Nutritional assessment: comparison of clinical assessment and objective variables for the prediction of length of hospital stay and readmission[1–3]

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ABSTRACT

Background: Nutritional assessment commonly includes multiple nutrition indicators (NIs). To promote efficiency, a minimum set is needed for the diagnosis of malnutrition in the acute care setting.

Objective: The objective was to compare the ability of different NIs to predict outcomes of length of hospital stay and readmission to refine the detection of malnutrition in acute care.

Design: This was a prospective cohort study of 1022 patients recruited from 18 acute care hospitals (academic and community), from 8 provinces across Canada, between 1 July 2010 and 28 February 2013. Participants were patients aged ≥18 y admitted to medical and surgical wards. NIs measured at admission were subjective global assessment (SGA; SGA A = well nourished, SGA B = mild or moderate malnutrition, and SGA C = severe malnutrition), Nutrition Risk Screening (2002), body weight, midarm and calf circumference, serum albumin, handgrip strength (HGS), and patient-self assessment of food intake. Logistic regression determined the independent effect of NIs on the outcomes of length of hospital stay (<7 d and ≥7 d) and readmission within 30 d after discharge.

Results: In total, 733 patients had complete NI data and were available for analysis. After we controlled for age, sex, and diagnosis, only SGA C (OR: 2.19; 95% CI: 1.28, 3.75), HGS (OR: 0.98; 95% CI: 0.96, 0.99 per kg of increase), and reduced food intake during the first week of hospitalization (OR: 1.51; 95% CI: 1.08, 2.11) were independent predictors of length of stay. SGA C (OR: 2.12; 95% CI: 1.24, 3.93) and HGS (OR: 0.96; 95% CI: 0.94, 0.98) but not food intake were independent predictors of 30-d readmission.

Conclusions: SGA, HGS, and food intake were independent predictors of outcomes for malnutrition. Because food intake in this study was judged days after admission and HGS has a wide range of normal values, SGA is the single best predictor and should be advocated as the primary measure for diagnosis of malnutrition. This study was registered at clinicaltrials.gov as NCT02351661. *Am J Clin Nutr* 2015;101:956–65.

Keywords: length of stay, malnutrition, nutritional assessment, readmission rate, subjective global assessment

INTRODUCTION

Malnutrition occurs when net nutrient intake is less than requirements, leading to physiologic changes, reduced organ and tissue function, and loss of body mass (1). Nutritional status is commonly assessed by individual nutrition indicators (NIs)[4] assessing components of nutritional status: BMI; midarm circumference (MAC) or calf circumference (CC) (2); biochemical analysis, such as plasma albumin (PA) (3); and handgrip strength (HGS). These individual NIs vary in their capacity to assess nutrition. For example, PA has been shown to lack specificity, especially in adults (1) and the elderly (4), whereas HGS has been shown to predict postoperative complications (5) and length of stay (LOS) in the hospital (6) and is associated with reduced food intake (7).

In the hospitalized patient, the nutritional status is not only altered by an imbalance of intake modified potentially by an abnormal absorption of food but also influenced by disease, trauma, sepsis, and fever. Therefore, in the hospital patient,

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[4] Abbreviations used: BW, body weight; CC, calf circumference; CCI, Charlson Comorbidity Index; HGS, handgrip strength; ICU, intensive care unit; LOS, length of stay; MAC, midarm circumference; NI, nutrition indicator; NPV, negative predictive value; NRS, Nutrition Risk Screening; PA, plasma albumin; PPV, positive predictive value; REB, research ethics board; SGA, subjective global assessment.

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a composite of these factors considered together is more likely to predict outcome than any single variable. A simple composite evaluation of nutritional status at the bedside, called subjective global assessment (SGA), was shown to predict postoperative hospital infection (8). The SGA tool evaluates several components of nutritional status: body weight (BW) change, previous and ongoing; dietary intake; risk factors and, specifically, gastrointestinal symptoms that can influence food intake/nutrient utilization; functional capacity; metabolic stress; and 3 areas of physical examination (fat loss, muscle wasting, and presence of edema). These components are used in a holistic way to classify patients as well nourished (SGA A), mildly/moderately malnourished (SGA B), or severely malnourished (SGA C) on the basis of clinical judgment. Detsky et al. (9) showed that SGA had better sensitivity and specificity than individual NIs in predicting outcome. Since the publication of the SGA in 1982, there has been criticism over the subjectiveness of the SGA (10). In response, a number of clinically based tools have attempted to expand on this concept of a composite measure and incorporate several objective measures in an attempt to better predict outcome (11–17). Examination of these different composite tools shows that they all use some of the variables first described in the SGA, but none includes muscle function.

