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RESEARCH ARTICLE

Nutritional status and out-of-hospital mortality in vascular surgery patients

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Data Availability Statement: The Partners Human Research Committee (PHRC) has determined that data from this study are available through the Nathan E. Hellman Memorial Laboratory for researchers who meet the criteria for access to confidential data, such as having internal review board approval to access the data as part of their research request. Access to data from this study is subject to review as noted as it contains potentially identifiable patient information. Authors from this study may be contacted through the Nathan Hellman Memorial Laboratory (chorkan@bwh).

Abstract

Background

Malnutrition is often present in vascular surgery patient during hospital admission. The present evidence of the consequence malnutrition has on morbidity and mortality is limited.

Aim

The purpose of this study was to determine the effect of nutritional status on out-of-hospital mortality in vascular surgery patients.

Methods

An observational cohort study was performed, studying non-cardiac vascular surgery patients surviving hospital admission 18 years or older treated in Boston, Massachusetts, USA. The exposure of interest was nutritional status categorized as well nourished, at-risk for malnutrition, nonspecific malnutrition or protein-energy malnutrition. The all cause 90-day mortality following hospital discharge was the primary outcome. Adjusted odds ratios were estimated by multivariable logistic regression models.

Results

This cohort included 4432 patients comprised of 48% women and a mean age 61.7 years. After evaluation by a registered dietitian, 3819 patients were determined to be well nourished, 215 patients were at-risk for malnutrition, 351 had non-specific malnutrition and 47 patients had protein-energy malnutrition. After adjustment for age, sex, ethnicity, medical versus surgical Diagnosis Related Group type, Deyo-Charlson index, length of stay, and vascular Current Procedural Terminology code category, the 90-day post-discharge mortality odds ratio for patients with non-specific malnutrition OR 1.96 (95%CI 1.21, 3.17) and for protein-energy malnutrition OR 3.58 (95%CI 1.59, 8.06), all relative to patients without malnutrition.

harvard.edu). The non-author contact information for data access is Patricia Reaser, preaser@bwh.harvard.edu, Administrative Director, Renal Division Brigham and Women's Hospital.

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Discussion

Nutritional status is a strong predictor of out-of-hospital mortality. This suggests that patient with vascular disease suffering from malnutrition could benefit from more intensified in-hospital and out-of-hospital dietary guidance and interventions.

Introduction

Malnutrition in hospitalized patients is common and associated with adverse outcomes yet is undervalued and often underreported [1–7]. Malnutrition in general and subspecialty surgical patients is an important predictor of increased hospital stay, major complications, hospital readmissions and mortality [8–11]. Adverse outcomes associated with malnutrition are heightened in the critically ill and elderly patients [12–14].

Data describing the effects of malnutrition on mortality and other adverse events in vascular surgery patients are limited to small studies [6, 15, 16]. Patients with pre-operative protein energy depletion more frequently develop systemic inflammatory response syndrome (SIRS) following major vascular surgery especially after open vascular surgery [17]. In amputation patients, known for their high pre-existing co-morbidities, pre-operative hypoalbuminemia is associated with increased perioperative mortality [16]. This association is also known for aortic aneurysm patients [18]. As albumin is also a negative acute phase reactant it may be more an indicator of inflammation rather than malnutrition directly as the inflammation is a contributor to the development of malnutrition. Existing malnutrition studies in vascular surgery focus on in-hospital outcomes. Outcomes in survivors of hospitalization are unexplored in vascular surgery patients.

Therefore we performed an observational study on inpatients who underwent vascular surgery and survived hospitalization. We utilized data determined by a registered dietitian (RD) evaluation to study the association of nutrition status and post-discharge outcomes. We hypothesized that patients who underwent vascular surgery and survived hospitalization, malnutrition would independently be associated with mortality and other adverse events following hospital discharge.

Materials and methods

Source population

Administrative and laboratory data were extracted from individuals admitted to Brigham and Women's Hospital (BWH) in Boston, Massachusetts, USA. BWH is a 793 bed primary and tertiary care facility that provides full spectrum vascular surgery to an ethnically and socioeconomically diverse population within eastern Massachusetts and the surrounding area.

Data sources

Data on eligible patients were obtained through the Research Patient Data Registry (RPDR) between 2004 and 2012. The RPDR is a computerized registry that serves as a central data warehouse for all inpatient and outpatient records at Partners HealthCare sites [19, 20] including the BWH and Massachusetts General Hospital (MGH). The RPDR has been used for other clinical research studies, and mortality and coding data from the RPDR have been validated [5, 21]. Since 2004, the Department of Nutrition at the BWH has collected inpatient nutrition information in an electronic data capture system. The nutrition status evaluations are

performed by RDs who collect data related to energy and protein intake, wasting of muscle mass and subcutaneous fat as well as weight loss [22]. Approval for the study was granted by the Partners Human Research Committee (Institutional Review Board). Requirement for individual patient consent was waived as the data were analysed anonymously.

