Role of nutritional indices in predicting outcomes of vascular surgery

Jana Jabbour, LD, MPH, PhD,[a,b,c] Adham N. Abou Ali, MD,[a,d] Wissam Rabeh, MD,[a,e] Laila Al-Shaar, MS, MPH,[a,f] Efthymios D. Avgerinos, MD,[d] *and* Robert H. Habib, PhD,[a,f,g] *Beirut, Lebanon; Marseille, France; Pittsburgh, Pa; and Cleveland, Ohio*

ABSTRACT

Background: Malnutrition is frequent among vascular surgery patients, given their age, chronic comorbidities, and poor functional status, and it is believed to increase their operative risk. We aimed to assess the combined use of recent significant weight loss (>10% body mass) and serum albumin levels as a nutritional status index to predict outcomes.

Methods: We analyzed vascular surgery data from the American College of Surgeons National Surgical Quality Improvement Program database (2005-2012; N = 238,082) to compare operative death (in-hospital and 30-day operative death) across eight nutritional status groups based on weight loss (yes/no) and albumin category: very low albumin level (VL-Alb; <2.50 g/dL), low albumin level (L-Alb; 2.50-3.39 g/dL), normal albumin level (N-Alb; 3.40-4.39 g/dL), and high albumin level (H-Alb; 4.40-5.40 g/dL). Risk-adjusted odds ratios (AOR) with 95% confidence intervals were estimated by multivariable logistic regression (N-Alb [no weight loss], reference).

Results: The study population included 113,936 patients for whom albumin level was available (age, 67 ± 13 years; 60.2% male). Operative death was documented in 5160 (4.53%) patients. The eight-category nutritional status was more predictive of operative death than age alone (C statistic, 0.74 vs 0.63). A high discrimination multivariable model for operative death was derived (C statistic, 0.851). Low albumin level was associated with increased death that worsened in case of weight loss: VL-Alb + WL, AOR = 3.83 (3.03-4.83); VL-Alb, AOR = 3.36 (3.06-3.69); L-Alb + WL, AOR = 2.46 (1.98-3.05); and L-Alb, AOR = 1.99 (1.84-2.15). Weight loss was associated with increased death even if albumin level was normal: N-Alb + WL, AOR = 1.77 (1.34-2.35); and H-Alb + WL, AOR = 1.91 (0.69-5.31). H-Alb was protective (AOR = 0.65 [0.55-0.76]).

Conclusions: Nutritional status predicts outcomes of vascular surgery. Serum albumin level and weight loss should be incorporated in patients' risk stratification. (J Vasc Surg 2019;70:569-79.)

Keywords: Malnutrition; Vascular surgery; Serum albumin; Weight loss; Risk stratification

Malnutrition, a prevalent condition in surgery patients, is found in between 17% and 64% of these patients, depending on patient factors and surgery types.[1,2] In particular, vascular surgery patients often have one or more risk factors, such as old age and chronic diseases, that are commonly associated with altered nutrient absorption and limited functional status, which increases their likelihood of malnutrition.[3] Prevalence of malnutrition may also vary among patients undergoing different kinds of vascular surgery. Assignment of the nutritional status of patients may also depend on the specific assessment tool used.[4] The prevalence of preoperative malnutrition has been reported to be as low as 10%[4] and as high as 73%.[4,5]

In the setting of malnutrition, energy and protein requirements cannot be met because of compromised nutrient intake, absorption, or utilization.[6] Malnourished patients at risk for development of postoperative complications are those who have had significant weight loss, are underweight, and are hyperinflammatory. The increased risk is usually associated with compromised wound healing, cardiac and respiratory functions, and immune competence.[7]

There is no single parameter used to assess patients' nutritional status. A combination of factors is usually considered for screening and assessment of patients, including anthropometric, biochemical, and clinical factors. Recommended nutrition assessment and screening tools are the Mini Nutritional Assessment Short Form, Subjective Global Assessment, Malnutrition Universal Screening Tool, Nutritional Risk Screening 2002, and Nutrition Risk in Critically Ill.[8,9] These various validated nutritional assessment tools generally involve patient variables such as body mass index (BMI), weight loss,

From the Scholars in HeAlth Research Program, Faculty of Medicine,[a] Vascular Medicine Program, Faculty of Medicine,[f] and Department of Internal Medicine,[g] American University of Beirut, and the Department of Clinical Nutrition, American University of Beirut Medical Center,[b] Beirut; the Ecole Doctorale Sciences de la Vie et de la santé, Aix Marseille Université, Marseille[c]; the Division of Vascular Surgery, University of Pittsburgh Medical Center, Pittsburgh[d]; and the Department of Cardiovascular Medicine, Cleveland Clinic Foundation, Cleveland.[e]

J.J., A.N.A.A., and W.R. were supported by NIH Training grant 1D43TW009118-01A1 awarded to Scholars in HeAlth Research Program, American University of Beirut, Beirut, Lebanon.

Author conflict of interest: none.

Additional material for this article may be found online at www.jvascsurg.org.

Correspondence: Robert H. Habib, PhD, Director, STS Research Center, The Society of Thoracic Surgeons, 633 N Saint Clair St, Chicago, IL 60611-3658 (e-mail: rhabib@sts.org).

The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

0741-5214

https://doi.org/10.1016/j.jvs.2018.10.116

being nil per os for >5 days, dietary recall, physical examination, and disease severity. Applying these tools, however, is time intensive, and they are rarely performed in surgery patients as a routine component of assessing surgical risk before the operation.

Significant weight loss is one of the most commonly used indicators to flag malnutrition,[8] and it has been recommended to be used as an indicator of malnutrition by leading academies and societies in the field of nutrition.[9,10] In the setting of vascular surgery, significant weight loss, defined as loss of 10% of body mass in the past 6 months, has been linked with increased mortality and morbidity among male patients.[11]

Serum albumin is a widely studied serum protein and is commonly used to reflect patients' inflammatory state and nutritional status. In their guidelines on the use of enteral nutrition in surgery patients, the European Society of Parenteral and Enteral Nutrition classified hypoalbuminemia (<30 g/L) as one of the defining characteristics of malnutrition.[12] Yet, the sensitivity of serum albumin concentration as an indicator of nutritional status remains controversial. Recent guidelines highlighted that serum albumin level should not be used in isolation to assess nutritional status because it has been shown to be not sensitive to nutritional interventions.[9,13] Nonetheless, studies have reported serum albumin concentration to be a powerful predictor of mortality after vascular surgery.[14]

In this study, we investigated the potential—separate and combined—role of preoperative significant recent weight loss and circulating albumin levels as surrogate indicators of patients' nutritional status and whether this status would be systematically predictive of operative outcomes of vascular surgery. This was accomplished by analyzing a multiyear vascular surgery cohort from the American College of Surgeons National Surgery Quality Improvement Program (ACS NSQIP) database.

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective analysis of prospectively collected American College of Surgeons National Surgical Quality Improvement Program data
- **Key Findings:** Low preoperative serum albumin levels were associated with increased operative death after all types of vascular surgery. The adverse effects of low serum albumin level were worsened in patients with substantial recent weight loss.
- **Take Home Message:** Nutritional status predicts outcomes of vascular surgery. Serum albumin levels and weight loss should be incorporated in risk stratification of vascular surgery.

