AN EVALUATION OF THE VALIDITY OF NUTRITION SCREENING AND ASSESSMENT TOOLS IN PATIENTS ADMITTED TO A VASCULAR SURGERY UNIT

Jolene Thomas[1], Billingsley Kaambwa[2], Christopher Delaney[2,3], Michelle Miller[1]

[1] College of Nursing and Health Sciences, Flinders University, Bedford Park South Australia.

[2] College of Medicine and Public Health, Flinders University, Bedford Park South Australia

[3] Department Vascular and Endovascular Surgery, Southern Adelaide Local Health Network, Adelaide South Australia.

Corresponding Author:

Jolene Thomas

Nutrition and Dietetics, Flinders University

GPO BOX 2100 Adelaide

South Australia 5001

Ph: +61 8 7221 8857 fax: +61 8 204 6406

Email: jm.thomas@flinders.edu.au

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Abstract

Vascular surgery patients are nutritionally vulnerable. Various malnutrition screening and assessment tools are available however none were developed or validated in vascular patients. This study aimed to: (1) investigate the validity of four commonly administered malnutrition screening tools (Malnutrition Screening Tool (MST), Malnutrition Universal Screening Tool (MUST), Nutrition Risk Screen -2002 (NRS-2002) and the Mini-Nutritional Assessment – Short Form (MNA-SF)) and an assessment tool the Patient- Generated Subjective Global Assessment, (PG-SGA) compared against a comprehensive Dietitian's assessment and (2) evaluate the ability of the instruments to predict outcomes. Vascular inpatients were screened using the four malnutrition screening tools and assessed using the PG-SGA. Each was assessed by a Dietitian incorporating nutritional biochemistry, anthropometry and changes in dietary intake. Diagnostic accuracy, consistency and predictive ability were determined. Three hundred and twenty two (69.3% male) patients participated, with 75% having at least one parameter indicating nutritional deficits. No instrument achieved the a-priori levels for sensitivity (14.9-52.5%). Neither tool predicted EQ-5D-5L score. All tools except the MNA-SF were associated with length of stay, however the direction varied with increased risk of malnutrition on the MUST and NRS-2002 being associated with shorter LOS (p=0.029 and 0.045) and the reverse with the MST and PG-SGA (p=0.005 and <0.001). The NRS-2002 was associated with increased risk of complications (p=0.039). The MST, NRS-2002 and PG-SGA were predictive of discharge to an institution (p= 0.004, 0.005 and 0.003). The tools studied were unable to identify the high prevalence of undernutrition hence vascular disease-specific screening and/or assessment tools are warranted.

Introduction

Malnutrition, specifically undernutrition, refers to deficiencies or imbalances in the intake of energy and/or nutrients which can lead to weight loss, muscle wasting and micronutrient deficiencies or insufficiencies.[1] In vascular surgery patients, studies have reported rates of malnutrition as high as 60-90% based on a variety of assessment methods and tools.[2-4] Previous work by the authors revealed that 16% of patients admitted to a tertiary acute care vascular surgery unit were malnourished according to the Patient-Generated Subjective Global Assessment (PG-SGA).[5]

The identification and management of malnutrition in patients admitted to a vascular surgery unit is critical due to its reported association with poorer clinical outcomes. [6-8] Despite these consequences and the prevalence observed, malnutrition across clinical specialties remains under-recognised despite the availability of a number of validated malnutrition screening tools.

A malnutrition screening tool should be quick and simple to administer and able to be completed by an individual with minimal training or by the patients themselves. A variety of tools exist with commonly used ones being the Malnutrition Screening Tool (MST),[9] Malnutrition Universal Screening Tool (MUST),[10] the Nutrition Risk Screen -2002 (NRS-2002)[11] and the Mini-Nutritional Assessment – Short Form (MNA-SF).[12] A detailed description of each of these tools is available elsewhere,[9-12] but in summary, each tool consists of a number of items (2 to 6) pertaining to nutritional parameters known to be associated with malnutrition, with a weighted scoring system for each item and a defined cut-off score to indicate possible malnutrition, warranting further investigation by a Dietitian. It is well recognised that malnutrition screening tools need to be validated for the population in which they are to be administered to expedite nutrition assessment and interventions where indicated and allow resources to be used efficiently.[13] All four tools mentioned have been validated across a number of patient populations[14-20] and in a variety of settings.[17, 21-24]

In some settings a standardised approach to nutrition assessment is undertaken using a validated nutrition assessment tool. A commonly used tool is the scored Patient-Generated Subjective Global Assessment (PG-SGA), which awards patients with a score and a global rating of nutritional status. A detailed description of the PG-SGA can be found elsewhere.[25] While originally developed in cancer patients[26] the PG-SGA has since been validated in a number of patient groups[27-29] with high levels of sensitivity (92-100% and specificity (84-96.7%).