Study population

Patients eligible for inclusion were hospitalized adults aged ≥ 18 years who were admitted to intensive care unit (ICU) or in-patient care ward and who underwent non-cardiac vascular surgery during their hospitalization and survived to hospital discharge. All patients were assigned at least one Current Procedural Terminology (CPT) code for vascular surgery [23] (S1 File), and were assigned a Diagnostic Related Group (DRG) code. Patients treated with open vascular surgery as well as endovascular procedures were included. In the analytic cohort we excluded patients who died in hospital, did not have vascular surgery related CPT codes assigned, a DRG code assigned or had missing data for confounding variables (age, sex, ethnicity, length of stay). Between 2004 and 2012, there were 4432 patients in the analytic cohort who met these inclusion criteria.

Exposure of interest and comorbidities

Malnutrition is diagnosed at BWH by an RD based on patient level data related to insufficient nutrient intake of energy or protein, wasting of muscle mass, and subcutaneous fat and unintentional weight loss [5, 9, 22]. In short, RDs screen all vascular surgery patients and those who are at risk are further evaluated with a formal structured objective assessment using clinical judgement and on data related to inadequate nutrient intake of energy and/or protein, wasting of muscle mass and/or subcutaneous fat and unintentional weight loss. Nutrient intake of energy and protein are determined by calorie counts of oral intake, documented intake of tube feedings and intravenous nutrient sources (dextrose, propofol, and parenteral nutrition). Energy needs are determined by the following: for BMI < 30 kg/m², basal metabolic rate is calculated based on body surface area [24] and age, then activity and stress factors are applied based on severity of illness (patients are generally fed between 30–35 kcal/kg). For BMI 30–35 kg/m² adjusted weight for obesity is calculated and used to calculate the basal metabolic rate based on body surface area and age, then activity and stress factors are applied based on severity of illness, similar to the approach for patients with a BMI < 30 kg/m² (these patients are generally fed between 25–35 kcal/kg). Critically ill patients with BMI 35–50 kg/m² are fed at 14 kcal/kg dry weight, and those with BMI > 50 kg/m² are fed at 25 kcal/kg ideal body weight [25–27].

Nutrition diagnoses were categorized a priori into malnutrition absent, at risk for malnutrition, nonspecific malnutrition, or any protein-energy malnutrition [22]. Patients were categorized as nonspecific malnutrition if the patient had known risk factors (inadequate nutrient intake of energy, protein, and micronutrients) with metabolic stress (increased calorie requirement) and/or overt signs of malnutrition (wasting of muscle mass and/or subcutaneous fat) without supporting anthropometric or biochemical data present. Metabolic stress factors are utilized from prior work which measured disease specific energy expenditure relative to the predicted energy expenditure via the Harris-Benedict equation [28]. To be categorized as protein-energy malnutrition, patients must have a combination of disease-related weight loss, underweight status based on percent ideal body weight [29], overt muscle wasting, peripheral oedema, inadequate energy, or protein intake. Serum albumin, total lymphocyte count, and transferrin are part of the malnutrition criteria but RDs are trained to consider these as invalid markers of nutrition in patients with significant inflammation, altered volume status, and

other conditions where these markers would be altered as a result of illness. Malnutrition was categorized as absent if patients were diagnosed as well-nourished and not at risk for malnutrition. For this study, malnutrition was considered present if the patient was diagnosed by an RD with non-specific malnutrition, mild protein-energy malnutrition, moderate protein-energy malnutrition, severe protein-energy malnutrition, marasmus, or kwashiorkor. The criteria per malnutrition category is listed in [S1 File](#).