A recent consensus statement stated that malnutrition could be identified by only 2 or more of the following: insufficient energy intake, weight loss, loss of muscle mass, loss of subcutaneous fat, localized or generalized fluid accumulation, and/or diminished functional status as measured by HGS (18). Yet, evidence to support if such an approach predicts an adverse outcome is lacking. Thus, the question remains as to whether a combination of any 2 indicators or the addition of anthropometric, functional, or other objective measures such as food intake to the SGA and to other widely used clinical assessments, such as the Nutrition Risk Screening (NRS) 2002, increases their identification of patients with increased LOS or readmission. The SGA can be done in 5–10 min, whereas additional anthropometric measurements and bloodwork result in extra time and effort, which may be unwarranted and inhibit the practice of nutritional assessment in a busy hospital setting.

The Nutrition Care in Canadian Hospitals study conducted by the Canadian Malnutrition Task Force is a large prospective multicenter cohort study that provides the opportunity to examine the above question. A diverse sample of patients with a rigorous data collection, including key health outcomes, allows for the determination of the addition of objective measurements to the SGA to determine their additional predictive validity.

METHODS

Subjects

Eligible participants were patients admitted to medical or surgical wards who were aged ≥18 y and able to understand the written informed consent. For those who were unable to give informed consent (e.g., language barrier, incapacitated, and/or mentally impaired) and where approved by the institutional research ethics board (REB), the power of attorney was approached to translate or to sign the consent. Patients were excluded if admitted directly to the intensive care unit (ICU); to obstetric, psychiatry, palliative, or pediatric wards; or to the medical day unit for an endoscopy procedure or other invasive treatment. In addition, patients with terminal cancer or other conditions requiring palliative care were excluded if these conditions were identified at admission.

Academic and community hospitals as well as large and small centers from Canada were made aware of the study by various modes of communication: presentations at national conferences, medical grand rounds across the country, direct contact to hospital dietitians and administrators, and creation of the following website: www.nutritioncareincanada.ca. Centers that expressed interest were provided with the study protocol, consent, and budget. Those agreeing to participate submitted the protocol to their respective REB with the help of the investigators. These 18 centers, recruited from 8 provinces in Canada, were classified as academic, community, small (≤200 beds), or large (>200 beds). Patients were enrolled according to a strict protocol. Small centers enrolled a total of 40 patients per facility, and large centers enrolled 60 patients. Days of enrollment rotated from Monday to Friday, with Monday capturing the weekend admissions from 1700 h on Friday to 1700 h on Monday. Consecutive admissions were approached for consent, and a maximum of 10 patients were followed at the same time because of study workload. The demographic characteristics (age and sex) of the total number of hospital admissions over the study period were provided by 10 hospitals, as approved by their local REB, to evaluate representativeness of the sample. Additional information, such as admitting diagnoses, could not be recorded because of REB restrictions and patient confidentiality issues.

TABLE 1
Patient characteristics (n = 733)[1]

Characteristic	Value
Sex	
Male	378 (51.6)
Female	355 (48.4)
Age, y	66 (54, 77)[2]
Number of diagnoses[3]	
1	445 (60.7)
2	207 (28.2)
3	81 (11.0)
Length of stay,[4] d	7.0 (4, 11)
Diagnostic categories[3]	
Cardiovascular	117 (16.0)
Gastrointestinal	218 (29.7)
Genitourinary	90 (12.3)
Respiratory	131 (17.9)
Musculoskeletal	92 (12.6)
Neurologic	41 (5.6)
Autoimmune	5 (0.7)
Metabolic	69 (9.4)
Sensory organ	7 (1.0)
Traumatic	18 (2.5)
Hematopoietic	64 (8.7)
Infection	141 (19.2)
Other	109 (14.9)

[1]Values are n (%) of patients unless otherwise indicated. Q, quartile.
[2]Median; Q1, Q3 in parentheses (all such values).
[3]Percentage of those having this diagnostic category out of a total number of patients in the study sample; some patients may have >1 diagnostic category.
[4]Based on n = 699 patients included in length-of-stay analysis.

