moderate (GNRI, 82–92), and mild (GNRI, 92–98). Geriatric Nutritional Risk Index greater than 98 constituted the normal nutrition group. Risk-adjusted multivariable logistic regressions were performed to study the relationship between malnutrition—measured using either GNRI, albumin level, or body mass index less than 18.5 kg/m^2—and the following postoperative outcomes: 30-day mortality, 30-day morbidity (including infectious and noninfectious complications), and hospital length of stay. The relationship between GNRI score and 30-day mortality for six common ES procedures was then assessed.

RESULTS: A total of 82,725 patients were included in the final analyses. Of these, 55,214 were malnourished with GNRI less than 98 (66.74%). Risk-adjusted multivariable analyses showed that, as malnutrition worsened from mild to very severe, the risk of mortality, morbidity, and the hospital length of stay progressively increased (all $p < 0.05$). Patients with very severe malnutrition had at least a twofold increased likelihood of mortality (odds ratio [OR], 2.79; 95% confidence interval [CI], 2.57–3.03), deep vein thrombosis (OR, 2.07; 95% CI, 1.77–2.42), and respiratory failure (OR, 1.95; 95% CI, 1.81–2.11). Geriatric Nutritional Risk Index predicted mortality better than albumin or body mass index alone for ES.

CONCLUSION: Malnutrition, measured using GNRI, is a strong independent predictor of adverse outcomes in the elderly ES patient and could be used to assess the nutrition status and counsel patients (and families) preoperatively. (*J Trauma Acute Care Surg.* 2020;89: 397–404. Copyright © 2020 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic study, Level IV.

KEY WORDS: GNRI; outcome; elderly patients; emergency surgery.

Malnutrition is prevalent in the elderly population and is particularly correlated with increased mortality, morbidity, hospital length of stay (LOS), and health care expenditure in hospitalized patients.[1–3] For the emergency surgery (ES) patient, malnutrition predicts serious adverse events.[4] Accordingly, the assessment of a patient's nutritional status is crucial to predicting postoperative outcomes and optimizing perioperative management.[5] In the United States, the Joint Commission recommends screening patients for malnutrition within 24 hours of their admission to an acute care center.[6] The optimal method for nutritional evaluation remains controversial. The European Society for Clinical Nutrition and Metabolism recently issued consensus-based guidelines to diagnose malnutrition in surgical patients.[7] According to these guidelines, severe malnutrition is defined as a body mass index (BMI) less than 18.5 kg/m^2 or a preoperative serum albumin less than 30 g/L.[7] The guidelines also recommended using more elaborate screening tools,[8,9] such as the Geriatric Nutritional Risk Index (GNRI). The GNRI was first described by Bouillanne et al.[8] as a tool to measure the nutritional status of hospitalized elderly patients. The score is based on the serum albumin concentration and the ratio of actual to ideal weight. The latter is calculated using the Lorentz formula.[8] Bouillanne et al.[8] suggested that GNRI is both simple to use and accurate in predicting the risk of morbidity and mortality in hospitalized elderly patients. Subsequent studies have also found that GNRI could be useful in assessing the nutritional status in the elderly surgical patient.[10,11]

However, it remains unclear whether GNRI can predict postoperative outcomes in elderly ES patients. This population carries one of the highest risks for postoperative morbidity and mortality, and the emergency nature of their condition leaves little time to optimize their nutritional status preoperatively. In this study, we aimed to determine whether preoperative malnutrition, as measured by GNRI, is independently correlated with postoperative mortality and morbidity in the elderly ES patient. We also aimed to compare the performance of GNRI to traditional measures of malnutrition, namely, BMI and albumin.

METHODS

Patient Selection

The 2007 to 2016 American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database was used to identify all elderly patients who underwent ES. For the purpose of this study, "elderly" was defined as 65 years or older. Emergency surgery was defined as "a case which is performed as soon as possible and no later than 12 hours after the patient has been admitted to the hospital or after the onset of related preoperative symptomatology." Patients with missing height, weight, or preoperative albumin data were excluded.

Nutritional Status Assessment and Classification

Geriatric Nutritional Risk Index was calculated using the following ACS-NSQIP variables: weight, height, and albumin. The formula used to calculate the score was: GNRI = (1.489 × albumin [g/L]) + (41.7 × [weight/WLo]). WLo is the ideal weight which can be derived from the Lorentz equations: WLo