DRG type was defined as medical or surgical and incorporates the Diagnostic Related Grouping (DRG) methodology, devised by the Centres for Medicare & Medicaid Services and is reflective of case mix and resource utilization [21–23, 30]. Ethnicity was either self-determined or designated by a patient representative/healthcare proxy. We utilized validated International Classification of Diseases, Ninth Revision (ICD-9) coding algorithms to derive the Deyo-Charlson index comorbidity score to assess the burden of chronic illness for each patients [31–33]. We used the Healthcare Cost and Utilization Project Clinical Classification Software (CCS) multi diagnosis categories to determine diabetes, hypertension, congestive heart failure, chronic obstructive pulmonary disease, cirrhosis, and metastatic malignancy [34]. For the Deyo-Charlson index and the CCS data, chronic diagnoses were determined by ICD-9 codes assigned as outpatients or inpatients. Patients considered Emergent were admitted to the hospital via the emergency room while non-Emergent patients were admitted to the hospital following referral from an outpatient clinic or another facility. CPT code assignment was determined from dated daily clinician billing and defined according to the CPT code set maintained and published yearly by the American Medical Association [35–38]. A total of 162 vascular surgery related CPT codes were combined into Vascular Surgery Procedure Code Categories ([S2 File](#)).

End points

The primary end point was 90-day all-cause mortality following hospital admission. Information on mortality was obtained through the Social Security Administration Death Master File which has previously been validated in our dataset for in-hospital and out-of-hospital mortality [21]. Death Master File data indicated that one hundred percent of the parent and analytic cohorts had vital status (alive or deceased) determined at 365 days following hospital discharge. The censoring date was December 31, 2013, and 100% of the parent and analytic cohorts had at least 90-day mortality follow-up after hospital discharge.

Secondary outcomes were unplanned 30-day hospital readmission to the BWH or MGH, discharge to a care facility and 365-day mortality. Thirty-day hospital readmission was determined from RPDR hospital admission data as previously described [39] and defined as a subsequent or unscheduled admission to BWH or MGH within 30 days of discharge following the hospitalization associated with the vascular surgery or intervention [23, 40, 41]. We excluded 73 readmissions with DRG codes that are commonly associated with planned readmissions in addition to DRGs for transplantation, procedures related to pregnancy, and psychiatric issues [39, 40].

Power calculations and statistical analysis

Based on prior studies [5, 39, 42, 43], we assumed that 90-day post-discharge hospital mortality would increase a relative 50% in patients with malnutrition (7.5%) compared to those without malnutrition (5%). With an alpha error level of 5% and a power of 80%, the minimum sample size thus required for our primary end point is 4,096 total patients.

Categorical covariates were described by frequency distribution and compared across nutrition status groups using contingency tables and chi-square testing. Continuous covariates

were examined graphically and in terms of summary statistics and compared across nutrition status groups using one-way analysis of variance (ANOVA). Unadjusted associations between nutrition status groups and outcomes were estimated by bivariable logistic regression analysis. Adjusted odds ratios [44] were estimated by multivariable logistic regression models with inclusion of covariate terms thought to plausibly interact with both nutrition status and mortality. Overall model fit was assessed using the Hosmer-Lemeshow (HL) test. The performance of the model was assessed by the area under the receiver operating curve. Analyses based on fully adjusted models were performed to evaluate the malnutrition-mortality association, and P-interaction was determined to explore for any evidence of effect modification. All P values presented are 2-tailed; values below .05 were considered nominally significant. All analyses were performed using STATA 14.2MP (StataCorp LP, College Station, TX).

Results

In [Table 1](#) the characteristics of the 4432 patient analytic cohort were stratified according to 90-day post-discharge mortality. Most patients were men (52%), white (82%) with a mean (SD) age of 61.7 (16.7) years. The 90, 180 and 365-day post-discharge mortality rates were 3.6%, 5.9% and 9.1%, respectively. After hospitalization, 62.8% were discharged home. The 30 day hospital readmission rate was 11.5%. The median [IQR] in-hospital length of stay was 5 [1, 11] days. Factors that were associated with increased 90-day post-discharge mortality included higher age, medical DRG type, higher Deyo-Charlson index, diabetes, congestive heart failure, chronic obstructive pulmonary disease, cirrhosis, metastatic malignancy, chronic kidney disease, nutritional status, increased length of stay in hospital, discharge to facility and 30-day hospital readmission ([Table 1](#)). Vascular Surgery Procedure Code Categories associated with increased 90-day post-discharge mortality were embolectomy or thrombectomy, graft excision, major amputation, and blood vessel repair ([S1 Table](#)).

Patient characteristics were stratified according to nutritional status categories ([Table 2](#)). Significant differences were observed in patient age, ethnicity, DRG type, Deyo-Charlson index, congestive heart failure, chronic obstructive pulmonary disease, chronic kidney disease, emergent hospitalization, hospital length of stay, and 30 day readmission with respect to nutrition status categories. Details on Vascular Surgery Procedure Code Categories relative to nutrition status categories are presented in [S2 Table](#).