METHODS

Data source. The ACS NSQIP is a validated, prospectively maintained database that incorporates data on 30-day mortality and morbidity for major surgery in adult patients (≥18 years) in institutions in the United States and around the world. The ACS NSQIP aims to assess risk-adjusted surgical outcomes to enhance surgical care. Information on relevant risk factors and outcomes is collected by trained clinical reviewers using definitions standardized across hospitals and is ascertained using medical records or by contacting the patients.[15] Authors agreed to and signed the data use agreement of the ACS NSQIP data set. This retrospective study analyzes deidentified registry-based patient data. It adheres to the principles of the Declaration of Helsinki. The study protocol was reviewed and approved by the Biomedical Institutional Review Board at the American University of Beirut. The study was approved as exempt research, and the requirement for informed patient consent was waived.

We considered patients who underwent vascular surgery procedures in the ACS NSQIP (2005-2012; 912 *Current Procedural Terminology* codes, N = 238,082 operations). Vascular surgery types were adapted from an article by Davenport et al[16] and included five categories: aortoiliac, cerebrovascular, lower limb, amputations, and other. The *Current Procedural Terminology* codes corresponding to vascular surgery types are shown in Supplementary Table I (online only). Patients were excluded from the analysis in case of missing albumin level (n = 117,681), rarely in case of very high albumin level (>5.4 g/dL; n = 145), in case of extreme body weights (<30 kg or >300 kg), or in case of extreme heights (<1.2 meters or >2.2 meters).

Study groups. Individual patients were allocated to one of eight possible nutritional status study groups on the basis of recent weight loss status (yes/no; >10% of body mass 6 months before index surgery; n = 2629 [2.3%]) and according to one of four serum albumin level categories: very low albumin level (VL-Alb; <2.50 g/dL; n = 10,092 [8.9%]), low albumin level (L-Alb; 2.50-3.39 g/dL; n = 25,764 [22.6%]), normal albumin level (N-Alb; 3.40-4.39 g/dL; n = 63,577 [55.8%]), and high albumin level (H-Alb; 4.40-5.40 g/dL; n = 14,503 [12.7%]). Accordingly, we derived an eight-category nutritional status index consisting of four no-weight loss groups of VL-Alb, L-Alb, N-Alb (reference group), and H-Alb and four weight loss groups (+WL).

Study outcomes. The primary study end point was operative death, defined as any in-hospital death during the same admission as the index surgery or within 30 days of that operation. We also studied unplanned related reoperation as a secondary outcome, and this was defined as occurring during the same hospitalization as the index surgery or during a subsequent hospitalization within 30 days of the index surgery.

Study covariates. Demographic and clinical factors were studied (Table I). System-specific comorbidities were grouped together into multiple dichotomous categorical variables including cardiac history (angina, chronic heart failure, previous myocardial infarction, previous percutaneous coronary intervention, or previous cardiac surgery), pulmonary history (dyspnea, pneumonia at the time of surgery, history of chronic obstructive pulmonary disease, or ventilator dependent), central nervous system (CNS) history (coma, hemiplegia, transient ischemic attack, stroke with or without neurologic deficit, paraplegia, quadriplegia), and cancer history (disseminated cancer, chemotherapy in the last 30 days, radiotherapy for malignant disease in the last 90 days, CNS tumor). Missing data for these covariates were rare; missing data were imputed on the basis of means and modes for continuous and categorical variables, respectively.

Statistical analysis. Patients' characteristics (demographics, nutritional predictors, clinical comorbidities, lifestyle habits, and surgery complexity) were compared by univariate analysis on the basis of albumin level categories (Table I) and weight loss groups (Table II) as well as for operative mortality (yes/no) and reoperation (yes/no) outcomes groups (Table III). Continuous variables are summarized as mean ± standard deviation and categorical variables as counts and percentages.

Group comparisons were performed using χ^2 tests, independent *t*-tests, and analysis of variance tests as applicable, and post hoc analyses were also conducted. Different multivariable logistic regression models were estimated on the whole sample and after stratifying by type of surgery (aortoiliac, cerebrovascular, lower limb, amputation, and other). Models were computed using the backward conditional method (elimination for variables with *P* values >.2). The patient's age was always included in all risk model predictions. Variables considered in all multivariable models were age (always entered), nutritional index, sex, race, ethnicity, American Society of Anesthesiologists class, functional status, BMI, excessive alcohol consumption, diabetes, dialysis, renal failure, hypertension, bleeding disorder, ascites, cardiac history, pulmonary history, smoking, neurologic history, cancer, peripheral vascular disease, surgery type, operation time, and emergency status.

The discriminatory ability of the different models was assessed using the C statistic or area under the receiver operating characteristic curve. The C statistic was first derived for the eight-category nutritional status index and age as single variables and then for the full multivariable model. This was repeated for both outcomes—operative mortality and reoperation. Risk-adjusted odds ratios (AORs) with 95% confidence intervals were also estimated by the multivariable logistic regression models with the normal albumin level and no weight loss group used as the reference cohort (N-Alb).

A two-sided *P* value <.05 was used to indicate significance. Statistical analyses were conducted using IBM Statistical Package for Social Sciences version 22 (IBM Corp, Armonk, NY) and Stata Statistical Software release 13 (StataCorp LP, College Station, Tex). Figures were constructed using Sigma Plot 11.0 (Systat Software, San Jose, Calif).

RESULTS

Characteristics of the patients. The final study population included 113,936 vascular surgery cases after application of the following exclusion criteria: extreme weights or heights (n = 6465 [2.7%]), very high albumin level (>5.4 g/dL; n = 145 [0.12%]), and missing albumin level (n = 117,536 [49%]). The mean age for the final study population was 67 ± 13 years, and it included 60.2% men (n = 68,561). The distribution of surgery types and the level of complexity of cases are shown in Supplementary Table II (online only). The aortoiliac and lower limb operations were associated with the longest mean operation time of 185 ± 105 minutes and 197 ± 109 minutes as well as with the highest work relative value unit means of 28 ± 10 and 23 ± 6, respectively.

Patients' characteristics across the different categories of albumin levels and presence of recent weight loss are compared in Tables I and II, respectively. Notably, weight loss and very low albumin levels—broadly suggestive of suboptimal nutritional status—were more frequent among women, patients who were underweight (BMI <18.5 kg/m^2), and patients in a dependent functional status. These patients were also more likely to have other comorbidities ($P < .05$). Alternatively, obese patients had relatively greater incidence of low serum albumin levels ($P < .05$). Factors such as American Society of Anesthesiologists class, diabetes, history of pulmonary disease, history of coma, and history of stroke with neurologic deficit did not differ across the different weight loss and albumin level groups. Patients with missing albumin levels were generally younger and healthier than the studied population and were generally similar to the N-Alb and H-Alb groups (Table I).

Operative outcomes. The operative death and reoperation study outcomes were observed in 5160 (4.53%) and 2081 (1.83%) cases, respectively. Operative death was highest among amputation patients (9.42%) and lowest among cerebrovascular operations (1.33%). Need for reoperation within 30 days of index surgery was highest in lower limb surgery patients (3.08%) and lowest among cerebrovascular surgery patients (0.64%). Patients with missing albumin levels had lower adverse operative outcomes (Supplementary Table III, online only).