To date, neither malnutrition screening tools or the PG-SGA have been validated specifically in patients with vascular disease, a group characterised by a heterogeneous aetiology of disease and

presence of complex comorbidities that are growing in prevalence. Hence it is critical that we investigate methods to identify those who are nutritionally vulnerable to optimise their nutritional health and overall clinical outcomes. Therefore, the aims of this study were to (1) investigate the validity of the four commonly adopted malnutrition screening tools (the MST, MUST, NRS-2002 and the MNA-SF), and a commonly used nutritional assessment tool (PG-SGA) when compared against a dietitians clinical assessment in inpatients admitted to a vascular surgery unit and (2) evaluate the ability of the malnutrition screening tools and the PG-SGA to predict clinical outcomes, namely length of hospital stay, in-hospital complications, quality of life and discharge destination in the same population.

Methods

Study Sample

Participants were recruited consecutively from the Southern Adelaide Health Local Network (SAHLN) Vascular Surgery Unit, Adelaide Australia. Participants were aged 18 years and over and were able to provide informed written consent or where this was not appropriate, consent was obtained from the participant's legal next of kin/guardian. Participants were excluded if they presented to the emergency department without admission to the Vascular Surgery Unit or were subsequently transferred to a private hospital, or if they were admitted for day procedures only. Those who were admitted to the vascular unit were excluded if they were unable to be recruited within 72 hours of admission. Participants recruited to the study during previous admissions were also excluded. This study received ethical approval from the Southern Adelaide Health Research and Ethics Committee (approval number 258.14) and governance approval from the Flinders Medical Centre.

Data collection

Data were collected between October 2014 and August 2016. All demographic data and admission/discharge details were collected by the research team. Nutrition screening was completed by nursing staff on the vascular surgery unit within 24 hours of recruitment. Where this was not possible, a member of the research team completed the screening. Nutrition assessment was completed by the research Accredited Practising Dietitian at the bedside within 72 hours of admission to the ward, accompanied by blood test results relating to nutrient biochemistry.

Demographic data were collected from the medical records and included age, gender, and type of vascular disease. Vascular disease types were classified according to surgeon diagnosis as

aneurysmal, peripheral arterial disease (PAD) (encompassing aorto-iliac and infra-inguinal disease), occlusive other (encompassing carotid and upper limb ischaemia), venous, diabetic foot infection and other. Those classified as other included renal access, surgical management of thoracic outlet syndrome, trauma, ulcers of mixed or unknown aetiology, admission for post-operative complications and lower limb infection not attributed to occlusive disease or diabetes.

Malnutrition Screening

Data required for completion of the four malnutrition screening tools (MST, MUST, NRS-2002 and MNA-SF) were completed on entry to the study. This included the collection of body weight, using a calibrated weigh chair (HVL-CS Hospital Chair Scale, A&D Mercury Pty Ltd) in light clothing and recorded to the nearest 0.1kg, and ulna length to allow for the estimation of height (BAPEN). Following discharge, the research dietitian scored each of the four screening tools. Participants were classified as 'at risk of malnutrition' for each tool separately if they scored 2 or more on the MST or MUST, 3 or more on the NRS-2002, and 11 or less on the MNA-SF.[9-12]

Assessment of Nutritional Status.

Nutritional status was assessed by an Accredited Practicing Dietitian (APD) within 72 hours of admission during an in-person consultation, using the scored Patient Generated Subjective Global Assessment (PG-SGA)[25] with each participant being awarded a PG-SGA score and a PG-SGA global rating of A (well nourished), B (suspected or moderately malnourished) or C (severely malnourished).

Comprehensive Dietetic Assessment of Nutritional Status

The dietitian's assessment was conducted retrospectively using all data collected during the data collection as described above inclusive of nutritional biochemistry. Fasting blood samples were collected by a phlebotomist and analysed by the hospital or state pathology service depending on the analytical test. Blood samples were analysed and determined as low, normal or high based on the reference ranges (shown in parentheses) provided by the analysing laboratory, for Iron (8-30umol/L), vitamin B12 (>260mg/L) and folate (6.5-45ug/L), vitamin A (1-3.1umol/L), vitamin C (26-85umol/L), vitamin E (12-46umol/L) and vitamin D (60-160nmol/L) and the trace elements zinc (9-21umol/L) and selenium (0.8-1.64umol/L).

A participant was determined to be malnourished if they displayed a deficiency in any of the micronutrients according to the following guidelines, vitamin C $\leq$ 0.29mg/dl,[30] vitamin B12 <

200mg/l,[31] folate < 3ug/l,[31] zinc <9.0umol/l, selenium <0.7umol/l,[32] vitamin A <1umol/l[31] or vitamin D <60nmol/L or any of the following characteristics underweight (BMI of <22kgm^2 for those aged 65 years or more[33] and <18.5kgm^2 for those aged under 65 years[34]), PG-SGA score ≥ 9,[25] PG-SGA global rating B or C,[26] or Iron-deficiency anaemia (Ferritin<15ug/L plus Haemoglobin <130g/l for males and <120g/L for females).[35]

Ability of the screening and assessment tools to predict clinical outcomes

Admission complications and discharge destination were collected from the medical records following discharge to enable the evaluation of the ability of the screening tools to predict clinical outcomes. Admission complications included infections, cardiovascular events, unplanned surgery or procedures, deterioration or development of an ulcer or wound and vascular restenosis/acute occlusion and acute renal failure.