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men = height − 100 − [(height − 150)/4], and WLo women = height − 100 − [(height − 150)/2.5]. If weight exceeded WLo, the weight/WLo was set to 1. Setting WLo to 1 for patients with weight greater than WLo was used when the GNRI score was developed. If WLo was not capped at 1, malnourished patients who are overweight or obese would be missed. Patients were then classified into the following groups[8]: very severe malnutrition (GNRI, <73), severe malnutrition (GNRI, ≥73 and <82), moderate malnutrition (GNRI, ≥82 and <92), mild malnutrition (GNRI, ≥92 and ≤98), and normal nutritional status (GNRI, >98). The albumin levels corresponding to the severity of malnutrition were: very severe hypoalbuminemia less than 2.5 g/dL, severe hypoalbuminemia as 2.5 g/dL or greater and less than 3.0 g/dL, moderate hypoalbuminemia as 3.0 g/dL or greater and less than 3.5 g/dL, mild hypoalbuminemia as 3.5 g/dL or greater and less than 3.8 g/dL, and normal albumin as 3.8 g/dL or greater.[8] In addition, BMI less than 18.5 kg/m^2 was defined as underweight.[12]

Postoperative Outcomes

Our primary outcome was 30-day postoperative mortality. Our secondary outcomes were 30-day postoperative morbidity (including infectious and noninfectious complications), hospital LOS, and 30-day postoperative mortality for six common ES procedures: appendectomy, cholecystectomy, laparotomy, partial colectomy, operative management of peptic ulcer disease, and lysis of adhesions. Infectious complications included superficial, deep and organ space surgical site infection, urinary tract infection, wound disruption, pneumonia, and sepsis. Noninfectious complications included reintubation, respiratory failure requiring a mechanical ventilator for longer than 48 hours, pulmonary embolism, deep vein thrombosis, progressive renal insufficiency, acute renal failure, stroke, cardiopulmonary resuscitation, myocardial infarction, blood transfusion, and return to the operating room.

Statistical Analysis

The χ^2 test was used for the univariate analyses. Multivariable logistic regressions were conducted with mortality, morbidity, individual postoperative complications and LOS as dependent variables, and the nutritional parameters (GNRI, hypoalbuminemia, underweight status) as independent variables. The confounders adjusted for in the multivariable analyses included demographic information (e.g., age, sex, ethnicity), comorbidities (e.g., diabetes mellitus, chronic obstructive pulmonary disease, dyspnea, ascites, heart failure, hypertension, hemodialysis, steroid use, disseminated cancer), operation complexity/specifics (e.g., operative time, American Society of Anesthesiologists (ASA) classification, relative value units as proxy to complexity, wound classification) and the acuity of illness preoperatively (e.g., all preoperative laboratory tests, sepsis prior to surgery, bleeding disorder, and preoperative blood transfusions). The odds ratios (ORs) and their 95% confidence intervals (CI) were calculated for the effects of interest (with normal nutritional status as reference) to assess the independent impact of malnutrition as measured by GNRI, hypoalbuminemia, and underweight status on postoperative outcomes. To compare the performance of the three malnutrition measures, logistic models were built for GNRI, albumin, and weight with the outcomes as dependent variables and the malnutrition measures as the only predictors. The areas under the receiver operating characteristics curve (AUCs) were computed and reported for all the logistic models. Youden's J statistic was calculated to determine the ideal GNRI cutoff value for survival that would minimize both false-positive and false-negative errors. Tests were two-tailed, and statistical significance was defined as p less than 0.05. All statistical analyses were performed on Stata 14.0. The study was submitted to institutional review board and was deemed exempt from review because of the absence of any patient identifiers in the national database.

Sensitivity Analyses

A sensitivity analysis excluding obese patients (BMI ≥ 30 kg/m^2) was conducted to evaluate the impact of obesity on the performance of different malnutrition measures in predicting all-cause mortality. The AUCs of GNRI, albumin, and weight status were assessed. Another sensitivity analysis was performed to compare the discriminatory power of GNRI versus albumin for all-cause mortality. A multivariable logistic regression was conducted where both GNRI and albumin were included as independent variables for the primary outcome.

RESULTS

A total of 82,725 elderly patients who underwent ES were included in the final analyses. The median age was 75 years (IQR = 69–82 years), and 55.6% of the patients were men. The demographic and population characteristics of included patients are summarized in Table 1.

Prevalence of Malnutrition

The prevalence of malnutrition, defined as GNRI score of 98 or less, was 66.74% (55,214 patients): 18.33% with mild malnutrition, 22.46% with moderate malnutrition, 15.35% with severe malnutrition, and 10.60% with very severe malnutrition. The prevalence of hypoalbuminemia (serum albumin, <3.8 g/dL) was 65.59% (54,259 patients): 15.65% with mild hypoalbuminemia, 19.48% with moderate hypoalbuminemia, 15.01% with severe hypoalbuminemia, and 15.44% with very severe hypoalbuminemia. A total of 4,091 (4.9%) patients were identified as underweight (BMI < 18.5 kg/m^2).

Univariate Analyses

Table 2 displays the unadjusted postoperative outcomes of the malnutrition groups as defined by GNRI. In summary, malnourished patients with GNRI score of 98 or less had significantly higher rates of 30-day mortality, 30-day total morbidity, and each of the postoperative complications compared with patients with normal nutritional status. Furthermore, as the severity of the malnutrition increased, the postoperative outcomes (mortality and morbidity) worsened in a clear stepwise fashion. Hospital LOS was also prolonged with increased malnutrition severity.