Patients' characteristics, including composite nutrition status categories, were compared across both operative outcomes for those with and without the adverse events (Table III). Operative death patients and those who experienced reoperation had a longer mean operation time

Table I. Patients' characteristics by serum albumin level compared with patients with absent serum albumin levels

Variable	Serum albumin level				Missing albumin level (n = 117,681)	*P* value[b]
	VL-Alb (n = 10,092)	L-Alb (n = 25,764)	N-Alb (n = 63,577)	H-Alb (n = 14,503)		
Age, years	66.2 ± 13.4	68.2 ± 13.3	67.9 ± 12.7	63.6 ± 14.0	65.0 ± 14.0	a, b, c, d
Total operation time,[a] minutes	111 ± 99.8	137 ± 106	148 ± 98.9	145.5 ± 97.0	137 ± 97.0	a, c, d
Female[a]	4347 (43.1)	10,679 (41.5)	24,844 (39.1)	5505 (38.0)	49,981 (42.5)	a, b, c, d
Race						<.01
Black	2454 (24.3)	4799 (18.6)	6521 (10.3)	1018 (7.0)	9846 (8.4)	a, b, c, d
White	7380 (73.1)	20,234 (78.5)	55,408 (87.2)	13,140 (90.6)	93,756 (79.7)	a, b, c, d
Other	258 (2.56)	731 (2.84)	1648 (2.59)	345 (2.38)	14,079 (11.9)	c, d
Hispanic	554 (5.49)	1344 (5.22)	2694 (4.24)	671 (4.63)	4950 (4.2)	a, b, c
ASA class						<.01
No disturbance	89 (0.88)	274 (1.06)	796 (1.25)	176 (1.21)	5309 (4.5)	a, b, c, d
Mild systemic disease	932 (9.24)	2408 (9.35)	5989 (9.42)	1369 (9.44)	20,966 (17.8)	a, b, c, d
Severe systemic disease	6377 (63.2)	16,299 (63.3)	40,080 (63.0)	9207 (63.5)	73,014 (62)	a, b, c, d
Life-threatening disease	2605 (25.8)	6569 (25.5)	16177 (25.4)	3633 (25.1)	17,992 (15.3)	a, b, c, d
Moribund	89 (0.88)	214 (0.83)	535 (0.84)	118 (0.81)	400 (0.3)	a, b, c, d
Functional status[a]						<.01
Independent	4900 (48.6)	17,965 (69.7)	57,745 (90.8)	13,978 (96.4)	108,788 (92.4)	a, b, c, d
Partially dependent	3392 (33.61)	5946 (23.1)	4944 (7.8)	448 (3.1)	7375 (6.3)	a, b, c, d
Totally dependent	1800 (17.8)	1853 (7.2)	888 (1.4)	77 (0.53)	1518 (1.3)	a, b, c, d
BMI[a]						<.01
Underweight (<18.5 kg/m^2)	711 (7.05)	1456 (5.65)	1855 (2.92)	352 (2.43)	3179 (2.7)	a, b, c, d
Normal (18.5-24.9 kg/m^2)	3620 (35.9)	8882 (34.5)	19,084 (30.0)	4428 (30.5)	35,310 (30)	a, b
Overweight (25.0-29.9 kg/m^2)	2772 (27.5)	7775 (30.2)	22,290 (35.1)	5649 (38.95)	41,888 (35.6)	a, b, c, d
Obese I (30.0-34.9 kg/m^2)	1558 (15.4)	4312 (16.7)	12,556 (19.8)	2791 (19.2)	22,989 (19.5)	a, b
Obese II (35.0-39.9 kg/m^2)	774 (7.67)	1924 (7.47)	4876 (7.67)	858 (5.92)	9086 (7.7)	d
Obese III (≥40 kg/m^2)	657 (6.51)	1415 (5.49)	2916 (4.59)	425 (2.93)	5229 (4.4)	a, b, d
Weight loss[a]	607 (6.0)	992 (3.9)	935 (1.5)	95 (0.7)	1011 (0.9)	a, b, c, d
Excessive alcohol consumption	303 (3)	769 (2.98)	2271 (3.57)	666 (4.59)	3732 (3.2)	a, b, c, d
Diabetes						<.01
Diabetes not on insulin	1436 (14.2)	3790 (14.7)	9155 (14.4)	2106 (14.5)	8219 (7.5)	a, c, d
Diabetes on insulin	1931 (19.1)	4765 (18.5)	11,566 (18.2)	2637 (18.2)	13,772 (12.5)	a, b, c, d
Dialysis[a]	2561 (25.4)	4564 (17.7)	3680 (5.8)	390 (2.7)	6040 (5.1)	a, b, c, d
Renal failure[a]	641 (6.35)	852 (3.31)	560 (0.88)	53 (0.37)	951 (0.8)	a, b, c, d
Hypertension[a]	8105 (80.3)	21,370 (83.0)	50,556 (79.5)	10,542 (72.7)	84,184 (71.5)	a, b, c, d
Bleeding disorder	2286 (22.65)	5773 (22.41)	14,114 (22.2)	3235 (22.31)	20,795 (17.7)	a, b, c, d
Ascites[a]	248 (2.46)	245 (0.95)	99 (0.16)	12 (0.08)	104 (0.1)	a, b, c
Cardiac history	3027 (29.99)	8012 (31.1)	19,924 (31.34)	4460 (30.75)	27,092 (23)	a, b, c, d
Pulmonary history	2682 (26.6)	7185 (27.9)	17,922 (28.2)	4116 (28.4)	23,783 (20.2)	a, b, c, d
Smoking[a]	3016 (29.9)	8415 (32.7)	21,007 (33.0)	4520 (31.2)	35,762 (30.4)	a, b, c, d
CNS history	10 (0.10)	29 (0.11)	95 (0.15)	15 (0.10)	18,569 (15.8)	a, b, c
Coma	660 (6.54)	1883 (7.31)	5059 (7.96)	1173 (8.09)	41 (0.0)	a, b
Stroke						<.01
With neurologic deficit	497 (4.92)	1354 (5.26)	3577 (5.63)	816 (5.63)	6242 (6.6)	a, b, c, d
With no neurologic deficit	275 (2.72)	724 (2.81)	2025 (3.19)	455 (3.14)	5081 (5.4)	a, b, c
Cancer[a]	681 (1.1)	519 (2.0)	11819 (18.6)	88 (0.61)	667 (0.6)	a, b, c,
PVD history[a]	11,819 (18.6)	8035 (31.2)	12,877 (20.3)	1989 (13.7)	21,585 (18.3)	a, b, c, d

Table I. Continued.