In the analytic cohort (N = 4432) comprising survivors of hospitalization, nutrition status was a significant predictor mortality 90 days following hospital discharge ([Fig 1](#), [Table 3](#)). Nutritional status remained a significant predictor of 90-day post-discharge mortality after adjustment for age, sex, ethnicity, Deyo-Charlson Index, DRG type, length of stay and vascular procedure code category ([Table 3](#), Model 3). The adjusted odds of 90-day post-discharge mortality in patients with nonspecific malnutrition or protein-energy malnutrition were 2.0-fold and 3.6-fold higher, respectively, relative to patients without malnutrition. The adjusted 90-day post-discharge mortality model showed good calibration (Hosmer-Lemeshow χ^2 8.4, P = 0.40) and good discrimination for 90-day post-discharge mortality (c-statistic = 0.83, 95% CI, 0.80–0.87).

Next, the association of malnutrition status and mortality following hospital discharge was analysed separately for men and women. Nonspecific malnutrition and specific protein-calorie malnutrition groups were combined due to low power. The 90-day post-discharge mortality rates were 3.3% in women and 3.9% in men. The adjusted associations of 90-day post-discharge mortality in patients with nonspecific malnutrition or protein-energy malnutrition had similar directionality, effects sizes and significance in both men and women ([Table 4](#)). There is

Table 1. Characteristics and unadjusted association of potential prognostic determinants of 90-day post discharge mortality^a (n = 4,432).

Characteristic	Alive ^a	Expired	Total	P-value	OR of 90-day post-discharge mortality (95%CI)
N	4271	161	4432		
Age-Mean ± SD	61.2 ± 16.6	72.9 ± 14.9	61.7 ± 16.7	<0.001 [†]	1.06 (1.04, 1.07)
Female Sex-No.(%)	2043 (48)	70 (43)	2113 (48)	0.28	0.84 (0.61, 1.15)
Ethnicity				0.59	
White-No.(%)	3498 (82)	132 (82)	3630 (82)		1.00 (Referent)
Asian-No.(%)	73 (2)	1 (1)	74 (2)		0.36 (0.05, 2.63)
Black-No.(%)	255 (6)	10 (6)	265 (6)		1.04 (0.54, 2.00)
Hispanic-No.(%)	122 (3)	2 (1)	124 (3)		0.43 (0.11, 1.78)
Not Recorded-No.(%)	247 (6)	11 (7)	258 (6)		1.18 (0.63, 2.21)
Other-No.(%)	71 (2)	5 (3)	76 (2)		1.74 (0.69, 4.38)
Non-White Ethnicity-No.(%)	773 (18)	29 (18)	802 (18)	0.98	0.99 (0.66, 1.50)
Medical DRG Type-No.(%)	702 (16)	48 (30)	750 (17)	<0.001	2.16 (1.53, 3.06)
Deyo-Charlson Index-Mean ± SD	2.7 ± 2.4	4.8 ± 2.8	2.8 ± 2.5	<0.001 [†]	1.28 (1.22, 1.34)
Diabetes-No.(%)	929 (22)	49 (30)	978 (22)	0.009	1.57 (1.12, 2.22)
Hypertension-No.(%)	1832 (43)	73 (45)	1905 (43)	0.54	1.10 (0.81, 1.52)
Congestive Heart Failure-No.(%)	653 (15)	62 (39)	715 (16)	<0.001	3.47 (2.50, 4.82)
Chronic Obstructive Pulmonary Disease-No.(%)	243 (6)	22 (14)	265 (6)	<0.001	2.62 (1.64, 4.19)
Cirrhosis-No.(%)	24 (1)	7 (4)	31 (1)	<0.001	8.04 (3.41, 18.95)
Metastatic Malignancy-No.(%)	48 (1)	5 (3)	53 (1)	0.023	0.82 (1.11, 7.18)
Chronic Kidney Disease-No.(%)	248 (6)	21 (13)	269 (6)	<0.001	2.43 (1.51, 3.92)
Endovascular-No.(%)	2013 (47)	85 (53)	2098 (47)	0.16	1.26 (0.92, 1.72)
Emergent Hospital Admission-No.(%)	858 (20)	41 (25)	899 (20)	0.096	1.36 (0.95, 1.95)
Nutrition Status				<0.001	
No malnutrition-No.(%)	3704 (87)	115 (71)	3819 (86)		1.00 (Referent)
At risk for malnutrition-No.(%)	206 (5)	9 (6)	215 (5)		1.41 (0.70, 2.81)
Non-specific malnutrition-No.(%)	324 (8)	27 (17)	351 (8)		2.68 (1.74, 4.14)
Protein-energy malnutrition-No.(%)	37 (1)	10 (6)	47 (1)		8.71 (4.23, 17.93)
Length of Stay days-Median [IQR]	5 [1, 11]	12 [6, 22]	5 [1, 11]	<0.001 [‡]	1.02 (1.01, 1.02)
Discharge to Home-No.(%)	2738 (64)	47 (29)	2785 (63)	<0.001	0.23 (0.16, 0.33)
30-day Readmission-No.(%)	463 (11)	47 (29)	510 (12)	<0.001	3.39 (2.38, 4.83)

Data presented as No. (%) unless otherwise indicated. P determined by chi-square except for † determined by ANOVA or ‡ determined by Kruskal-Wallis test.

a. Expired within 90-days following hospital discharge.