Table 3 displays the unadjusted postoperative outcomes of the malnutrition groups as defined by hypoalbuminemia. Similarly, malnourished patients with low albumin levels had significantly higher rates of 30-day mortality, 30-day total morbidity, and each of the postoperative complications. Furthermore, as the severity of the malnutrition increased, the postoperative outcomes (mortality and morbidity) also worsened in a stepwise fashion. Hospital LOS also increased with lower albumin levels.

TABLE 1. Demographic Characteristics of Elderly ES Patients With and Without Malnutrition as Defined by GNRI

	All Patients, N = 82,725 (%)	GNRI >98, n = 27,511 (%)	GNRI 92–98, n = 15,164 (%)	GNRI 82–92, n = 18,851 (%)	GNRI 73–81, n = 12,699 (%)	GNRI <73, n = 8,770 (%)	*p*
Age: median (IQR), y	75 (69–82)	74 (68–80)	76 (70–83)	76 (70–83)	76 (70–83)	75 (70–82)	<0.001
Sex, male	45,989 (55.6)	15,058 (54.7)	8,577 (56.6)	10,441 (56.2)	7,053 (55.5)	4860 (55.4)	0.002
Race							
Black	7,333 (10.3)	2,082 (8.7)	1,338 (10.2)	1,751 (11.0)	1,267 (11.6)	895 (12.2)	<0.001
Other	2,957 (4.2)	984 (4.1)	503 (3.8)	716 (4.5)	454 (4.2)	300 (4.1)	
White	60,906 (85.5)	20,806 (87.2)	11,330 (86.0)	13,486 (84.5)	9,169 (84.2)	6115 (83.7)	
BMI							
<18.5	54,359 (65.7)	18,685 (67.9)	10,016 (66.1)	12,279 (66.1)	8,156 (64.2)	5,223 (59.6)	<0.001
18.5–29	4,091 (4.9)	265 (1.0)	462 (3.0)	1,067 (5.7)	1,023 (8.1)	1,274 (14.5)	
30–34	13,889 (16.8)	5,184 (18.8)	2,648 (17.5)	2,929 (15.8)	1,907 (15.0)	1,221 (13.9)	
35–39	5,902 (7.1)	1,997 (7.3)	1,127 (7.4)	1,316 (7.1)	869 (6.8)	593 (6.8)	
≥40	4,484 (5.4)	1,380 (5.0)	911 (6.0)	990 (5.3)	744 (5.9)	459 (5.2)	
Current smoker	10,443 (12.6)	2,872 (10.4)	1,789 (11.8)	2,420 (13.0)	1,869 (14.7)	1,493 (17.0)	<0.001
Preoperative transfusion	5,110 (6.2)	317 (1.2)	460 (3.0)	1,202 (6.5)	1,491 (11.7)	1,640 (18.7)	<0.001
Diabetes mellitus	17,610 (21.3)	4,790 (17.4)	3,191 (21.0)	4,251 (22.9)	3,151 (24.8)	2,227 (25.4)	<0.001
COPD	10,805 (13.1)	2,395 (8.7)	1,857 (12.2)	2,753 (14.8)	2,142 (16.9)	1,658 (18.9)	<0.001
Dyspnea							
None	71,858 (86.9)	25,353 (92.2)	13,406 (88.4)	15,884 (85.5)	10,397 (81.9)	6,818 (77.7)	<0.001
On moderate exertion	7,297 (8.8)	1,716 (6.2)	1,333 (8.8)	1,859 (10.0)	1,421 (11.2)	968 (11.0)	
At rest	3,570 (4.3)	442 (1.6)	425 (2.8)	838 (4.5)	881 (6.9)	984 (11.2)	
Ventilator dependent	5,165 (6.2)	330 (1.2)	354 (2.3)	946 (5.1)	1,414 (11.1)	2,121 (24.2)	<0.001
Ascites	3,470 (4.2)	521 (1.9)	416 (2.7)	786 (4.2)	808 (6.4)	939 (10.7)	<0.001
Heart failure	3,658 (4.4)	487 (1.8)	521 (3.4)	990 (5.3)	912 (7.2)	748 (8.5)	<0.001
Hypertension	58,295 (70.5)	18,635 (67.7)	10,823 (71.4)	13,376 (72.0)	9,241 (72.8)	6,220 (70.9)	<0.001
Dialysis	2,959 (3.6)	337 (1.2)	372 (2.5)	716 (3.9)	775 (6.1)	759 (8.7)	<0.001
Disseminated cancer	4,297 (5.2)	619 (2.3)	683 (4.5)	1,197 (6.4)	1,030 (8.1)	768 (8.8)	<0.001
Bleeding disorders	14,238 (17.2)	3,553 (12.9)	2,484 (16.4)	3,542 (19.1)	2,640 (20.8)	2,019 (23.0)	<0.001
Steroid use	6,559 (7.9)	1,207 (4.4)	1,061 (7.0)	1,711 (9.2)	1,433 (11.3)	1,147 (13.1)	<0.001

COPD, chronic obstructive pulmonary disease.