TABLE 2
Pairwise associations between nutritional indicators (n = 733)[1]

	BW	MAC	CC	HGS	PA
BW, kg	1	0.81 (<0.001)	0.81 (<0.001)	0.30 (<0.001)	0.10 (0.006)
MAC, cm		1	0.82 (<0.001)	0.29 (<0.001)	0.13 (<0.001)
CC, cm			1	0.32 (<0.001)	0.07 (0.05)
HGS, kg				1	0.07 (0.04)
PA, g/L					1

[1]Values are presented as Pearson correlation coefficients; P values in parentheses. BW, body weight; CC, calf circumference; HGS, handgrip strength; MAC, midarm circumference; PA, plasma albumin.

Ethics

The study was approved by each hospital's administration and REB, as well as the REB of the Universities of Waterloo, Guelph, and Toronto.

Data collection

A comprehensive nutritional assessment and data collection were performed within 72 h of patients' admission to the ward by a trained site coordinator; 14 of 18 coordinators were registered dietitians. Several nutritional variables and clinical outcomes were recorded during the hospital stay. Patient demographic characteristics (sex, age), living arrangements, food-related activities of daily living, level of education, contact information, primary diagnosis, secondary diagnoses, Charlson Comorbidity Index (CCI) (19), number and type of medications, number of surgeries, and other reported acute care admissions in the past 5 y were obtained by interview with the patient or from the medical record at admission. The main admission diagnosis was classified under 11 broad standard categories: cardiovascular, gastrointestinal, genitourinary, respiratory, musculoskeletal, neurologic, autoimmune disease, metabolic disorder, sensory-organ impairment, trauma, hematopoietic disorder, and other. Presence or absence of cancer on admission was also recorded. For some patients, a new diagnosis was also recorded during the hospital stay. In cases where there was more than one category of diagnosis for the same patient, second and third diagnostic categories were coded. These diagnostic categories (admission and new diagnoses) were categorized for further analyses as the number of diagnoses (1, 2, or 3), whereas the presence of cancer recorded at admission or during the hospital stay was used as a specific variable in analyses.

SGA was used as the primary measure of nutritional status (20). Patients were classified as well nourished (SGA A), moderately malnourished (SGA B), or severely malnourished (SGA C). Malnutrition was defined as SGA B or C. In addition, the NRS 2002 (15), used in Europe, was completed. The site coordinator measured BW with the patient in light clothes in a chair scale (Seca 952 Chair Scale; Weigh and Measure LLC), except for those who exceeded 200 kg (440 lb). For those few patients, the hospital scale or a bed scale was used. Standing height (cm) was measured, and for all patients >65 y or those unable to stand, height was estimated from knee height (SHORR Knee height caliper; Weigh and Measure LLC). BMI was calculated. MAC and CC were completed by using standardized procedures. HGS was measured by using a hydraulic hand dynamometer (Jamar Hydraulic Hand dynamometer; Weigh and Measure LLC) according to a standardized procedure (21). PA within 2 d of admission was determined. Global dietary intake was estimated by the patient-generated Nutrition Day Form, which has been used in previous studies (22, 23). Dietary intake by using this method has been shown to predict outcome by being inversely related to hospital mortality (22). This form was completed by the patient at lunchtime for 3 d of the first-week stay and recorded as 0%, 25%, 50%, or 100% consumption of their main plate. For analysis, the mean intake across 3 d was categorized as <50% or ≥50%. In the case of cognitive impairment, a family care partner who witnessed meal consumption was used as a proxy for the Nutrition Day Form. The site coordinator also verified with the patient or the family member the recording of food intake. To avoid intra- or interobserver variability, all study coordinators were trained in a standardized way by the national coordinator (BD) that included video, concrete examples, and practice with SGA and other measures.