Health-related quality of life (HRQoL) is commonly examined in the literature when investigating clinical outcomes and in this study was included as an outcome in the predictive validity analyses. In this study, HRQoL was assessed using the EuroQoL 5 Dimensions 5 Levels (EQ-5D-5L)[36] which includes five questions related to mobility, self-care, usual activities, pain/discomfort and anxiety/depression with five levels of impairment recognised in each domain: no, slight, moderate, severe and extreme problems in the relevant dimension of health. Using these responses, an EQ-5D-5L utility value was created using a valuation algorithm.[37] EQ-5D-5L utility values have a range of -0.624 to 1: the maximum score of 1 representing perfect health, a score of 0 representing death while scores less than 0 represent health states that are worse than death.[38-40]

Statistical Analysis

The calculation of sample size was based on determining the precision of the expected sensitivity and specificity of the proposed screening tools.[9, 12] A prevalence of malnutrition of 61% was determined from a prospective, observational, audit of vascular surgery patients in an elective setting.[2] A total sample size of 322 participants would need to be recruited to obtain 197 participants with malnutrition (prevalence of the malnutrition is 61%). The sample size calculation allows a point estimate of 85% sensitivity and specificity to be measured with a precision of +/- 5% with 95% confidence. The sample size calculation was also based on investigating the effect of nutritional status on complications and health care outcomes. Although several outcomes have been addressed, patient's mortality was chosen to justify the power and sample size calculation. Using a hierarchical cox regression model on a

3 year follow-up study of vascular patients with lower limb ulcers, Miller et al[41] demonstrated that those patients with BMI <30 kg/m^2 were 4.6 times more likely to die than those with BMI ≥30 kg/m^2 (95% confidence interval [CI]: 1.04-20.4; *P* 0.04). As the confidence interval was so wide, we used a risk of death at the lower end of the confidence interval to detect a large sample size. A two-sided log rank test with an overall sample size of 266 subjects (133 in the BMI < 30 kg/m2 group and 133 in the BMI ≥30 kg/m2 group) achieves 90.0% power at a 0.05 significance level to detect a hazard ratio of 1.50. The Power Analysis & Sample Size Software (PASS) was used to calculate the sample size.[42]

Statistical analysis was conducted using SPSS for Windows version 25 (SPSS Inc, Chicago, IL) and Stata version 14.0 (StataCorp LLC, College Station, TX). Significance was set at the P<0.05 level. Continuous variables were assessed for normality using the Shapiro Wilk test and reported as mean (standard deviation - SD). If not normally distributed, the median (interquartile range - IQR) is reported. Sample characteristics are expressed as frequencies (n, %). Contingent on the normality tests, the Independent Samples T-test or Mann-Whitney U Test were used for testing differences across two groups for continuous variables.

To determine the concurrent validity of the five tools (four screening tools and the PG-SGA), measures of diagnostic accuracy were determined. Sensitivity (Sn), specificity (Sp), positive predictive value (PPV), and negative predictive value (NPV) were determined against the results of the dietitian's clinical assessment (the reference standard). In the reference standard, respondents were classified as either 'malnourished' or 'not malnourished'. To facilitate comparison to the reference standard and in keeping with clinical practice, two levels of risk were considered for each screening tool namely 'at risk' (aggregating participants with high or moderate risk of malnutrition) and 'not at risk'. Similarly, the PG-SGA global rating was classified into 'malnourished' and 'not malnourished' with ratings B (moderately, suspected malnourished) and C (severely malnourished) aggregated into one group (malnourished) as is common practice in similar literature.[16, 43, 44] A-priori values of ≥80% for sensitivity and ≥60% for specificity were used to indicate a valid instrument.[14] The dichotomous forms of each tool were used in all subsequent analyses to investigate validity in keeping with clinical practice where malnutrition screening tools have a defined cut-off to determine if a patient is 'at risk' or 'not at risk' of malnutrition. The diagnostic consistency between the five tools against the dietitians assessment was assessed by kappa (k) statistic.[45] The value of k varies from 0 to 1 with values <0.2 indicating poor, 0.21-0.4 fair, 0.41-0.6 moderate, 0.61-0.8 substantial and >0.8 as almost perfect concordance. Negative kappa values

indicates that the number of agreements observed is fewer than would be expected by chance indicating poor consistency overall.[46]

The ability of the five tools to predict clinical and HRQoL outcomes was tested using multivariate regression analysis. In all regressions, dichotomous screening and assessment tool variables (at risk or malnutrition/malnourished or not at risk/well-nourished) were entered as independent variables with age, gender, disease type and smoking status included as potential cofounders. To predict continuous dependent variables or outcomes (length of stay and EQ-5D-5L scores), generalised linear models (GLM) were fitted. To identify an appropriate family for the GLM, a modified Park Test was conducted following standard procedures.[47] For GLM models where the LOS was the dependent variable, coefficients of predicted dependent values in the modified park test indicated that the Poisson (for models including the MST and MUST) and Inverse Gaussian (for models incorporating the NRS2002, MNA-SF and PG-SGA) family of GLM were appropriate for analysis. The OLS regression model was appropriate for all models where the EQ-5D-5L Index was the dependent variable. To predict binary outcomes (1 = return to prior residence or to an institution such as residential aged care, rehabilitation or another hospital, 0 = other discharge destination and; 1 = nosocomial complications, 0 = no complications), binary regression models were fitted.