Table 4 displays the unadjusted postoperative outcomes of normal weight versus underweight patients (BMI < 18.5 kg/m^2). Underweight patients had higher rates of mortality and morbidity and a longer hospital LOS. However, several individual complication rates were similar between the two groups, such as surgical site infection, deep vein thrombosis, pulmonary embolism, and wound dehiscence.

Multivariable Analyses

After adjusting for all previously mentioned confounders, malnutrition as measured by GNRI or hypoalbuminemia was independently associated with increased 30-day mortality, 30-day morbidity (including infectious complication and noninfectious complication), and longer hospital LOS. Underweight status did not correlate with 30-day morbidity. As malnutrition worsened from mild to very severe, the risk of 30-day mortality, 30-day morbidity (including most of the studied complications), and hospital LOS gradually increased (Table 5). While the adjusted ORs for mortality were persistently higher for GNRI than for the equivalent levels of hypoalbuminemia and for underweight status (Table 5), the discriminatory power of GNRI as determined by the AUC of the predictive models overlaps with that of albumin (Supplemental Digital Content 1, Table 1, https://links.lww.com/TA/B662). However, both GNRI and albumin had a significantly higher predictive power than weight. For the morbidity models, the adjusted ORs and AUCs were similar for GNRI and hypoalbuminemia and were higher than those of underweight status. Additionally, malnutrition was strongly associated with higher mortality in each of the six common ES procedures. Patients with GNRI score less than 73 who underwent an appendectomy had a ninefold increase in mortality, and those who underwent operative management of peptic ulcer disease and lysis of peritoneal adhesions had a fivefold increase in mortality (Supplemental Digital Content 2, Table 2, Fig. 1, http://links.lww.com/TA/B663). Also, as malnutrition worsened from mild to very severe, the risk of complication (infectious and noninfectious) increased for each of the six procedures. The calculated Youden's J statistic for mortality was equal to 0.35 for a GNRI cutoff value of 87.

When examining individual postoperative complications, malnutrition, as measured by GNRI, strongly correlated with all complications except myocardial infarction and pulmonary

TABLE 2. Outcomes of Elderly ES Patients With and Without Malnutrition as Defined by GNRI

	GNRI >98	Malnutrition Status (GNRI≤98)				
Outcomes	**Normal, n = 27,511 (%)**	**Mild, n = 15,164 (%)**	**Moderate, n = 18,581 (%)**	**Severe, n = 12,699 (%)**	**Very Severe, n = 8,770 (%)**	***p***
30-d Mortality	1,379 (5.0)	1,404 (9.3)	2,873 (15.5)	3,064 (24.1)	3,340 (38.1)	<0.001
30-d Morbidity	7,701 (28.0)	5,533 (36.5)	8,939 (48.1)	7,986 (62.9)	6,596 (75.2)	<0.001
Infectious complication	5,674 (20.6)	3,872 (25.5)	6,060 (32.6)	5,300 (41.7)	4,258 (48.6)	<0.001
Superficial SSI	1,089 (3.96)	645 (4.25)	787 (4.24)	555 (4.37)	329 (3.75)	<0.001
Deep SSI	290 (1.05)	196 (1.29)	278 (1.50)	240 (1.89)	164 (1.87)	<0.001
OSI	876 (3.18)	576 (3.8)	865 (4.66)	823 (6.48)	616 (7.02)	<0.001
pneumonia	1,360 (4.94)	985 (6.50)	1,734 (9.33)	1,600 (12.60)	1,398 (15.94)	<0.001
UTI	712 (2.59)	525 (3.46)	786 (4.23)	628 (4.95)	501 (5.71)	<0.001
WD	313 (1.14)	236 (1.56)	354 (1.91)	342 (2.69)	234 (2.67)	<0.001
Sepsis	2,979 (10.83	2,238 (14.76)	3,730 (20.07)	3,584 (28.22)	3,011 (34.33)	<0.001
Noninfectious complication	4,228 (15.4)	3,510 (23.2)	6,256 (33.7)	6,146 (48.4)	5,669 (64.6)	<0.001
Cardiac arrest	291 (1.1)	282 (1.9)	516 (2.8)	458 (3.6)	480 (5.5)	<0.001
MI	407 (1.48)	277 (1.83)	407 (2.19)	288 (2.27)	232 (2.65)	<0.001
Stroke	119 (0.43)	114 (0.75)	176 (0.95)	149 (1.17)	113 (1.29)	<0.001
DVT	393 (1.43)	327 (2.16)	530 (2.85)	523 (4.12)	477 (5.44)	<0.001
Severe bleeding	1,544 (5.61)	1,510 (9.96)	2,955 (15.90)	3,274 (25.78)	3,153 (35.95)	<0.001
PE	221 (0.80)	162 (1.07)	205 (1.10)	164 (1.29)	101 (1.15)	<0.001
Reintubation	1,036 (3.77)	818 (5.39)	1,313 (7.07)	1,178 (9.28)	1,107 (12.62)	<0.001
Renal failure	768 (2.79)	658 (4.34)	1,379 (7.42)	1,408 (11.09)	1,394 (15.90)	<0.001
Ventilator >48 h	1,719 (6.25)	1,442 (9.51)	2,713 (14.60)	3,035 (23.9)	3,210 (36.6)	<0.001
TLOS, median (% with >8 d)	8,070 (29.3)	6,015 (39.7)	9,980 (53.7)	8,615 (67.8)	6,605 (75.3)	<0.001