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no significant effect modification of the nutrition status-mortality association on the basis of sex (interaction p = 0.30).

Finally, we analysed the association of malnutrition status with other outcomes following hospital discharge. Univariate data show that malnourished patients were significantly less likely to be discharged to home and more likely to be readmitted to hospital (Tables 2 & 5). Such significant associations were also present following multivariable adjustment, patients with malnutrition have a 52% lower odds of being discharged to home and a 50% higher odds of 30-day hospital readmission (Table 5).

Discussion

Malnutrition in hospitalized patients is a robust risk factor for adverse outcomes [45]. In our study we evaluated the association between malnutrition and major post-discharge outcomes in vascular surgery patients. We demonstrate that malnutrition in vascular surgery patients

Table 2. Characteristics of the study cohort stratified by nutritional status (n = 4,432).

Characteristic	No malnutrition	At risk for malnutrition	Non-specific malnutrition	Protein-energy malnutrition	P-value
N	3,819	215	351	47	
Age-Mean \pm SD	62 \pm 16.5	58.9 \pm 17.2	59.3 \pm 17.8	64.4 \pm 17.7	0.001†
Female Sex-No.(%)	1821 (48)	110 (51)	161 (46)	21 (45)	0.64
Ethnicity					0.010
White-No.(%)	3144 (82)	159 (74)	289 (82)	38 (81)	
Asian-No.(%)	61 (2)	5 (2)	6 (2)	2 (4)	
Black-No.(%)	221 (6)	19 (9)	23 (7)	2 (4)	
Hispanic-No.(%)	93 (2)	15 (7)	15 (4)	1 (2)	
Not Recorded-No.(%)	227 (6)	15 (7)	13 (4)	3 (6)	
Other-No.(%)	73 (2)	2 (1)	5 (2)	1 (2)	
Non-White Ethnicity-No.(%)	675 (18)	56 (26)	62 (18)	9 (19)	0.021
Medical DRG Type-No.(%)	226 (6)	17 (8)	14 (4)	8 (17)	<0.001
Deyo-Charlson Index-Mean \pm SD	2.6 \pm 2.4	4.0 \pm 2.7	3.7 \pm 2.8	5.1 \pm 3.3	<0.001†
Diabetes-No.(%)	844 (22)	46 (21)	78 (22)	10 (21)	0.99
Hypertension-No.(%)	1669 (44)	78 (36)	136 (39)	22 (47)	0.055
Congestive Heart Failure-No.(%)	551 (14)	52 (24)	99 (28)	13 (28)	<0.001
Chronic Obstructive Pulmonary Disease-No.(%)	226 (6)	17 (8)	14 (4)	8 (17)	0.003
Cirrhosis-No.(%)	21 (1)	4 (2)	6 (2)	0 (0)	
Metastatic Malignancy-No.(%)	40 (1)	4 (2)	7 (2)	2 (4)	0.068
Chronic Kidney Disease-No.(%)	201 (5)	18 (8)	37 (11)	13 (28)	<0.001
Endovascular-No.(%)	1806 (47)	115 (53)	157 (45)	20 (43)	0.20
Emergent Hospital Admission-No.(%)	690 (18)	74 (34)	124 (35)	11 (23)	<0.001
Length of Stay days-Median [IQR]	4 [1, 8]	17 [11, 23]	19 [14, 28]	17 [10, 27]	<0.001‡
Discharge to Home-No.(%)	1722 (45)	20 (9)	21 (6)	4 (9)	<0.001
30-day Readmission-No.(%)	394 (10)	38 (18)	67 (19)	11 (23)	<0.001

Data presented as No. (%) unless otherwise indicated. P determined by chi-square except for

† determined by ANOVA or

‡ determined by Kruskal-Wallis test.

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was strongly associated with out-of-hospital mortality. In addition to this, vascular surgery patients with malnutrition had a significantly less likelihood of being discharged to home compared to those without malnutrition. These findings confirm the intuitive reasoning that malnutrition contributes to adverse events in vascular surgery patients even after hospital discharge.