Results

A total of 2229 patients were admitted to the vascular surgery ward during the study period all of whom were screened for study eligibility. Of these, 1327 (59.5%) were ineligible, 568 (25.5%) did not wish to participate, and 12 (0.5%) participants withdrew before data collection resulting in 322 participants (14.4%). Table 1 displays the participant demographics. The majority of study participants were male (69.3%) and over 65 years old (61.6%). Nearly all (95.7%) lived independently, either alone or with another person/s with the majority (82.1%) returning to their pre-admission residence on discharge. Twenty-one percent of participants had at least one in-hospital complication and the median (IQR) hospital length of stay was 8 (5, 12) days. Median (IQR) quality of life score was 0.72 (0.46, 0.82).

Table 2 shows the results of the malnutrition screening using the four screening tools, micronutrient status and the proportion of participants assessed as malnourished by the PG-SGA and by the dietitian's clinical assessment. The malnutrition screening tools showed variable results ranging from 12.5% at risk of malnutrition according to the MUST up to 47.5% with the MNA-SF. According to the PG-SGA, 15.8% of participants were assessed as either moderately/suspected

malnourished (PG-SGA B) or severely malnourished (PG-SGA C). Suboptimal micronutrient status was prevalent with greater than 40% having suboptimal iron, zinc or vitamin B12 levels, 55.6% showed low vitamin D levels, and approximately 18% were low in selenium or vitamin A. Prevalence of suboptimal vitamin C was the greatest with 78.6% classified as having suboptimal levels and 57.2% being vitamin C deficient. The dietitian's assessment of nutritional status revealed that 75.5% of study participants had at least one nutritional parameter indicating that intervention may be warranted.

Table 2 Number and proportion of vascular surgery participants at risk of malnutrition according to the four screening tools and those assessed as malnourished according to the PG-SGA, and the dietitian's clinical assessment.

Validity of the screening and assessment tools

A higher prevalence of malnutrition (75.5% overall) was observed as a result of the dietitian's clinical assessment when compared to the PG-SGA results (Table 2). Concurrent validity and agreement of the malnutrition screening tools and the PG-SGA against the dietitian's clinical assessment is displayed in Table 3. Overall, while the MNA-SF performed best, none of the four screening tools or the PG-SGA achieved the a-priori levels for Sn and Sp and all showed poor NPV. Negative kappa values were observed between all four malnutrition screening tools and PG-SGA when compared to the dietitian's assessment indicating poor diagnostic consistency between the dietitian's clinical assessment and the tools (Table 3).

Results of the regression analyses are displayed in Tables 4 and 5. A significant association was observed between LOS and four tools (the MST, MUST, NRS-2002 and PG-SGA). However, the direction of the relationship differed. The MST and PG-SGA had positive associations (Coefficient (SE) 0.1061 (0.0376), p=0.005 and 5.02 (1.33), p<0.001 respectively) indicating that those at risk of malnutrition or already malnourished had a longer LOS while the reverse was true for the MUST (-0.00006 (0.00003), p=0.029) and NRS-2002 (-0.004 (0.002), p=0.045). No significant association was observed between LOS and MNA-SF. Associations were also observed between LOS and disease type and age in some of the models (Table 4). No significant associations were observed in the models for EQ-5D-5L Index indicating no association between the predictor variables and HRQoL. Results of the logistic regression analyses are shown in Table 5. MST, NRS-2002 and PG-SGA all showed a significant association with discharge destination when all confounders were included with participants at risk of malnutrition or already malnourished being at least 2.3 times

more likely to be discharged to another institution (OR(SE), 2.36 (0.71), p=0.004, 2.38(0.74) p=0.005 and 2.91 (1.03), p=0.003 respectively). There were no other significant associations identified with discharge destination. When in-hospital complications were examined, only NRS-2002 had a significant association with at risk participants being 1.85 (0.56) (OR(SE)) times more likely to have complications when confounders were controlled for.

Discussion

This is the first study to explore the validity of commonly used malnutrition screening tools as well as a nutrition assessment tool (PG-SGA) exclusively in vascular surgery patients. The MNA-SF achieved a better concurrent validity than the other screening tools when compared to the clinical dietitians assessment however none of the four malnutrition screening tools or the PGSGA exhibited optimal concurrent validity as they did not achieve the a-priori acceptable levels and had low negative predictive values indicating that all underestimated the presence of malnutrition in the participants. There was poor diagnostic consistency between each of the screening tools and the PG-SGA when compared with the dietitian's assessment according to Kappa values.