Variable	Serum albumin level				Missing albumin level (n = 117,681)	*P* value[b]
	VL-Alb (n = 10,092)	L-Alb (n = 25,764)	N-Alb (n = 63,577)	H-Alb (n = 14,503)		
Surgery type[a]						<.01
Aortoiliac	3536 (13.72)	12,877 (20.25)	672 (6.66)	2612 (18.01)	18,536 (15.8)	a, b, c, d
Cerebrovascular	3223 (12.5)	17,693 (27.8)	314 (3.1)	4373 (30.2)	27,419 (23.3)	a, b, c, d
Lower limb	7749 (30.1)	17,606 (27.7)	2260 (22.4)	3343 (23.1)	31,294 (26.6)	b, c, d
Amputations	5030 (19.5)	2303 (3.6)	4278 (42.4)	149 (1.0)	5308 (4.5)	a, b, c, d
Other	6226 (24.2)	13,098 (20.6)	2568 (25.5)	4026 (27.8)	35,124 (29.8)	a, b, c, d
Emergency[a]	2329 (23.1)	4649 (18.0)	5869 (9.2)	884 (6.1)	9665 (8.0)	a, b, c, d

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *CNS*, central nervous system; *H-Alb*, high albumin; *L-Alb*, low albumin; *N-Alb*, normal albumin; *PVD*, peripheral vascular disease; *VL-Alb*, very low albumin.
Categorical variables are presented as number (%). Continuous variables are presented as mean ± standard deviation.
[a]Reflects a *P* value <.05 for comparison of the four albumin groups.
[b]Letters a, b, c, and d reflect significant differences between very low, low, normal, and high albumin groups, respectively, with the group of missing albumin.

($P < .05$). Operative death patients were more likely to be of white race, partially dependent, and on dialysis; they were more likely to have renal failure, hypertension, bleeding disorder, cardiac disease, and CNS disease and to be lower limb surgery candidates ($P < .05$). Patients who experienced reoperation were more likely to be of white race, smokers, partially dependent, and on dialysis; they were more likely to have renal failure, hypertension, and bleeding disorder; and they were more likely to have a history of cardiac, pulmonary, and CNS disease and to have undergone lower limb surgery ($P < .05$). Across surgery types, the highest operative death rate was for the amputation group (9.42%; $P < .05$).

Risk-adjusted effects of nutritional status on operative outcomes. Construction of single covariate logistic regression models showed that the proposed eight-category nutritional composite index (albumin level-weight loss) provided superior prediction of operative outcomes compared with the substantial prediction power of the patient's age at time of surgery: operative death C statistic of 0.74 vs 0.63 (albumin level-weight loss vs age) and reoperation C statistic of 0.63 vs 0.53 (Fig 1). After adjusting for multiple risk factors including age, multiple comorbid conditions (cardiac, CNS, pulmonary, cancer) and surgical complexity factors, AOR for mortality decreased progressively with higher levels of albumin and was generally increased for a given albumin level category in case of weight loss (Table IV). The full model predicting operative death showed high discrimination with a C statistic (standard error) of 0.851 (0.003); Fig 1, *left*). The full model prediction for reoperation was moderate with a C statistic of 0.74 (Fig 1, *right*).

The risk-adjusted results for the patient's nutritional status on operative outcomes are summarized in Table IV. A low albumin level was associated with increased death that worsened in case of weight loss: VL-Alb + WL, AOR = 3.83 (3.03-4.83); VL-Alb, AOR = 3.36 (3.06-3.69); L-Alb + WL, AOR = 2.46 (1.98-3.05); and L-Alb, AOR = 1.99 (1.84-2.15). Weight loss was associated with increased death even if albumin level was normal: N-Alb + WL, AOR = 1.77 (1.34-2.35); and H-Alb + WL, AOR = 1.91 (0.69-5.31). H-Alb was protective (AOR = 0.65 [0.55-0.76]).

The AORs for the secondary outcome were similarly changed with nutritional status category, although the effect magnitudes were generally lesser.

The association between albumin level-weight loss or nutritional group and operative death was seen in all surgery subtypes, with the most pronounced impact on aortoiliac and cerebrovascular patients (Fig 2). Additional details related to vascular surgery subtypes are provided in Supplementary Tables III to V (online only). Note that the superiority of weight loss-albumin level as a single predictor compared with age alone seen for the full vascular surgery population was also true in case of the individual vascular surgery types (Supplementary Table V, online only).

DISCUSSION

Our study—based on an analysis of a multiyear, multi-institutional, national-scale cohort of patients from the ACS NSQIP—showed that the proposed composite pre-surgery nutritional status index based on albumin level and weight loss is a strong predictor of operative mortality and reoperation events in patients undergoing vascular surgery. The association between low albumin level and mortality has been widely suggested among general surgery patients.[17] A previous study among male surgery patients showed a strong association between preoperative albumin levels and postoperative complications.[11] Although not as strong as serum albumin levels, weight loss also predicted operative mortality.[11] Our study, conducted on a substantially larger multi-institutional and national-scale population of vascular surgery patients including both sexes, confirms results of the previous study, yet we further showed

Table II. Characteristics of patients by weight loss >10% category

Patient factors	Weight loss group	
	No weight loss (n = 111,307)	Weight loss (n = 2629)
Age, years	67.27 ± 13.15	67.58 ± 12.75
Albumin level,[a] g/dL	3.60 ± 1	3.07 ± 1
Total operation time,[a] minutes	141.59 ± 100.37	156.29 ± 123.49
Serum albumin level		
VL-Alb (1.0-2.49 g/dL)	9485 (8.5)	607 (23.1)
L-Alb (2.5-3.39 g/dL)	24,772 (22.2)	992 (37.7)
N-Alb (3.4-4.39 g/dL)	62,642 (56.3)	935 (36.6)
H-Alb (4.4-5.4 g/dL)	14,408 (12.9)	95 (3.6)
Female[a]	44,248 (39.8)	1127 (42.9)
Race		
Black	14,423 (13.0)	369 (14.0)
White	93,956 (84.4)	2206 (83.9)
Other	2928 (2.6)	54 (2.1)
Ethnicity Hispanic	5152 (4.6)	111 (4.2)
ASA classification		
No disturbance	1309 (1.2)	26 (1.0)
Mild systemic disease	10,472 (9.4)	226 (8.6)
Severe systemic disease	70,298 (63.2)	1665 (63.3)
Life-threatening disease	28,297 (25.4)	687 (26.1)
Moribund	931 (0.84)	25 (0.95)
Functional status[a]		
Independent	92,947 (83.5)	1641 (62.4)
Partially dependent	14011 (12.6)	719 (27.3)
Totally dependent	4349 (3.9)	269 (10.2)
BMI[a]		
Underweight (<18.5 kg/m^2)	34,728 (31.2)	1286 (48.9)
Normal (18.5-24.9 kg/m^2)	3818 (3.4)	556 (21.1)
Overweight (25.0-29.9 kg/m^2)	37,982 (34.1)	504 (19.2)
Obese I (30.0-34.9 kg/m^2)	21,018 (18.9)	199 (7.6)
Obese II (35.0-39.9 kg/m^2)	8379 (7.5)	53 (2.0)
Obese III (≥40 kg/m^2)	5382 (4.8)	31 (1.2)
Excessive alcohol consumption[b]	3903 (3.5)	106 (4.0)
Diabetes		
Diabetes not on insulin	16,080 (14.4)	407 (15.5)
Diabetes on insulin	20,405 (18.3)	494 (18.8)
Dialysis[a]	10,896 (9.8)	299 (11.4)
Renal failure[a]	2021 (1.8)	85 (3.2)
Hypertension[a]	88,572 (79.6)	2001 (76.1)
Bleeding disorder	24,841 (22.3)	567 (21.6)
Ascites[a]	540 (0.48)	64 (2.4)
Cardiac history	90 (0.1)	15 (0.6)
Pulmonary history	31,196 (28)	709 (27)
Smoking[a]	35,836 (32.2)	1122 (42.7)
CNS history	3388 (3)	90 (3.4)
Cancer[a]	1401 (1.3)	171 (6.5)
PVD history[a]	25,031 (22.5)	791 (30.1)

Table II. Continued.