SSI, surgical site infection; UTI, urinary tract infection; OSI, organ space infection; WD, wound dehiscence; MI, myocardial infarction; DVT, deep vein thrombosis; PE, pulmonary embolism; TLOS, total LOS.

TABLE 3. Outcomes of Elderly ES Patients With and Without Hypoalbuminemia

	Albumin >3.8 g/dL	Hypoalbuminemia Status (Albumin<3.8 g/dL)				
Outcomes	**Normal, n = 28,466 (%)**	**Mild, n = 12,947 (%)**	**Moderate, n = 16,118 (%)**	**Severe, n = 12,420 (%)**	**Very Severe, n = 12,774 (%)**	***p***
30-d Mortality	1,546 (5.4)	1,167 (9.0)	2,298 (14.3)	2,645 (21.3)	4,404 (34.5)	<0.001
30-d Morbidity	8,049 (28.3)	4,678 (36.1)	7,405 (45.9)	7,261 (58.1)	9,407 (73.6)	<0.001
Infectious complication	5,890 (20.7)	3,303 (25.6)	5,052 (31.3)	4,800 (38.7)	6,119 (47.9)	<0.001
Superficial SSI	1,111 (3.90)	540 (4.17)	685 (4.25)	569 (4.58)	500 (3.91)	0.016
Deep SSI	295 (1.04)	154 (1.19)	251 (1.56)	224 (1.80)	244 (1.91)	<0.001
OSI	895 (3.14)	492 (3.80)	721 (4.47)	724 (5.83)	924 (7.23)	<0.001
Pneumonia	1,453 (5.1)	851 (6.57)	1,429 (8.87)	1,399 (11.26)	1,945 (15.23)	<0.001
UTI	748 (2.63)	451 (3.48)	636 (3.95)	591 (4.76)	726 (5.68)	<0.001
WD	328 (1.15)	190 (1.47)	309 (1.92)	314 (2.53)	338 (2.65)	<0.001
Sepsis	3,099 (10.89	1,874 (14.47	3,100 (19.23)	3,135 (25.24)	4,334 (33.93)	<0.001
Noninfectious complication	4,487 (15.8)	2,918 (22.5)	5,065 (31.4)	5,415 (43.6)	7,924 (62.0)	<0.001
Cardiac arrest	311 (1.09)	234 (1.81)	427 (2.65)	424 (3.41)	631 (4.94)	<0.001
MI	443 (1.56)	231 (1.78)	349 (2.17)	279 (2.25)	309 (2.42)	<0.001
Stroke	136 (0.48)	98 (0.76)	146 (0.91)	124 (1.00)	167 (1.31)	<0.001
DVT	413 (1.45)	274 (2.12)	415 (2.57)	465 (3.74)	683 (5.35)	<0.001
Severe bleeding	1,679 (5.90)	1,211 (9.35)	2,403 (14.91)	2,734 (22.01)	4,409 (34.52)	<0.001
PE	221 (0.78)	136 (1.05)	178 (1.10)	159 (1.28)	159 (1.24)	<0.001
Reintubation	1,113 (3.91)	694 (5.36)	1,084 (6.73)	1,062 (8.55)	1,499 (11.73)	<0.001
Renal failure	795 (2.79)	553 (4.27)	1,059 (6.57)	1,188 (9.57)	2,012 (15.75)	<0.001
Ventilator >48 h	1,816 (6.38)	1,194 (9.22)	2,159 (13.39)	2,541 (20.46)	4,409 (34.52)	<0.001
TLOS, median (% with >8 d)	8,528 (30.0)	5,037 (38.9)	8,240 (51.1)	7,947 (64.0)	9,533 (74.6)	<0.001