TABLE 3
Nutrition indicators and food intake in different SGA groups[1]

	Overall (n = 733)			SGA A (n = 388)			SGA B (n = 257)			SGA C (n = 88)			
	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max	P value
BW	77.8 ± 23.4	31.4	200.9	83.8[a] ± 21.7	36.5	189.9	75.5[b] ± 23.7	36.5	200.9	57.6[c] ± 16.6	31.4	110.7	<0.0001
MAC	30.5 ± 6.0	14.1	56.7	32.3[a] ± 5.3	21.3	55.7	30.0[b] ± 5.7	16.1	56.7	23.9[c] ± 5.3	14.1	39.5	<0.0001
CC	36.0 ± 5.7	18.5	61.7	37.7[a] ± 5.0	25.0	59.0	35.5[b] ± 5.4	23.1	61.7	30.2[c] ± 5.4	18.5	46.7	<0.0001
HGS	21.8 ± 11.2	0	61.0	23.8[a] ± 11.2	0.3	61.0	20.5[b] ± 10.8	0.0	59.0	17.1[c] ± 10.5	0.0	46.0	<0.0001
PA	32.5 ± 6.0	12.0	51.0	33.8[a] ± 5.4	19.0	51.0	31.5[b] ± 6.2	12.0	46.0	29.4[c] ± 6.4	14.0	46.0	<0.0001
Food intake <50%, n (%)	242 (33.0)			106 (27.3)			99 (38.5)			37 (42.1)			0.002

[1]One-factor ANOVA with pairwise post hoc t tests for continuous nutrition indicators, χ^2 test for food intake. Means not sharing a common superscript letter are significantly different at Bonferroni-corrected 0.05 level based on t test. BW, body weight; CC, calf circumference; HGS, handgrip strength; MAC, midarm circumference; Max, maximum; Min, minimum; PA, plasma albumin; SGA A, subjective global assessment, well nourished; SGA B, subjective global assessment, mildly/moderately malnourished; SGA C, subjective global assessment, severely malnourished.

TABLE 4
Logistic regression models predicting SGA B/C by nutrition indicators (n = 733)[1]

	BW, kg	MAC, cm	CC, cm	PA, g/L	HGS, kg	Food intake <50%
Univariate models	0.70 (0.66, 0.74)2	0.70 (0.66, 0.74)	0.70 (0.66, 0.74)	0.62 (0.58, 0.66)	0.61 (0.57, 0.65)	0.56 (0.53, 0.59)
Models controlled for age ≥65 y and sex	0.71 (0.68, 0.75)	0.70 (0.67, 0.74)	0.70 (0.66, 0.74)	0.63 (0.59, 0.67)	0.63 (0.59, 0.67)	0.58 (0.54, 0.62)
P value (De Long test of difference between univariate and controlled model c-statistics)	0.03	0.4	0.9	0.09	0.03	0.05

[1]Values are presented as c-statistics; 95% CIs in parentheses. BW, body weight; CC, calf circumference; HGS, handgrip strength; MAC, midarm circumference; PA, plasma albumin; SGA B/C, subjective global assessment, mildly/moderately and severely malnourished.

A listserv was used to discuss data collection and any challenges to ensure consistent procedures among sites.

During the hospital stay, the site coordinator reviewed the chart every 2 d to determine transfer within the hospital and number of days in the ICU, any surgical procedures, new diagnosis, change in medications, use of antibiotics, and any charted adverse events (e.g., fall). In addition, nutrition care was excerpted from the patient's chart and included diet orders, dates and changes from which were derived the total number of days the patient was nil per os, and the presence or absence of nutrition support. The date and number of dietitian/diet technician or dietetic intern visits were also recorded. Weight was measured every 2 d.

Clinical outcomes and selection of covariates

The main outcome, length of hospital stay, was defined as the difference between the date of discharge or transfer to another hospital and the date of admission to the hospital ward; deceased patients and patients transferred to other hospitals within 7 d from admission were excluded from analysis. Readmission within 30 d after discharge was obtained by a phone call from the site coordinator to the patient or family. Other outcomes recorded included mortality during hospitalization and up to 30 d after discharge. Two nutrition-related outcomes were chosen to examine predictive ability of different nutrition indicators: dichotomized length of hospital stay (short stay <7 d, long stay ≥7d) and readmission within 30 d after discharge.