Patient factors	Weight loss group	
	No weight loss (n = 111,307)	Weight loss (n = 2629)
Surgery type[a]		
Aortoiliac	19,162 (17.2)	535 (20.3)
Cerebrovascular	25,394 (22.8)	209 (7.9)
Lower limb	30,295 (27.2)	663 (25.2)
Amputations	11,243 (10.1)	517 (19.7)
Other	25,213 (22.7)	705 (26.8)
Emergency[a]	13,253 (11.9)	478 (18.2)

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *CNS*, central nervous system; *H-Alb*, high albumin; *L-Alb*, low albumin; *N-Alb*, normal albumin; *PVD*, peripheral vascular disease; *VL-Alb*, very low albumin.
Categorical variables are presented as number (%). Continuous variables are presented as mean ± standard deviation.
[a] *P* value <.05.
[b] Excessive alcohol consumption was defined as an average daily drink that exceeds two daily for the last 2 weeks before admission.

that the increased adverse event association with low albumin levels is exacerbated significantly when it coincides with significant recent weight loss (>10% in the past 6 months). Notably, the proposed composite nutritional index, when considered alone, was associated with a significantly greater prediction of poor vascular surgery outcomes than age of the patient.

Serum albumin is a marker of inflammatory etiology and has not been widely accepted as a stand-alone nutritional index. It is nevertheless powerful in predicting mortality and reoperation. Our study shows novel evidence that the two nutritional indices—serum albumin level and weight loss—are powerful determinants of surgical outcomes surpassing the effect of increased age, particularly when low albumin levels and weight loss are concurrent.

Vascular surgery patients constitute an elderly population with a high prevalence of comorbidities,[18] and they are more prone to malnutrition.[19,20] Our study shows similar results, in which malnourished patients were at the extreme levels of BMI; they were more likely to be underweight or obese (BMI ≥40 kg/m^2) and had an impaired functional status (Tables I and II). Across surgery types, the nutritional composite predicted operative death among lower limb surgery patients and reoperation among aortoiliac patients (Supplementary Table V, online only). The lower limb group had the highest mortality and odds of reoperation consistent with the pathophysiologic process of arterial disease in the lower extremities. The lower limb surgery's highest case complexity can explain the higher odds of mortality and reoperation in these vascular surgery types (Supplementary Table II, online only).

We noted presence of significant interaction between the two components of the nutritional composite. Whereas high albumin level was associated with a protective effect on mortality and reoperation even after comprehensive risk adjustment, this seemed to be reversed when high albumin level was concurrent with weight loss, although the limited number of such patients did not allow a statistically significant finding. The fact that N-Alb + WL patients showed a considerable and significantly worse risk-adjusted outcome supports this contention. Few articles have reported the interaction between these two variables.[21] Addressing this interaction appears prudent in future models investigating vascular surgery outcomes. Albumin concentration correlates with patients' inflammatory status more than with their nutritional status.[9,13] This could explain the lack of consensus with respect to albumin's role in the evaluation of malnutrition. Weight loss is nevertheless a reliable indicator for malnutrition.[9] A study aimed at identifying the most consistent screening tool for use in surgical wards showed that a nutritional risk index based on two factors, albumin level and patient's weight, is a weak nutritional screening tool and has a low agreement with Subjective Global Assessment, a reliable standard in nutritional assessment.[22] Yet, significant recent weight loss proved to be a reliable nutritional parameter.[22]

Limitations. Our study shares many of the limitations and advantages of retrospective analyses based on large multi-institutional (national-scale) clinical databases. First, our derived nutritional composite is limited by the absence of potentially important data elements that also may contribute to surgical outcomes and are not available in the NSQIP database, such as macronutrient intake and body composition changes over time. Second, weight loss (>10% body weight) before surgery is another important nutritional factor that is available only as a categorical variable (yes/no). This factor can vary widely below and above the 10% threshold, and hence this categorization will include heterogeneous groups of patients, which may have influenced our findings. Third, almost half of the vascular surgery patients in the NSQIP database had missing albumin levels (49%) and thus were excluded from the analysis. Descriptive analysis comparing patients with available vs missing

Table III. Patient and operative data in outcome groups

	Operative mortality			Reoperation		
Patient variables	**Yes (n = 5160)**	**No (n = 108,776)**	***P* value**	**Yes (n = 2081)**	**No (n = 11,1855)**	***P* value**
Age, years	66.5 ± 12.4	67.3 ± 13.2	<.001	66.5 ± 12.4	67.3 ± 13.2	.002
Total operation time, minutes	170 ± 129	141 ± 100	<.001	170 ± 129	141 ± 100	<.001
Nutritional status index			<.001			<.001
VL-Alb	1394 (27.0)	8091 (7.4)		313 (15.0)	9172 (8.2)	
L-Alb	1835 (35.6)	22,937 (21.1)		704 (33.8)	24,068 (21.5)	
N-Alb (reference)	1470 (28.5)	61,172 (56.2)		888 (42.7)	61,754 (55.2)	
H-Alb	156 (3.0)	14,252 (13.1)		108 (5.2)	14,300 (12.8)	
VL-Alb + WL	118 (2.29)	489 (0.45)		15 (0.72)	592 (0.53)	
L-Alb + WL	123 (2.38)	869 (0.80)		32 (1.54)	960 (0.86)	
N-Alb + WL	60 (1.16)	875 (0.80)		18 (0.86)	917 (0.82)	
H-Alb + WL	4 (0.08)	91 (0.08)		3 (0.14)	92 (0.08)	
Demographics						
Female	2284 (44.3)	43,091 (39.6)	<.001	808 (38.8)	44,567 (39.8)	NS
Race			<.001			<.001
Black	765 (14.8)	14027 (12.9)		381 (18.3)	14411 (12.9)	
White	4255 (82.5)	91,907 (84.5)		1657 (79.6)	94,505 (84.5)	
Other	140 (2.71)	2842 (2.61)		43 (2.07)	2939 (2.63)	
Hispanic	53 (1.03)	1282 (1.18)	NS	93 (4.47)	5170 (4.62)	
BMI			<.001			<.001
Underweight (<18.5 kg/m^2)	423 (8.2)	3951 (3.6)		116 (5.6)	4258 (3.8)	
Normal (18.5-24.9 kg/m^2)	1955 (37.9)	34,059 (31.3)		696 (33.4)	35,318 (31.6)	
Overweight (25.0-29.9 kg/m^2)	1494 (29)	36,992 (34)		647 (31.1)	37,839 (33.8)	
Obese I (30.0-34.9 kg/m^2)	740 (14.3)	20,477 (18.8)		337 (16.2)	20,880 (18.7)	
Obese II (35.0-39.9 kg/m^2)	329 (6.4)	8103 (7.4)		174 (8.4)	8258 (7.4)	
Obese III (≥40 kg/m^2)	219 (4.2)	5194 (4.8)		111 (5.3)	5302 (4.7)	
Health factors						
Excessive alcohol	167 (3.2)	3842 (3.5)	NS	45 (2.16)	3964 (3.54)	.001
Smoking	1465 (28.4)	35,493 (32.6)	<.001	793 (38.1)	36,165 (32.3)	<.001
Diabetes						
No insulin	767 (14.9)	15,720 (14.5)		308 (14.8)	16,179 (14.5)	NS
Insulin	992 (19.2)	19,907 (18.3)		381 (18.3)	20,518 (18.3)	NS
Dialysis	1111 (21.5)	10,084 (9.3)	<.001	331 (15.9)	10,864 (9.7)	<.001
Renal failure	334 (6.47)	1772 (1.63)	<.001	70 (3.36)	2036 (1.82)	<.001
Hypertension	4231 (81.9)	86,342 (79.4)	<.001	1725 (82.9)	88,848 (79.4)	<.001
Bleeding disorder	1193 (23.1)	24,215 (22.3)	NS	518 (24.9)	24,890 (22.3)	.004
Cardiac disease history	1797 (34.8)	33,626 (30.9)	<.001	821 (39.5)	34,602 (30.9)	<.001
Pulmonary disease history				626 (30.1)	31,279 (28.0)	.033
CNS history	170 (3.29)	3308 (3.04)	NS	98 (4.71)	3380 (3.02)	<.001
PVD history	1388 (26.9)	24,434 (22.5)	NS	488 (23.5)	25,334 (22.7)	NS
Ascites	158 (3.06)	446 (0.41)	NS	7 (0.34)	597 (0.53)	NS
Cancer	447 (4.4)	9636 (95.6)	<.001	35 (1.68)	1537 (1.37)	NS
Functional status			<.001			<.001
Independent	2593 (50.3)	91,995 (84.6)		1619 (77.8)	92,969 (83.1)	
Partially dependent	1348 (26.1)	13,382 (12.3)		367 (17.6)	14,363 (12.8)	
Totally dependent	1219 (23.6)	3399 (3.1)		95 (4.6)	4523 (4.0)	
Operative factors						
Emergency	2109 (40.9)	11,622 (10.7)	<.001	478 (23.0)	13,253 (11.9)	<.001