TABLE 4. Outcomes of EGS With and Without Underweight and Weight Loss

Outcomes	Normal, n = 78,634 (%)	Underweight, n = 4,091 (%)	*p*
30-d Mortality	11,076 (14.1)	984 (24.1)	<0.001
30-d Morbidity	34,707 (44.1)	2,048 (50.1)	<0.001
Infectious complication	23,777 (30.2)	1,387 (33.9)	<0.001
Superficial SSI	3,276 (4.17)	129 (3.15)	0.001
Deep SSI	1,115 (1.42)	53 (1.3)	0.518
OSI	3,590 (4.57)	166 (4.06)	0.128
Pneumonia	6,584 (8.37)	493 (12.05)	<0.001
UTI	2,958 (3.76)	194 (4.74)	0.001
WD	1,397 (1.78)	82 (2.00)	0.284
Sepsis	14,703 (18.7)	839 (20.51)	0.004
Noninfectious complication	24,344 (31.0)	1,465 (35.8)	<0.001
Cardiac arrest	1,888 (2.4)	139 (3.4)	<0.001
MI	1,510 (1.9)	101 (2.47)	0.013
Stroke	618 (0.79)	53 (1.30)	0.002
DVT	2,133 (2.71)	117 (2.86)	0.572
Severe bleeding	11,693 (14.9)	743 (18.16)	<0.001
PE	820 (1.04)	33 (0.81)	0.145
Reintubation	5,043, (6.86)	409 (10)	<0.001
Renal failure	5,392 (5.95)	215 (5.26)	<0.001
Ventilator >48 h	11,430 (14.5)	689 (16.84)	<0.001
TLOS, median (% with >8 d)	36,999 (47.1)	2,286 (55.9)	<0.001

embolism (Table 6). As malnutrition worsened from mild to very severe, the risk of most complications incrementally increased (Supplemental Digital Content 3, Fig. 2, http://links.lww.com/TA/B664).

Sensitivity Analyses

The sensitivity analysis excluding obese patients showed that the AUCs for the predictive performance of GNRI, albumin, and weight status were equal to 0.722, 0.715, and 0.560, respectively. The second sensitivity analysis showed that after adjusting for albumin, the OR for all-cause mortality increased from 1.53 (95% CI, 1.32–1.78) in patients with a GNRI score between 92 and 98 to 3.25 (95% CI, 2.64–4.00) in patients with a GNRI score less than 73. The OR for all-cause mortality was similar in patients with mild, moderate, and severe hypoalbuminemia (OR, 0.82 (95% CI, 0.71–0.95; OR, 0.83; 95% CI, 0.70–0.98; OR, 0.83; 95% CI, 0.69–0.99, respectively) and lost significance in patients with very severe hypoalbuminemia (OR, 0.86; 95% CI, 0.70–1.04).

DISCUSSION

To the best of our knowledge, this is the first study that describes the value and power of GNRI in assessing malnutrition and predicting outcomes in the elderly ES patient. The ACS-NSQIP, a large multi-institutional validated database, provided us with enough sample power to validate GNRI and show its superiority in predicting mortality and morbidity in this high-risk population. We recommend that GNRI becomes the standard of care when assessing the nutritional status of the elderly patient about to undergo ES. The GNRI combines serum albumin, height, and weight in one score that has the advantage of minimizing the confounding effect of hydration status and predicting with high-accuracy postoperative outcomes. We also propose using the GNRI cutoff value of 87 to assess the mortality risk in elderly ES patients. Our findings are corroborated by Lee et al.[13] who showed that a GNRI score below 87 is an indicator of nutritional support need in an acute care setting. Additionally, we showed that GNRI quantifies the severity of malnutrition and its impact on individual postoperative complications. To date, the standard way to measure malnutrition and its resultant health risk in the hospitalized patient remains controversial. The performance of different nutritional assessment tools varies significantly from one population to another. For instance, a study showed that the Nutrition Risk Screening 2002 (NRS-2002), which is widely applied in preoperative nutritional status assessment, correlates poorly with mortality in patients requiring emergency care.[14,15] The Mini Nutrition Assessment, often considered as one of the best tools for assessing nutritional status in the elderly, showed worse applicability for classifying the nutritional status and identifying nutritional-related complications among hospitalized elderly patients compared with GNRI.[16] Marcadenti et al.[17] recently launched a novel nutrition screening tool named Emergency-2017 composed of six questions. Havens et al.[4] combined nutrient intake, wasting of muscle mass, subcutaneous fat loss, and weight loss to better define malnutrition and predict outcomes in ES patients. They showed that patients that met their criteria for malnutrition had 1.5 times the odds of mortality compared with patients without malnutrition.[4] In recent literature on GNRI, Balzano et al.[10] found that GNRI independently predicts 1-year mortality after pancreatic cancer resection. Gärtner et al.[18] found a positive correlation between a worse GNRI score and hospital LOS. Yamana et al.[11] found that GNRI predicts the risk of postoperative respiratory complications in patients undergoing esophagectomy and gastric tube reconstruction. Finally, Bouillanne et al.[8] and Cereda et al.[19] found that the patients with severe malnutrition, as defined by GNRI, had higher-risk complications.