Previous studies that have explored the validity of malnutrition screening tools have varied depending on the patient group in which the tools have been administered and the comparator/reference standard used. The MUST displayed excellent agreement (k 0.783) with the Subjective Global Assessment (SGA) in fifty medical inpatients (aged <65 years).[16] However in the current study, the MUST did not perform adequately (k -0.117, Sn 14.9%, Sp 94.9%) which was similar to findings in renal inpatients when compared to the SGA (Sn 53.8%, Sp 78.3%).[48] Variable results have also been found with the MST, NRS-2002 and the MNA-SF with good validity in some settings[17] and suboptimal[22, 48, 49] validity in others. The variable results lend support to the notion that there is no "one size fits all" approach to malnutrition screening.

The investigation of the ability of the tools to predict short-term clinical outcomes yielded variable results. The NRS-2002 showed the best predictive ability, with significant associations observed with discharge destination, in-hospital complications and hospital LOS indicating poorer outcomes in those classified as at risk of malnutrition.

Existing literature that has looked at the ability of the MUST, MST, NRS-2002 and MNA-SF to predict outcomes has also reported variable results, depending on the population studied, sample size and setting. Wang et al[50] found the NRS-2002 to be predictive of LOS, non-infectious complications and higher cost and mortality in Chinese GI patients whilst Raslan et al[51] found that

the NRS-2002 performed better than the MUST and MNA-SF despite it identifying the lowest proportion of nutritional risk out of the three tools studied. Both of these studies were conducted in acute care patients. However when the NRS-2002, MNA-SF and MUST were studied in nursing home residents, the MNA-SF demonstrated the better predictive ability.[44] The authors postulated this was due to the inclusion of functional, cognitive and psychological parameters in the MNA-SF. The MNA-SF has been studied more extensively, particularly in the older age groups, showing that it is associated with increased risk of discharge to institutional care[52] and longer LOS in geriatric rehabilitation[52, 53] and also long-term mortality.[50] However these results were contradicted by Marshall et al[28] who found that the MNA-SF was not able to detect a significant difference in similar outcomes in their sample of geriatric rehabilitation patients. In younger populations, the results are not clear cut. The MNA-SF was found to be strongly associated with mortality in younger Ugandan adults,[54] whereas a trend towards longer LOS and increased likelihood of readmission was observed in younger rehabilitation patients but the results failed to reach significance as the study was likely underpowered.[55] In the current study, the MST was predictive of discharge destination and LOS. Similar to the other screening tools, the literature is variable with the MST being predictive of LOS in acute care patients[9] but not in renal patients[48] and not predictive of any clinical outcomes in patients undergoing geriatric rehabilitation.[22] The variable results in the current study and also in existing literature highlight furtherthat no one screening tool is suitable for use across a range of population groups and selected tools need to be valid for the population for which it is intended.

The NRS-2002 is the only screening tool to have been examined in vascular patients to date. De Waele et al[2] found that the NRS-2002 did not result in any false positives, however the presence of false negatives was not mentioned, which was found to be high in the present study. Participants were limited to elective surgery patients and those needing urgent surgery and/or limb amputations were excluded whereas our sample included all surgery types, and both elective and emergency patients making it a more representative sample of a routinely heterogeneous acute vascular surgery unit.

The suboptimal performance of the malnutrition screening tools and the PG-SGA is likely related to the parameters included in each of these tools, which are of less relevance to vascular surgery patients. Malnutrition screening tools traditionally focus on weight and/or BMI status, unintentional weight loss and reduced appetite/oral intake. The NRS-2002 also accounts for disease severity and age while the MNA-SF incorporates parameters known to impact on nutritional status that may be more relevant to this patient group; suboptimal mobility,[56] increased psychological stress and depression.[57-59] The participants in this study were mostly overweight or obese with

minimal reporting of unintentional weight loss hence they would not score highly on the tools that focus solely on these parameters. The MNA-SF identified the highest proportion of 'at risk' participants likely due to the inclusion of broader parameters.

Overall, the four malnutrition screening tools and the PG-SGA performed poorly as they do not account for micronutrient status which we found to be a key nutritional issue in the participants of this study. Incorporating micronutrient status into the clinical dietitian's assessment provides a more comprehensive determination of nutritional status and this study has demonstrated that malnutrition screening tools or assessment tools that neglect this important area will likely be inadequate for implementation in a vascular surgery setting.

Micronutrients are crucial in this patient group for wound healing,[60] and vascular health[61] hence ensuring adequate micronutrient status is critical to ensure optimal perioperative and long-term outcomes. The malnutrition screening tools that are currently available in existing literature do not include biochemical assessment of micronutrients as this contravenes the premise that a screening tool should be quick and simple to administer by any trained person or the patient themselves due to the requirement for additional resources and time rendering it more costly, not quick, nor simple. A cost analysis would be important to support or refute the inclusion of nutritional biochemistry within a screening tool. It is important to consider the strengths and limitations of this study to enable us to draw conclusions. This study is the first of its kind to investigate a range of screening tools in the vascular surgery population. It has a large sample size of 322 participants that are heterogeneous and therefore representative of the spectrum of vascular disease likely to be encountered in a vascular surgery unit. Nutrition assessment bias was minimised by having an Accredited Practising Dietitian (APD) conduct the PG-SGA who was not involved in the screening process and all measurements were conducted by a trained APD. Nursing staff that conducted the nutrition screening were trained via in-service education sessions and individual support by research team members.