Table III. Continued.

Patient variables	Operative mortality			Reoperation		
	Yes (n = 5160)	No (n = 108,776)	*P* value	Yes (n = 2081)	No (n = 11,1855)	*P* value
Surgery type			<.001			<.001
Aortoiliac	1167 (22.6)	18,530 (17.0)		296 (14.2)	19,401 (17.3)	
Cerebrovascular	340 (7.0)	25,263 (23.2)		165 (7.9)	25,438 (22.7)	
Lower limb	1433 (27.8)	29,525 (27.1)		952 (45.8)	30,006 (26.8)	
Amputations	1108 (21.5)	10,652 (9.8)		237 (11.4)	11,523 (10.3)	
Other	1112 (21.6)	24,806 (22.8)		431 (20.7)	25,487 (22.8)	

ASA, American Society of Anesthesiologists; *BMI,* body mass index; *CNS,* central nervous system; *H-Alb,* high albumin; *L-Alb,* low albumin; *N-Alb,* normal albumin; *NS,* not significant ($P > .05$); *PVD,* peripheral vascular disease; *VL-Alb,* very low albumin.
Categorical variables are presented as number (%). Continuous variables are presented as mean ± standard deviation.

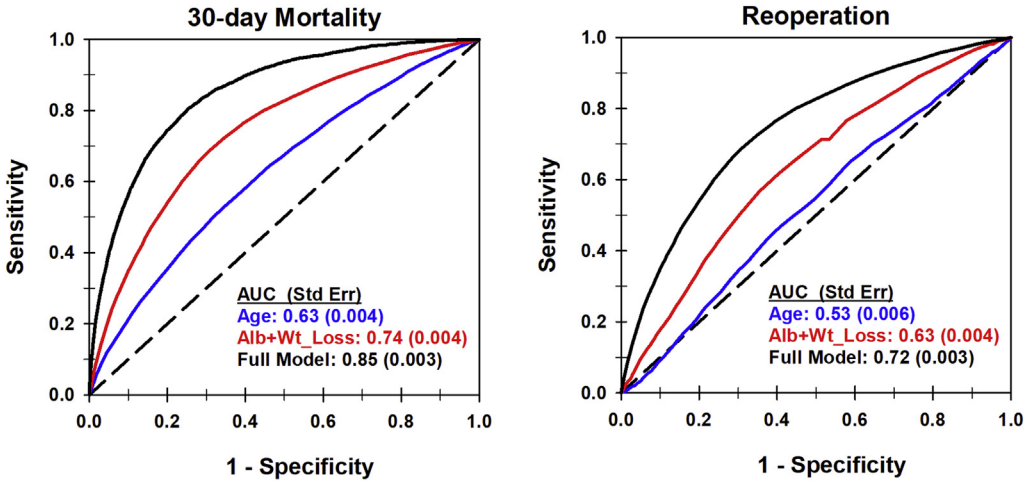

Fig 1. Receiver operating characteristic curve analysis for 30-day operative death (*left*) and reoperation (*right*). *Alb + Wt_Loss,* Albumin level and weight loss; *AUC,* area under the receiver operating characteristic curve; *Std Err,* standard error.

Table IV. Adjusted odds ratios (*AORs*) for adverse outcomes in nutritional status index subcohorts: All vascular surgery cases

Nutritional status index	Operative mortality			Reoperation		
	Event count	AOR (95% CI)	*P* value	Event count	AOR (95% CI)	*P* value
VL-Alb	1394	3.36 (3.06-3.69)	<.001	313	2.13 (1.84-2.47)	<.001
L-Alb	1835	1.99 (1.84-2.15)	<.001	704	1.76 (1.59-1.96)	<.001
N-Alb (reference)	1470	1 (reference)	1 (reference)	888	1 (reference)	1 (reference)
H-Alb	156	0.65 (0.55-0.76)	<.001	108	0.57 (0.47-0.7)	<.001
VL-Alb + WL	118	3.83 (3.03-4.83)	<.001	15	1.57 (0.93-2.66)	.09
L-Alb + WL	123	2.46 (1.98-3.05)	<.001	32	1.96 (1.36-2.83)	<.001
N-Alb + WL	60	1.77 (1.34-2.35)	<.001	18	1.18 (0.73-1.9)	.5
H-Alb + WL	4	1.91 (0.69-5.31)	.217	3	2.15 (0.68-6.86)	.2

CI, Confidence interval; *H-Alb,* high albumin; *L-Alb,* low albumin; *N-Alb,* normal albumin; *PVD,* peripheral vascular disease; *VL-Alb,* very low albumin; *WL,* weight loss.
Variables included in the model: age, sex, race, ethnicity, American Society of Anesthesiologists class, functional status, body mass index, excessive alcohol consumption, diabetes, dialysis, renal failure, hypertension, bleeding disorder, ascites, cardiac history, pulmonary history, smoking, neurologic history, cancer, peripheral vascular disease, surgery type, operation time, and emergency status.

preoperative serum albumin levels showed that the patients with missing albumin levels were younger and generally healthier and had better outcomes (lower mortality and reoperation). This likely reflected a clinical practice preference of selective ordering of preoperative serum albumin levels by many surgeons and hospitals in patients deemed at low risk of malnutrition or low albumin level. We believe that this has little or limited