However, these studies had small sample sizes, and none of them assessed the efficacy of GNRI in elderly ES patients. As such, our study supports the use of GNRI in the elderly ES patient since it strongly correlates with all postoperative outcomes including mortality, morbidity, LOS, and individual postoperative complications in a stepwise incremental fashion.

There is little evidence in the literature assessing the impact of malnutrition on individual ES operations in elderly patients. One study showed that patients with malnutrition who underwent appendectomy had more complications and a longer LOS than patients without malnutrition.[20] Another study showed that frailty predicted complications and hospital LOS in geriatric patients undergoing elective laparoscopic cholecystectomy.[21] To the best of our knowledge, our study is the first to show that malnutrition, measured with GNRI, predicts 30-day mortality for six of the most common ES procedures.

Our study also showed that GNRI performs similarly (and sometimes slightly better) to albumin and significantly better than BMI less than 18.5 kg/m^2 in predicting postoperative outcomes in the elderly ES patient. Despite the comparable performances, GNRI is superior to albumin in assessing nutritional

TABLE 5. Multivariable Logistic Regression Analyses Assessing the Risk-Adjusted Impact of Malnutrition on 30-Day Mortality, 30-Day Morbidity, and Hospital LOS

	OR (95% CI)				
Outcomes	**Mild**	**Moderate**	**Severe**	**Very Severe**	**AUCs of Risk Adjusted Models**
30-d Mortality					
GNRI	1.30 (1.19–1.41)	1.64 (1.53–1.77)	2.06 (1.91–2.23)	2.79 (2.57–3.03)	0.8549 (0.8516–0.8582)
Albumin	1.21 (1.11–1.31)	1.50 (1.40–1.62)	1.79 (1.66–1.93)	2.38 (2.21–2.56)	0.8540 (0.8507–0.8573)
Underweight	1.66 (1.52–1.83)				0.8501 (0.8467–0.8535)
30-d Morbidity					
GNRI	1.08 (1.03–1.13)	1.29 (1.24–1.35)	1.70 (1.62–1.80)	2.00(1.87–2.14)	0.8123 (0.8094–0.8152)
Albumin	1.08 (1.03–1.13)	1.25 (1.19–1.31)	1.52 (1.45–1.60)	2.00 (1.89–2.11)	0.8123 (0.8094–0.8152)
Underweight	1.05 (0.98–1.13)				0.8087 (0.8058–0.8116)
Infectious complication					
GNRI	1.04 (0.99–1.09)	1.18 (1.12–1.23)	1.39 (1.32–1.46)	1.45 (1.37–1.54)	0.7409 (0.7373–0.7444)
Albumin	1.06 (1.00–1.11)	1.16 (1.11–1.22)	1.31 (1.24–1.37)	1.49 (1.41–1.57)	0.7410 (0.7375–0.7445)
Underweight	1.02 (0.94–1.09)				0.7387 (0.7352–0.7423)
Noninfectious complication					
GNRI	1.18 (1.11–1.24)	1.43 (1.36–1.51)	1.88 (1.78–1.99)	2.44 (2.28–2.60)	0.8405 (0.8376–0.8432)
Albumin	1.14 (1.07–1.21)	1.35 (1.28–1.42)	1.67 (1.58–1.76)	2.29 (2.16–2.42)	0.8404 (0.8376–0.8432)
Underweight	1.09 (1.01–1.18)				0.8358 (0.8330–0.8387)
TLOS, median (>8 d)					
GNRI	1.21 (1.16–1.27)	1.78 (1.70–1.87)	2.62 (2.47–2.79)	2.67 (2.46–2.89)	0.8238 (0.8206–0.8269)
Albumin	1.17 (1.11–1.23)	1.62 (1.54–1.71)	2.34 (2.21–2.49)	2.83 (2.65–3.03)	0.8241 (0.8210–0.8273)
Underweight	1.19 (1.09–1.30)				0.8162 (0.8130–0.8194)

status.[8] This is particularly the case for ES where the high inflammatory response promotes the synthesis of cytokines that repress the production of albumin and increase capillary breakdown, allowing albumin to escape.[22,23] Therefore, this critically ill population is more prone to have low levels of albumin that are due to the acuity of ES and not to nutritional status. The utilization of both weight and albumin in the index minimizes confounding variables that are inherent to ES procedures, such as inflammation and hydration status. Although albumin is not considered a particularly good indicator of a patient's nutritional status, it is still widely used as a preoperative biomarker to predict mortality and other outcomes in surgery.[24,25] A recent systematic review showed that albumin is a reliable preoperative measure for identifying elderly patients at risk for complicated

TABLE 6. Multivariable Logistic Regression Analyses Assessing the Risk-Adjusted Impact of Occurrence of Malnutrition as Defined by GNRI on Identified Complications