The ACC-AHA Guidelines for the Management of Patients with peripheral artery disease (PAD) recommend that patients should be treated with an interdisciplinary care team including a dietitian and should be prescribed a heart-healthy diet like all other cardiovascular disease patients [46]. Although this seems logical as PAD belongs within the spectrum cardiovascular diseases, the guideline also identifies the existence of an evidence gap in the role of dietary intervention to improve outcomes in PAD patients which is especially apparent peri-operatively. Also, in the Global Vascular guidelines on the management of critical limb-threatening ischemia, malnutrition is only mentioned to have an influence on wound healing and it is mentioned that a nutritionist should be included in a multidisciplinary team to prevent amputations in diabetic patients [47].

There is no specific evidence presented on nutritional diagnostics or interventions and consequently no recommendations are made in the ACC-AHA Guidelines. The current dietary

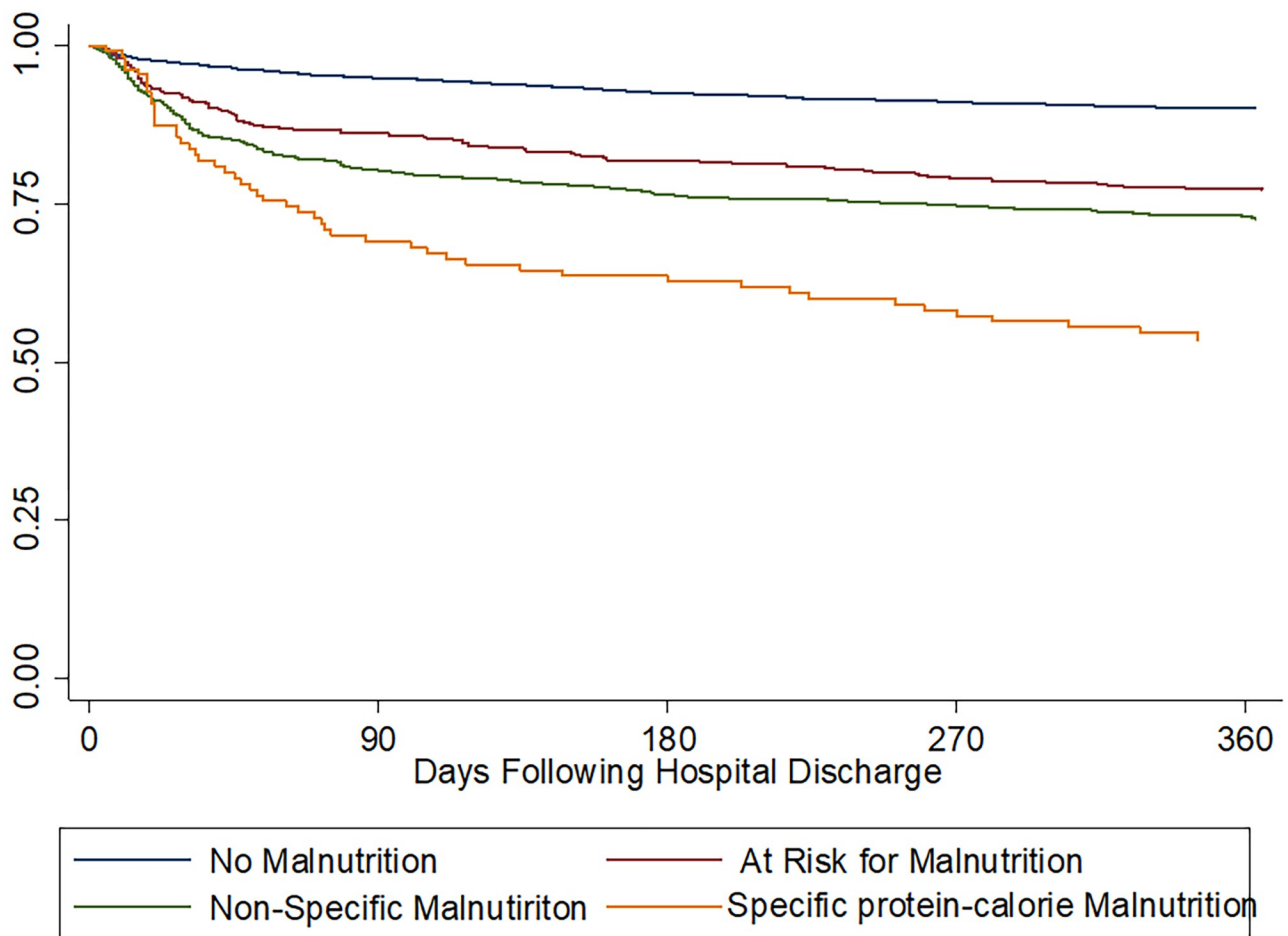


Fig 1. Time-to-event curves for mortality. Unadjusted mortality rates were calculated with Kaplan-Meier methods and compared with the log-rank test. Categorization of nutrition groups is per the primary analysis. The global comparison log rank P value is <0.001, indicating significantly different survival patterns.