Sample size

The sample size was estimated to determine the prevalence of malnutrition, considering a 95% confidence level, a 5% margin of error, and an estimated malnutrition prevalence of 32% (24). Because our study was based on a clustered sample, this estimate was multiplied by the effect of the plan of sampling (2 for nutritional surveys). The total sample size estimated to achieve this power was 666 subjects. We then enrolled >1000 patients to assess contributors of malnutrition and predictors of prolonged length of stay, based on the sample size of previous similar studies (25).

Statistical analysis

Continuous variables were characterized as means (±SDs), and categorical variables were determined as n (%). Independent samples t test and ANOVA were used to compare groups by continuous variables, and the Pearson χ^2 test was used to compare categorical variables. To address the research question, we included selected key NIs in predictive models with the SGA to determine whether they improved on the predictive ability of this tool. NIs included BW, MAC, CC, and HGS.

The predictive ability of these different NIs was estimated by using logistic regression models, and the area under a receiver operating characteristic curve (AUC) was calculated. Continuous NIs were included in the models as continuous variables. Different categories of the SGA were combined in models to distinguish between not malnourished (SGA A) patients and those severely malnourished (SGA C) and moderately malnourished (SGA B) patients. The discriminating ability (ability to discriminate between patients who have and do not have the outcome) of models was characterized by using c-statistics (concordance index), which is equal to the AUC. The incremental contribution of NIs in the models controlling for potential confounders (i.e., covariates) and the SGA was assessed by using Wald tests of significance (26, 27). The confounders chosen to control for in the models were age ≥65 y, sex (because anthropometric NIs depend on these characteristics), and variables characterizing disease status that showed a strong association with outcomes in preliminary analyses (LOS:

TABLE 5
Logistic regression models where combination of 2 nutritional indicators was used to predict SGA B/C (n = 733)[1]

	MAC, cm	HGS,[2] kg	PA, g/L	Food intake <50%
MAC, cm	0.70 (0.66, 0.74)	0.71 (0.67, 0.75)	0.72 (0.68, 0.76)	0.71 (0.67, 0.75)
HGS, kg		0.63 (0.59, 0.67)	0.67 (0.63, 0.71)	0.65 (0.61, 0.69)
PA, g/L			0.62 (0.58, 0.66)	0.64 (0.60, 68)
Food intake <50%				0.56 (0.53, 0.59)

[1]Values are presented as c-statistics; 95% CIs in parentheses. HGS, handgrip strength; MAC, midarm circumference; PA, plasma albumin; SGA B/C, subjective global assessment, mildly/moderately and severely malnourished.
[2]Controlled for age and sex.

TABLE 6
Logistic regression models, single nutrition indicator predicting length of stay ≥7 d (n = 699)[1]

	Unadjusted models			Adjusted models[2]		
Variable	OR (95% CI)	Wald test P value	Model c-statistic (95% CI)	OR (95% CI)	Wald test P value	Model c-statistic (95% CI)
SGA B/C			0.57 (0.53, 0.61)			0.63 (0.59, 0.68)
SGA B vs. SGA A	1.46 (1.05, 2.02)	0.02		1.34 (0.96, 1.86)	0.09	
SGA C vs. SGA A	2.51 (1.49, 4.23)	0.0005		2.39 (1.41, 4.06)	0.001	
NRS 2002 "at risk"	1.604 (1.17, 2.21)	0.004	0.55 (0.52, 0.59)	1.45 (1.04, 2.01)	0.03	0.62 (0.58, 0.66)
BW, kg	1.0 (0.99, 1.00)	0.1	0.53 (0.49, 0.57)	1.00 (0.99, 1.00)	0.2	0.61 (0.57, 0.66)
MAC, cm	0.98 (0.96, 1.01)	0.1	0.53 (0.48, 0.57)	0.98 (0.96, 1.01)	0.18	0.62 (0.58, 0.66)
CC, cm	0.97 (0.95, 1.00)	0.05	0.54 (0.50, 0.58)	0.98 (0.95, 1.00)	0.10	0.62 (0.58, 0.66)
HGS, kg	0.98 (0.97, 0.99)	0.002	0.56 (0.52, 0.60)	0.97 (0.96, 0.99)	0.002	0.64 (0.59, 0.68)
PA, g/L	0.97 (0.94, 0.99)	0.008	0.56 (0.52, 0.60)	0.97 (0.94, 0.99)	0.016	0.63 (0.58, 0.67)
Food intake <50%	1.54 (1.11, 2.12)	0.009	0.55 (0.51, 0.58)	1.56 (1.12, 2.18)	0.009	0.62 (0.58, 0.66)