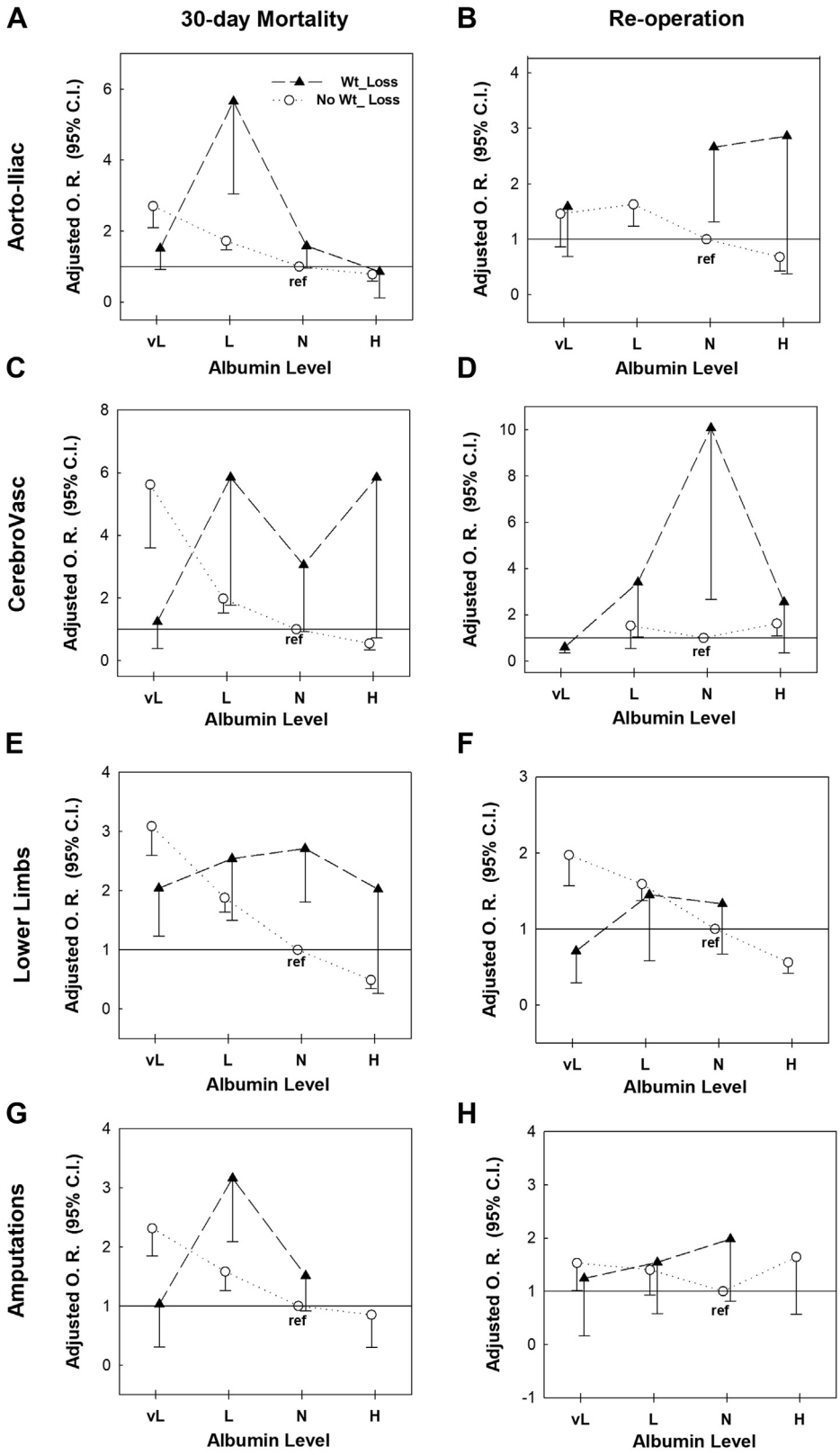

Fig 2. Adjusted odds ratio (*O.R.*) with 95% confidence interval (*C.I.*; *error bars*) for 30-day operative death (*left*) and reoperation (*right*) shown for the different vascular surgery types: **(A** and **B)**, aortoiliac; **(C** and **D)**, cerebrovascular; **(E** and **F)**, lower limbs; **(G** and **H)**, amputations. Each panel shows the derived adjusted odds ratio (AOR) in terms of albumin level category (*vL*, very low; *L*, low; *N*, normal; *H*, high) separately for patients with (*triangles*) and without (*circles*) recent significant weight loss (*Wt_Loss*).

effect on the generalizability of our main findings and that most of these patients will generally fall in the range of normal albumin levels and will have similar outcomes. Finally, these results apply only to the 30-day perioperative period available in the NSQIP data set.

CONCLUSIONS

Our study shows that accounting for nutritional status of patients through an indirect composite based on serum albumin levels and recent weight loss status may significantly enhance and possibly simplify risk prediction of outcomes in vascular surgery patients. These findings support a concerted effort to investigate the relative importance of this approach to other surgery cohorts in the ACS NSQIP as well as to extend them to other operative outcomes. Future studies should also consider investigating longer term outcomes.

AUTHOR CONTRIBUTIONS

Conception and design: JJ, AAA, WR, RH
Analysis and interpretation: LAS, EA, RH
Data collection: JJ, AAA, WR
Writing the article: JJ, AAA, WR
Critical revision of the article: LAS, EA, RH
Final approval of the article: JJ, AAA, WR, LAS, EA, RH
Statistical analysis: Not applicable
Obtained funding: Not applicable
Overall responsibility: RH
JJ and AAA contributed equally to this article and share co-first authorship.

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Submitted Mar 9, 2018; accepted Oct 23, 2018.

Additional material for this article may be found online at www.jvascsurg.org.

Supplementary Table I (online only). Vascular surgery categorization based on *Current Procedural Terminology* (*CPT*) codes

Surgery type	CPT codes
Aortoiliac	34800, 34802, 34803, 34804, 34805, 34825, 35082, 35091, 35092, 35102, 35103, 35131, 0078T, 0080T, 33880, 33881, 33877, 34151, 35631, 35631, 35637, 35560, 35531, 37220, 37221, 35638, 34900, 34812, 34831, 35081
Lower limb	35556, 35566, 35571, 35583, 35585, 35587, 35656, 35666, 35671, 35331, 35351, 35355, 35539, 35540, 35558, 35565, 35621, 35646, 35647, 35654, 35661, 35665, 34201, 34203, 35302, 35303, 35371, 35372, 35875, 35876, 34421, 37224, 37225, 37226, 37227, 37228, 35141, 35879, 35881, 35883, 35142, 35151
Amputations	27590, 27592, 27594, 27880, 27881, 27882, 27884, 27886, 27888, 28805, 27596, 28800
Cerebrovascular	35301, 35390, 35501, 35601, 35001, 37215, 34001, 34101
Other	All other vascular surgery CPT codes

Supplementary Table II (online only). Case complexity by surgery type

Surgery	Work RVUs, mean ± SD	Emergency, No. (%)	Operation time, minutes, mean ± SD
Aortoiliac	28 ± 10	2686 (19.6)	185 ± 105
Cerebrovascular	19 ± 2	986 (7.2)	116 ± 51
Lower limb	23 ± 6	4539 (33.1)	197 ± 109
Amputations	13 ± 2	1410 (10.3)	66 ± 38
Other	12 ± 9	4110 (29.9)	103 ± 95

RVUs, Relative value units.