<https://doi.org/10.1371/journal.pone.0270396.g001>

Table 3. Unadjusted and adjusted associations between nutrition status and 90-day post-discharge mortality (n = 4,432).

	Nutrition Status			
	No malnutrition ^a	At risk for malnutrition	Non-specific malnutrition	Protein-energy malnutrition
<i>90-day Post-Discharge Mortality</i>				
Crude	1.00 (Referent)	1.41 (0.70, 2.81) P = 0.334	2.68 (1.74, 4.14) P<0.001	8.71 (4.23, 17.93) P<0.001
Adjusted ^b	1.00 (Referent)	1.01 (0.49, 2.08) P = 0.970	1.95 (1.22, 3.11) P = 0.005	4.42 (2.01, 9.76) P<0.001
Adjusted ^c	1.00 (Referent)	0.98 (0.47, 2.05) P = 0.97	1.96 (1.21, 3.17) P = 0.006	3.58 (1.59, 8.06) P = 0.002
Adjusted ^d	1.00 (Referent)	0.94 (0.45, 1.99) P = 0.88	2.04 (1.26, 3.30) P = 0.004	4.36 (1.91, 9.93) P<0.001

Note

- a. Referent in each case is absence of malnutrition.
- b. Model 1: Estimates adjusted for age, sex, ethnicity, Deyo-Charlson index, DRG type, and length of stay.
- c. Model 2: Estimates adjusted for age, sex, ethnicity, Deyo-Charlson index, DRG type, length of stay and vascular procedure code category.
- d. Model 3: Estimates adjusted for age, sex, ethnicity, DRG type, length of stay, vascular procedure code category, diabetes, hypertension, congestive heart failure, chronic obstructive pulmonary disease, cirrhosis, metastatic malignancy, and chronic kidney disease.

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Table 4. Unadjusted and adjusted associations between nutrition status and 90-day post-discharge mortality relative to sex.

	Nutrition Status		
	No malnutrition ^a	At risk for malnutrition	Non-specific or Protein-energy malnutrition
Women (n = 2113)			
90-day Post-Discharge Mortality			
Crude	1.00 (Referent)	1.69 (0.66, 4.32) P = 0.28	3.18 (1.75, 5.79) P<0.001
Adjusted ^b	1.00 (Referent)	1.40 (0.49, 4.01) P = 0.53	2.14 (1.08, 4.25) P = 0.029
Men (n = 2319)			
90-day Post-Discharge Mortality			
Crude	1.00 (Referent)	1.18 (0.42, 3.30) P = 0.31	3.37 (2.03, 5.59) P<0.001
Adjusted ^b	1.00 (Referent)	0.77 (0.26, 2.27) P = 0.63	2.36 (1.31, 4.26) P = 0.004

Note

a. Referent in each case is absence of malnutrition.

b. Model 4: Estimates adjusted for age, ethnicity, Deyo-Charlson index, DRG type, length of stay and vascular procedure code category.

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evidence to prevent or treat vascular disease consists of retrospective and cross-sectional studies mainly with the outcome walking distance but lacks successful interventional clinical trials [48–52]. In the European guideline for abdominal aortic aneurysms it is recommended to measure serum albumin to assess the nutritional status of the patient [53]. This is based on research that identifies the association between pre-operative hypoalbuminemia and 30 day post-operative outcomes [18]. However, clinicians must recognize that albumin is a poor indicator of nutritional status since it is a negative acute phase protein and a low level may be more indicative of inflammation rather than malnutrition [54]. It is also advised to correct for any nutritional deficiencies by referral to an RD although the efficacy of this intervention has not been demonstrated by a randomized clinical trial [53]. Future research should focus more on dietary intervention for patients with vascular disease as a secondary prevention intervention but also as a peri-operative intervention to improve adverse outcomes and the effect of co-morbidities on malnutrition in vascular surgery patients.