While the study has many strengths, it is not devoid of limitations. The clinical dietitian's assessment was completed retrospectively utilising information collected via the screening and nutrition assessment processes, hencethe dietitian was not able to clarify information with individual participants and this may have influenced the assessment results. However this is not relevant to the biochemistry results and hence the impact on results is likely to be minimal. When investigating the validity of the tools, participants at medium and high risk of malnutrition according to the MNA-SF, MUST and the PG-SGA were merged for analysis so the relationship between the different levels of risk or malnutrition with clinical outcomes could not be explored.

Due to the small proportion of severely malnourished participants in this sample, it is unlikely that any statistically significant relationships would have been observed.

In conclusion, vascular surgery patients are complex with a range of pathologies influenced by nutrition. This study found a high prevalence of malnutrition secondary to suboptimal micronutrient status that was not identified by the four malnutrition screening tools investigated or the PG-SGA indicating that the development of vascular disease-specific screening and assessment tools that encompass additional parameters of relevance such as micronutrients and mobility measures are warranted to ensure that those at nutritional risk receive appropriate nutritional care to optimise patient and clinical outcomes.

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Table 1: Participant Characteristics of 322 vascular surgery patients participating in a validation study of malnutrition screening and assessment tools

Characteristic	N (%) unless indicated
Male	223 (69.3)
Age (mean, SD)	67.6 (14.14)
Age Categories	
<65 years	123 (38.2)
65 and above	199 (61.8)
Weight (kg)	
(Med/IQR)	85.5 (59.9, 111.1)
Median BMI	
(IQR) (n=320)	28.2 (20.3, 36.1)
Pre-admission living situation	
Lives alone	105 (32.6)
Lives with another person/s	203 (63.4)
SCF	2 (0.6)
RACF	12 (3.7)
EQ-5D-5L Score (Med/IQR)	0.72 (0.36, 1.08)
Proportion with noso-comial complications	69 (21.4)
Discharge Destination	
Return to prior living	260 (82.0)
D/c to institutional care	57 (18.0)
LOS (Med/IQR)	8 (1, 15)

Table 2 Number and proportion of vascular surgery participants at risk of malnutrition according to the four screening tools and those assessed as malnourished according to the PG-SGA, and the dietitian's clinical assessment.

Nutritional Parameter	**Proportion of participants (n=322)**
Nutritionally at risk	
MST	93 (28.8%)
MUST (n=320)	40 (12.5%)
NRS-2002	79 (24.5%)
MNA-SF (n=320)	152 (47.5%)
PG-SGA Rating	
A (well nourished)	272 (84.2%)
B (moderately/suspected malnutrition)	50 (15.5%)
C (Severely malnourished)	1 (0.3%)
Dietitians assessment	244 (75.5)

Table 3: Concurrent validity of four commonly used screening tools and the PGSGA against the clinical dietitian's assessment of malnutrition in 322 vascular surgery patients

	MST	MUST	NRS-2002	MNA-SF	PG-SGA
Sensitivity (Sn)	32.8	14.9	29.9	52.5	20.9
Specificity (Sp)	83.5	94.9	96.1	67.9	100
Positive Predictive Value (PPV)	86.0	90.0	92.4	83.6	100
Negative Predictive Value (NPA)	28.7	26.4	29.9	31.5	29
Kappa (k)	-0.154	-0.117	-0.223	-0.155	-0.237

Desirable cut-offs:

Sn ≥80, Sp ≥60,

k <0.2 poor agreement, 0.21-0.4 fair agreement, 0.41-0.6 moderate agreement, 0.61-0.8 substantial agreement, >0.8 excellent agreement