Supplementary Table III (online only). Operative outcomes by presence of serum albumin level

	Albumin level available, No. (%)	Albumin level missing, No. (%)	*P* value
All vascular surgery	11,3936	11,7681	<.05
Operative death	5160 (4.5)	2108 (1.8)	<.01
Reoperation	2081 (1.8)	1374 (1.2)	<.01
Surgery type and outcome			
Aortoiliac surgery	19,697 (17.3)	18,536 (15.9)	
Operative death	1167 (5.9)	617 (3.3)	<.01
Reoperation	296 (1.5)	220 (1.2)	<.01
Cerebrovascular surgery	25,603 (22.5)	27,419 (23.3)	<.01
Operative death	340 (1.3)	212 (7.7)	<.01
Reoperation	165 (6.4)	147 (5.4)	.25
Lower limb surgery	30,958 (27.2)	31,294 (26.6)	
Operative death	1433 (1.4)	689 (2.2)	<.01
Reoperation	952 (3.1)	695 (2.2)	<.01
Amputation surgery	11,760 (10.3)	5308 (4.5)	
Operative death	1108 (9.4)	254 (4.7)	<.01
Reoperation	237 (2.0)	86 (1.6)	.33
Other vascular surgery	25,918 (22.7)	35,124 (29.8)	
Operative death	1112 (4.3)	336 (1.0)	<.01
Reoperation	431 (1.7)	226 (0.6)	<.01

Supplementary Table IV (online only). Adjusted odds ratios (*AORs*) for significant and clinically relevant risk factors

	Mortality		Reoperation	
Variables	**AOR (95% CI)**	***P* value**	**AOR (95% CI)**	***P* value**
Male	0.9 (0.85-0.96)	.001	1.11 (1.01-1.21)	.03
Age	1.04 (1.04-1.04)	<.001	1.00 (0.99-1.00)	.21
Race		.03		.04
Black	0.77 (0.7-0.84)	<.001	1.12 (1.002-1.27)	.047
White	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Other	0.96 (0.79-1.16)	.659	0.78 (0.57-1.06)	.11
Hispanic	0.77 (0.66-0.9)	.001		
ASA class				.004
No disturbance			1 (reference)	1 (reference)
Mild systemic disease			0.81 (0.54-1.21)	.3
Severe systemic disease			0.69 (0.47-1.01)	.05
Life-threatening disease			0.6 (0.41-0.89)	.01
Moribund			0.61 (0.33-1.14)	.12
Functional status		<.001		.001
Independent	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Partially dependent	1.8 (1.66-1.94)	<.001	0.99 (0.87-1.12)	.81
Totally dependent	4.44 (4.05-4.86)	<.001	0.66 (0.53-0.83)	<.001
BMI		<.001		.086
Underweight (<18.5 kg/m^2)	1.39 (1.23-1.57)	<.001	1.16 (0.95-1.42)	.16
Normal weight (18.5-24.9 kg/m^2)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Overweight (25.0-29.9 kg/m^2)	0.87 (0.81-0.94)	<.001	0.95 (0.85-1.06)	.37
Obese I (30.0-34.9 kg/m^2)	0.84 (0.76-0.92)	<.001	0.89 (0.78-1.02)	.09
Obese II (35.0-39.9 kg/m^2)	0.93 (0.81-1.06)	.25	1.11 (0.94-1.32)	.22
Obese III (≥40 kg/m^2)	0.96 (0.82-1.12)	.57	1.03 (0.84-1.27)	.75
Excessive alcohol consumption	1.14 (0.96-1.36)	.14	0.56 (0.41-0.75)	<.001
Dialysis	2.24 (2.06-2.44)	<.001	1.4 (1.23-1.6)	<.001
Hypertension			1.22 (1.08-1.4)	.001
Bleeding disorder			1.09 (0.98-1.2)	.12
Renal failure	1.56 (1.36-1.8)	<.001		
Ascites	2.94 (2.37-3.65)	<.001	0.39 (0.18-0.83)	.014
Cardiac history	1.18 (1.1-1.26)	<.001	1.55 (1.41-1.7)	<.001
Pulmonary history			1.11 (1.004-1.22)	.042
Smoking	1.11 (1.03-1.19)	.007	1.18 (1.07-1.3)	.001
CNS history	1.14 (0.96-1.35)	.13	1.7 (1.35-2.06)	<.001
Cancer history	3.06 (2.61-3.59)	<.001		
PVD history	0.88 (0.81-0.94)	<.001	0.7 (0.63-0.78)	<.001
Surgery type		<.001		<.001
Aortoiliac	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Cerebrovascular	0.41 (0.36-0.47)	<.001	0.59 (0.49-0.72)	<.001
Lower limb	0.66 (0.6-0.72)	<.001	2.15 (1.87-2.47)	<.001
Amputation	0.96 (0.85-1.08)	.493	1.31 (1.07-1.61)	.01
Other	0.71 (0.64-0.79)	<.001	1.23 (1.05-1.45)	.012
Total operation time	1.037 (1.032-1.041)	<.001	1.033 (1.027-1.040)	<.001
Emergency	3.64 (3.4-3.89)	<.001	1.8 (1.62-2.01)	<.001

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *CI*, confidence interval; *CNS*, central nervous system; *PVD*, peripheral vascular disease.
Variables shown are those that remained in the model with *P* value <.2. Odds for total operation time are calculated per 15-minute increments.
Variables included in the model: age, sex, race, ethnicity, American Society of Anesthesiologists class, functional status, body mass index, excessive alcohol consumption, diabetes, dialysis, renal failure, hypertension, bleeding disorder, ascites, cardiac history, pulmonary history, smoking, neurologic history, cancer, peripheral vascular disease, surgery type, operation time, and emergency status.

Supplementary Table V (online only). Area under the receiver operating characteristic curve (C statistic) of age, weight loss-albumin level, and all risk factors combined for 30-day mortality and reoperation

	Mortality			Reoperation		
	C statistic	SE	*P* value	C statistic	SE	*P* value
Age						
Surgery type						
All	0.63	0.004	<.001	0.53	0.006	<.001
Aortoiliac	0.6	0.009	<.001	0.53	0.017	.057
Cerebrovascular	0.63	0.016	<.001	0.54	0.023	.068
Lower limb	0.65	0.008	<.001	0.53	0.01	.004
Amputations	0.64	0.008	<.001	0.57	0.018	<.001
Others	0.67	0.008	<.001	0.57	0.013	<.001
Weight loss-albumin level						
Surgery type						
All	0.74	0.004	<.001	0.62	0.006	<.001
Aortoiliac	0.67	0.009	<.001	0.61	0.017	<.001
Cerebrovascular	0.67	0.016	<.001	0.59	0.023	<.001
Lower limb	0.7	0.007	<.001	0.59	0.009	<.001
Amputations	0.6	0.009	<.001	0.54	0.018	.027
Others	0.76	0.008	<.001	0.67	0.013	.001
Whole model						
Surgery type						
All	0.85	0.003	<.001	0.72	0.005	<.001
Aortoiliac	0.85	0.006	<.001	0.72	0.015	<.001
Cerebrovascular	0.8	0.013	<.001	0.67	0.022	<.001
Lower limb	0.83	0.005	<.001	0.67	0.009	<.001
Amputations	0.76	0.007	<.001	0.5	0.009	<.001
Others	0.88	0.005	<.001	0.74	0.011	<.001

SE, Standard error.