	OR (95% CI)				
Complications	**Mild**	**Moderate**	**Severe**	**Very Severe**	**AUCs of Risk Adjusted Models**
Superficial SSI	0.99 (0.89–1.09)	0.91 (0.82–1.00)	0.90 (0.81–1.01)	0.80 (0.70–0.92)	0.6835 (0.6748–0.6921)
Deep SSI	1.10 (0.91–1.32)	1.15 (0.97–1.37)	1.32 (1.10–1.59)	1.27 (1.02–1.58)	0.6711 (0.6566–0.6855)
Organ space SSI	1.04 (0.93–1.16)	1.13 (1.02–1.25)	1.38 (1.24–1.53)	1.34 (1.19–1.52)	0.7215 (0.7139–0.7292)
Pneumonia	1.06 (0.97–1.16)	1.27 (1.17–1.37)	1.46 (1.34–1.58)	1.55 (1.41–1.69)	0.7307 (0.7252–0.7362)
UTI	1.17 (1.05–1.32)	1.30 (1.17–1.45)	1.44 (1.28–1.62)	1.62 (1.42–1.85)	0.6619 (0.6528–0.6710)
Wound dehiscence	1.12 (0.94–1.33)	1.15 (0.98–1.35)	1.41 (1.19–1.66)	1.27 (1.05–1.55)	0.7441 (0.7330–0.7552)
Sepsis	1.08 (1.02–1.15)	1.21 (1.15–1.29)	1.46 (1.38–1.56)	1.48 (1.38–1.58)	0.7797 (0.7759–0.7835)
Cardiac arrest	1.29 (1.09–1.52)	1.43 (1.23–1.66)	1.39 (1.18–1.63)	1.56 (1.32–1.84)	0.7924 (0.7835–0.8012)
MI	0.98 (0.84–1.15)	0.98 (0.85–1.14)	0.86 (0.73–1.02)	0.89 (0.74–1.07)	0.7011 (0.6895–0.7128)
Stroke	1.42 (1.09–1.84)	1.47 (1.16–1.87)	1.47 (1.13–1.91)	1.27 (0.95–1.71)	0.7100 (0.6920–0.7280)
DVT	1.26 (1.08–1.46)	1.42 (1.23–1.62)	1.78 (1.54–2.05)	2.07 (1.77–2.42)	0.7059 (0.6960–0.7158)
Severe bleeding	1.34 (1.24–1.45)	1.68 (1.57–1.80)	2.27 (2.11–2.44)	2.63 (2.43–2.85)	0.8294 (0.8258–0.8330)
PE	1.18 (0.96–1.44)	1.10 (0.90–1.34)	1.17 (0.94–1.46)	0.99 (0.76–1.29)	0.6821 (0.6650–0.6993)
Reintubation	1.14 (1.04–1.26)	1.23 (1.13–1.34)	1.36 (1.24–1.50)	1.63 (1.48–1.81)	0.7269 (0.7208–0.7331)
Renal failure	1.14 (1.01–1.27)	1.43 (1.30–1.58)	1.58 (1.43–1.75)	1.66 (1.49–1.86)	0.8612 (0.8565–0.8660)
Ventilator > 48 h	1.10 (1.02–1.19)	1.26 (1.17–1.35)	1.61 (1.49–1.73)	1.95 (1.81–2.11)	0.8497 (0.8463–0.8531)

postoperative course in general surgery.[26] Body mass index less than 18.5 kg/m^2 is still considered as one of the criteria for severe malnutrition in the European Society for Clinical Nutrition and Metabolism guidelines. A recent study showed that underweight patients (i.e., BMI < 18.5 kg/m^2) are at a greater risk for postoperative adverse events compared with patients with normal BMI.[25]

Our study has a few limitations. First, the ACS-NSQIP database only records 30-day mortality and morbidity and provides no data on the long-term outcomes or the quality of life. Second, we only had data on patients who underwent surgery and not those who declined surgical intervention, including those with severe malnutrition (selection bias). Third, adjustment for intrafacility clustering was not possible due to the deidentified nature of this dataset. Finally, the ACS-NSQIP database does not collect data about perioperative nutritional therapy (enteral and parenteral) which clearly impacts postoperative outcomes.

CONCLUSION

Malnutrition, as measured by GNRI, is a strong independent predictor of adverse outcome in the elderly ES patient and could be used to assess the nutritional status and counsel patients (and families) preoperatively.

AUTHORSHIP

J.Z. and H.M.A.K. designed this study. J.Z., M.E., A.T.N., and K.H. performed the data collection. J.Z., M.E., M.W.E., A.T.N., J.M.L., K.M., and N.K. performed the data analysis/interpretation. J.Z., M.E., A.T.N., J.M. L., and K.M. performed the statistical analysis. J.Z. and K.H. performed the literature search. J.Z., M.E., M.W.E., A.T.N., J.M.L., K.M., K.H., N.K., A.E.M., D.R.K., P.J.F., N.S., M.R., G.C.V., and H.M.A.K. contributed to the writing and critical revisions.

DISCLOSURE

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