Table 4 Generalised Linear Model (GLM) results

	Dependent variable = Length of Stay (LOS)									
	Model inc MST[a]		**Model inc MUST[a]**		**Model inc NRS2002[b]**		**Model inc MNASF[b]**		**Model inc PGSGA[b]**	
Predictors	Coefficient (SEM)[d]	P value	Coefficient (SEM)[d]	P value	Coefficient (SEM)[d]	P value	Coefficient (SEM)[d]	P value	Coefficient (SEM)[d]	P value
MST	0.1061 (0.0376)	0.005	-		-		-		-	
MUST	-		-0.00006 (0.00003)	0.029	-		-		-	
NRS-2002	-		-		-0.004 (0.002)	0.045	-		-	
MNA-SF	-		-		-		0.00001 (8.08e-6)	0.183	-	
PG-SGA	-		-		-		-		5.02 (1.33)	<0.001
Gender	0.0087 (0.0385)	0.821	0.004 (0.038)	0.913	-0.0003 (0.002)	0.889	-0.0003(0.002)	0.875	0.28 (1.04)	0.785
Smoker	0.012 (0.052)	0.819	0.0096 (0.052)	0.852	-0.0004 (0.003)	0.890	-0.0002(0.003)	0.936	0.22 (1.39)	0.874
Age	0.004 (0.001)	0.004	0.0041 (0.001)	0.003	6.00E-05(0.0001)	0.378	-0.00009 (0.00007)	0.230	0.02 (0.04)	0.636
Venous	-0.22 (0.11)	0.05	-0.203 (0.11)	0.065	0.009 (0.008)	0.301	0.007 (0.008)	0.372	-2.51 (2.49)	0.313
Aneurysmal	0.335 (0.08)	<0.0001	0.351 (0.083)	<0.0001	-0.007 (0.005)	0.155	-0.008 (0.005)	0.113	2.76 (2.18)	0.206
PAD	0.256 (0.07)	<0.0001	0.26 (0.073)	<0.001	-0.006 (0.005)	0.211	-0.006 (0.005)	0.191	1.63 (1.84)	0.173
DM limb	0.32 (0.07)	<0.001	0.324 (0.074)	<0.001	-0.007 (0.004)	0.127	-0.007 (0.005)	0.114	2.53 (1.85)	0.173

Other vascular	0.150 (0.08)	0.06	0.170 (0.08)	0.033	-0.004 (0.005)	0.442	-0.004 (0.005)	0.398	0.60 (1.99)	0.763
Constant	1.79 (0.123)	<0.001	1.82 (0.123)	<0.001	0.02 (0.007)	0.003	0.021 (0.007)	0.002	6.62 (3.14)	0.036
	Dependent variable = EQ-5D-5L Index									
	Model inc MST[d]		**Model inc MUST[d]**		**Model inc NRS2002[d]**		**Model inc MNASF[d]**		**Model inc PGSGA[d]**	
Predictors	Coefficient (SEM)[c]	P value	Coefficient (SEM)[c]	P value	Coefficient (SEM)[c]	P value	Coefficient (SEM)[c]	P value	Coefficient (SEM)[c]	P value
MST	54.15 (87.10)	0.535	-		-		-		-	
MUST	-		0.0005 (0.047)	0.992	-		-		-	
NRS2002	-		-		70.40 (91.95)	0.444	-		-	
MNASF	-		-		-		-0.0005 (0.057)	0.994	-	
PGSGA	-		-		-		-		-85.1 (110.2)	0.441
Gender	-58.23 (86.30)	0.50	-60.69 (86.26)	0.482	-56.96 (86.31)	0.510	-60.61 (86.66)	0.485	-65.15 (86.37)	0.451
Age	3.51 (3.04)	0.249	3.52 (3.04)	0.249	3.35 (3.05)	0.273	3.52 (3.06)	0.251	3.88 (3.07)	0.208
Smoker	198.93 (115.09)	0.085	199.13 (115.20)	0.085	200.46 (115.06)	0.082	199.08 (115.36)	0.085	197.32 (115.07)	0.087
Venous	14.11 (206.11)	0.945	8.599 (207.13)	0.967	9.28 (205.87)	0.964	9.03 (208.01)	0.965	23.79 (206.77)	0.908
Aneurysmal	-24.50 (180.8)	0.892	-15.95 (180.35)	0.930	-24.69 (180.54)	0.891	-15.83 (181.64)	0.931	-3.33 (180.91)	0.985
PAD	79.95 (151.75)	0.599	82.01 (151.80)	0.589	78.48 (151.73)	0.605	82.09 (152.05)	0.590	95.96 (152.72)	0.530
DM limb	129.40 (153.40)	0.400	132.10 (153.43)	0.390	129.67 (153.32)	0.398	132.12 (153.68)	0.391	141.92 (153.81)	0.357
Other vascular	14.03 (164.76)	0.932	15.81 (165.63)	0.924	15.54 (164.68)	0.925	16.07 (165.43)	0.923	29.13 (165.56)	0.860
Constant	-247.99 (261.45)	0.344	-233.460 (260.75)	0.371	-239.19 (260.44)	0.359	-233.85 (262.36)	0.373	-252.48 (261.48)	0.335

[a] GLM model family for LOS model that included results of the malnutrition screening tool (MST) and malnutrition Universal Screening Tool (MUST) assessments (both coded as 1 = at risk and 0 = not at risk) was Poisson and link was log;

[b] GLM model family for LOS model that included results of the Nutrition Risk Screen -2002 (NRS-2002) and the Mini-Nutritional Assessment – Short Form (MNA-SF) assessments (both coded as 1 = at risk and 0 = not at risk) was Inverse Gaussian and link was power $^{-2}$;

[c] SEM = Standard Error of the Mean

d Regression model for EQ-5D-5L model that included results of the Nutrition Risk Screen -2002 (NRS-2002) and the Mini-Nutritional Assessment – Short Form (MNA-SF) assessments (both coded as 1 = at risk and 0 = not at risk) was ordinary least squares (OLS).