[1]ORs for continuous predictors are given per unit change. BW, body weight; CC, calf circumference; HGS, handgrip strength; MAC, midarm circumference; NRS, Nutrition Risk Screening; PA, plasma albumin; SGA A, subjective global assessment, well nourished; SGA B, subjective global assessment, mildly/moderately malnourished; SGA C, subjective global assessment, severely malnourished.
[2]Adjusted for age ≥65 y, sex, and number of diagnoses.

number of diagnostic categories; 30-d readmission: CCI at admission). In addition to the SGA, another tool widely used in Europe, the NRS 2002, was compared on its predictive ability for LOS and 30-d readmission. This analysis identified that the SGA, HGS, and food intake were the only NIs predictive of outcomes.

Subsequently, the age- and sex-specific cutoff points were estimated for HGS to distinguish patients with and without the defined outcomes of LOS and 30-d readmission. The cutoffs were found based on the maximum Youden index (difference between sensitivity and 1 − specificity) obtained from age (dichotomized at 65 y) and sex-specific logistic models. The sensitivity and specificity to predict outcomes were determined individually for SGA-dichotomized HGS and food intake in the hospital. Logistic regression models including these 3 predictors (HGS was included as continuous) were built for LOS and 30-d readmission, and the sensitivity and specificity at different estimated probability cutoffs were obtained for these models. Optimal sensitivity and specificity combinations (maximum Youden index) were obtained for the models at probability cutoffs of 0.54 for LOS and 0.18 for 30-d readmission.

Of the full sample of 1022 participants, 733 patients had complete data on all nutrition-related variables and were thus the basis for this analysis; a further 34 patients were excluded for the LOS outcome because 18 died in the hospital, 9 had LOS missing, and for 7 it was impossible to determine whether the LOS was more or less than 7 d (transferred to another hospital within 7 d from admission). For analysis of readmission, we excluded deceased patients, 43 patients who did not have readmission data, and 11 patients with missing CCI at admission. There were no differences between these subgroups and the final sample of 733 patients included in this analysis for age, sex, number of diseases per patient, and disease classification (data not shown). The analysis was performed by using SAS 9.3 software (SAS Institute). All tests were 2-sided, and a significance level of 5% was used.

RESULTS

Patient characteristics

In total, 733 patients were included in this analysis, and their characteristics are provided in **Table 1**. There was an approximately equal sex distribution. The mean age was 66 y, and about half had only one diagnosis, whereas the rest had 2 or 3 diagnoses.

Relation between NI variables

In **Table 2**, the association between the NIs is shown. Anthropometric variables MAC, BW, and CC are highly correlated with each other but poorly correlated with PA and HGS. In view

TABLE 7
Logistic regression models where a combination of nutritional assessment tool (SGA) and one of the NIs was used to predict length of hospital stay ≥7 d (n = 699)[1]

	OR (95% CI)					
Model[2]	SGA B vs. SGA A	SGA C vs. SGA A	P value[3]	OR (95% CI) + Other NI	P value[3]	c-statistic (95% CI)
SGA + PA, g/L	1.27 (0.91, 1.78)	2.19 (1.28, 3.75)	0.01	0.98 (0.95, 1.00)	0.09	0.64 (0.60, 0.68)
SGA + HGS, kg	1.27 (0.91, 1.77)	2.10 (1.22, 3.60)	0.02	0.98 (0.96, 0.996)	0.02	0.65 (0.61, 0.69)
SGA + food intake <50%	1.30 (0.93, 1.81)	2.31 (1.36, 3.93)	0.006	1.51 (1.08, 2.11)	0.02	0.64 (0.60, 0.68)

[1]ORs for continuous predictors are given per unit change. HGS, handgrip strength; NI, nutrition indicator; PA, plasma albumin; SGA, subjective global assessment; SGA A, subjective global assessment, well nourished; SGA B, subjective global assessment, mildly/moderately malnourished; SGA C, subjective global assessment, severely malnourished.
[2]All models controlled for age ≥65 y, sex, and number of diagnoses.
[3]F test.