The knowledge of how nutrition might influence post-discharge outcomes after vascular surgery can help surgeons to improve risk stratification and personalize postoperative care. If patients are electively admitted, prior dietary optimization could lower perioperative risk. Understanding what the risk of death comprises following vascular surgery is vital in the

Table 5. Unadjusted and adjusted associations between nutrition status and post-discharge outcomes (n = 4,432).

	Nutrition Status		
	No malnutrition ^a	At risk for malnutrition	Non-specific or Protein-energy malnutrition
Discharge to Home			
Crude	1.00 (Referent)	0.22 (0.16, 0.29) P<0.001	0.17 (0.14, 0.22) P<0.001
Adjusted ^b	1.00 (Referent)	0.47 (0.33, 0.66) P<0.001	0.48 (0.36, 0.63) P<0.001
30-day Hospital Readmission			
Crude	1.00 (Referent)	1.87 (1.29, 2.69) P = 0.001	2.12 (1.62, 2.77) P<0.001
Adjusted ^c	1.00 (Referent)	1.44 (0.98, 2.11) P = 0.063	1.65 (1.24, 2.21) P = 0.001

Note

a. Referent in each case is absence of malnutrition.

b. Model 5: Estimates adjusted for age, sex, ethnicity, Deyo-Charlson index, DRG type, length of stay and vascular procedure code category.

c. Model 6: Estimates adjusted for age, sex, ethnicity, Deyo-Charlson index, DRG type, length of stay and vascular procedure code category.

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decision-making process for surgeon, patient and their family [55]. Unfortunately, no peri-operative risk scores include nutritional status for risk stratification in vascular surgery patients due to lack of evidence [56, 57]. Our data show that malnutrition is clearly related to the severity of co-morbidities, i.e. the Deyo-Charlson index, and therefore was included as a confounder in the multivariable analysis of outcomes. Taken into account the severity of co-morbidities malnutrition does show to be a robust risk factor for adverse outcomes following hospital discharge. The inclusion of the nutritional status in the pre-operative decision making process can aid in the counselling of patients and their family by providing information on prognostic factors.

Nutritional status is a potentially modifiable risk factor. In the postoperative setting, nutritional status optimization may help vascular surgery patients who are more likely to develop adverse events. This is corroborated by our findings that patients with malnutrition had a lower chance of discharge to home as well as higher mortality risk. These patients may benefit from an intensified follow-up in the care facility or in their own home. For example, in cardiac surgery patients who are discharged from the hospital, frequent home visits by a hospital nurse practitioner in the post-discharge period improved readmission and mortality rates [9, 58]. These kind of interventions aimed to improve post-discharge care could potentially improve outcomes for vascular surgery patients as well.

Potential limitations of this study include ascertainment bias as only vascular surgery patients deemed at nutritional risk were fully evaluated by an RD. This can limit the generalizability of the study findings. Despite multivariable adjustment, residual confounding is likely to be present. By determining covariates on the basis of ICD-9 codes it is likely that comorbidities are underestimated [59]. Though MGH and BWH contain 55% of hospital beds in Boston, we are not able to determine all readmissions to all hospitals for each patient. Lastly, although the BWH inpatient nutrition status evaluations have been shown to be predictive of outcomes, they are based on the malnutrition definitions guidelines that were recommended at the time of data collection and not perfectly aligned with the newest guidelines [5, 44]_ENREF_37.

The study has several strengths. The cohort contains a large number of vascular surgery patients which results in ample statistical power to detect a clinically relevant difference in 90-day post-discharge mortality if one exists. Linkage to the SSA Master Death file allows for out of hospital follow-up with high accuracy which was previously validated in our dataset [21]. The RPDR data sources have been validated for CPT code assignment [21], ICD-9 diagnosis [60, 61], and demographics [60]. Finally, all patients were screened for nutrition risk. Those at risk were assessed in-person for malnutrition risk by a highly trained nutrition professional rather than relying on self-reported malnutrition assessment surveys.

Conclusions and implications

These data demonstrate that in vascular surgery patients, malnutrition is associated with increased post-discharge mortality. Further, those with malnutrition are more likely not to be discharged to home and to be readmitted to the hospital within 30 days. As malnutrition is a potentially modifiable risk factor, improvement of nutritional status may be a target for intervention in the already vulnerable vascular surgery patient population.

Supporting information

S1 File. Supplemental methods.
(DOCX)

S2 File. Supplemental data.

(DOCX)

S1 Table. Characteristics of vascular surgery procedure code categories stratified by 90-day post discharge mortality in the analytic cohort (n = 4432).

(DOCX)

S2 Table. Characteristics of vascular surgery procedure code categories stratified by nutritional status in the analytic cohort (n = 4432).

(DOCX)

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