Table 5: Binary Logistic Regressions results

	Dependent variable = Discharge Destination									
	Model inc MST		**Model inc MUST**		**Model inc NRS2002**		**Model inc MNASF**		**Model inc PGSGA**	
Predictors	OR (SE)[a]	P value	OR (SE)[a]	P value	OR (SE)[a]	P value	OR (SE)[a]	P value	OR (SE)[a]	P value
MST	2.36 (0.71)	0.004	-		-		-		-	
MUST	-		0.58 (0.30)	0.295	-		-		-	
NRS-2002	-		-		2.38 (0.74)	0.005	-		-	
MNASF	-		-		-		1.0 (0.003)	0.821	-	
PGSGA	-		-		-		-		2.91 (1.03)	0.003
Gender	0.98 (0.31)	0.937	0.89 (0.28)	0.698	0.96 (0.30)	0.90	0.94 (0.29)	0.843	0.98 (0.31)	0.953
Age	1.00 (0.01)	0.710	1.00 (0.01)	0.774	1.00 (0.01)	0.90	1.01 (0.01)	0.641	1.00 (0.01)	0.943
Smoker	0.53 (0.26)	0.194	0.55 (0.27)	0.215	0.55 (0.27)	0.22	0.55 (0.27)	0.217	0.54 (0.27)	0.211
Venous	0.44 (0.39)	0.356	0.45 (0.40)	0.363	0.41 (0.37)	0.32	0.44 (0.39)	0.349	0.31 (0.28)	0.196
Aneurysmal	0.40 (0.29)	0.206	0.52 (0.38)	0.369	0.41 (0.3)	0.22	0.49 (0.35)	0.313	0.37 (0.27)	0.176
PAD	1.19 (0.63)	0.748	1.26 (0.66)	0.655	1.17 (0.62)	0.76	1.21 (0.63)	0.714	1.00 (0.53)	0.999
DM limb	0.80 (0.44)	0.684	0.91 (0.50)	0.863	0.82 (0.45)	0.72	0.85 (0.46)	0.759	0.72 (0.40)	0.552
Other vascular	0.84 (0.50)	0.771	1.02 (0.60)	0.974	0.87 (0.52)	0.82	0.90 (0.52)	0.853	0.71 (0.42)	0.559
Constant	0.17 (0.17)	0.067	0.25 (0.24)	0.147	0.22 (0.20)	0.10	0.21 (0.2)	0.10	0.30 (0.28)	0.200
	Dependent variable = In-hospital Complications									
	Model inc MST		**Model inc MUST**		**Model inc NRS2002**		**Model inc MNASF**		**Model inc PGSGA**	
Predictors	OR (SE)[a]	P value	OR (SE)[a]	P value	OR (SE)[a]	P value	OR (SE)[a]	P value	OR (SE)[a]	P value
MST	0.64 (0.20)	0.159	-		-		-		-	-
MUST	-		0.87 (0.38)	0.754	-		-		-	
NRS2002	-		-		1.85 (0.56)	0.039	-		-	

MNASF	-		-		-		1.00 (0.14)	0.945	-	
PGSGA	-		-		-		-		1.72 (0.61)	0.128
Gender	0.98 (0.30)	0.951	0.99 (0.30)	0.970	1.03 (0.31)	0.916	1.02 (0.31)	0.956	1.02 (0.31)	0.932
Age	1.00 (0.01)	0.965	1.00 (0.01)	0.956	0.99 (0.01)	0.825	1.00 (0.01)	0.973	1.00 (0.01)	0.778
Smoker	1.19 (0.46)	0.654	1.17 (0.45)	0.678	1.21 (0.47)	0.626	1.18 (0.46)	0.673	1.20 (0.46)	0.642
Venous	0.39 (0.34)	0.282	0.43 (0.38)	0.340	0.40 (0.35)	0.300	0.43 (0.38)	0.337	0.36 (0.32)	0.253
Aneurysmal	1.36 (0.83)	0.618	1.30 (0.80)	0.670	1.17 (0.72)	0.796	1.31 (0.80)	0.661	1.16 (0.71)	0.805
PAD	1.20 (0.63)	0.726	1.19 (0.62)	0.736	1.17 (0.72)	0.796	1.18 (0.61)	0.755	1.07 (0.56)	0.898
DM Limb	1.11 (0.59)	0.843	1.11 (0.59)	0.842	1.06 (0.56)	0.913	1.09 (0.58)	0.869	1.02 (0.54)	0.977
Other vascular	0.76 (0.45)	0.638	0.80 (0.48)	0.716	0.74 (0.44)	0.609	0.77 (0.45)	0.653	0.68 (0.40)	0.516
Constant	0.31 (0.28)	0.200	0.28 (0.26)	0.169	0.26 (0.24)	0.147	0.26 (0.24)	0.141	0.32 (0.29)	0.211

[a] OR (SEM) = Odds ratio (standard error of the mean)