TABLE 8
Logistic regression models where a combination of nutritional assessment tool (NRS 2002) and one of the NIs was used to predict length of hospital stay ≥7 d (n = 699)[1]

Model[2]	NRS 2002 "at risk" alone, OR (95% CI)	P value[3]	OR (95% CI) + Other NI	P value[3]	c-statistic (95% CI)
NRS 2002 + PA, g/L	1.35 (0.97, 1.89)	0.08	0.97 (0.95, 0.999)	0.04	0.63 (0.59, 0.67)
NRS 2002 + HGS, kg	1.40 (1.01, 1.95)	0.04	0.97 (0.96, 0.99)	0.003	0.64 (0.60, 0.68)
NRS 2002 + food intake <50%	1.37 (0.99, 1.91)	0.06	1.50 (1.07, 2.10)	0.02	0.63 (0.59, 0.67)

[1]ORs for continuous predictors are given per unit change. HGS, handgrip strength; NI, nutrition indicator; NRS, Nutrition Risk Screening; PA, plasma albumin.
[2]All models controlled for age ≥65 y, sex, and number of diagnoses.
[3]Wald test.

of the high correlation between anthropometric variables, they will be highly collinear in multiple logistic regression modeling, essentially carrying the same information. Hence, we have used MAC alone to represent MAC, BW, and CC in subsequent bivariate or multiple logistic models.

Relation between SGA status and NIs

In **Table 3** the positive association between all NIs and the SGA is confirmed; the means of the NIs were significantly lower in patients with SGA B and C than in those with SGA A. Similarly, the proportion of patients with reduced food intake during the first week of admission was higher in SGA B and C than in SGA A. However, individually, all NIs had a poor ability to discriminate between SGA categories (**Table 4**). Logistic regression models in which NIs were used to predict SGA B and C while controlling for age and sex had low discriminating ability; a c-statistic that was at best 0.71 is on the borderline between "no discrimination" and "acceptable" discrimination (28). Combining 2 NIs did not improve discrimination (**Table 5**); the highest c-statistic (for a combination of MAC+PA) was only 0.72. Hence, no single NI or a combination of 2 NIs appears to predict SGA categories.

SGA, NRS 2002, and LOS

To confirm that SGA is at least equivalent and potentially superior to individual NIs, we undertook logistic regression to determine their predictive ability when modeled alone as an NI by using the outcome of LOS (**Table 6**) and when adjusted for key covariates. The NRS 2002, a tool based on more than one NI, was also included for comparison. The SGA is equivalent or superior to other NIs, including the NRS 2002; the only potentially superior NI was HGS in adjusted analyses. However, none of the NIs had a c-statistic that exceeded 0.70, considered by Hosmer and Lemeshow (28) as the level of acceptable discrimination.

The potential additive effect of including individual NIs with the SGA by using the outcome of LOS is demonstrated in **Table 7**. Anthropometric measurements were not significant predictors of LOS (Table 6). Hence, they were not tested in models in combination with the SGA (Table 7). PA, HGS, and food (>50%) intake were negatively associated with LOS, indicating that, with improvement of those NIs, there was a shorter LOS (Table 6). The SGA was a significant predictor of LOS (Table 6) and also remained significant in combination with PA (P = 0.01), HGS (P = 0.02), and food intake (P = 0.006) (Table 7). Yet, the c-statistic of the SGA, when modeled in combination with PA (0.64), HGS (0.65) or food intake (0.64), was nominally better than with the SGA alone (0.63). On the other hand, when modeled in combination with the SGA, PA lost significance (Table 7; P = 0.09). Although the Wald tests showed that HGS and food intake were statistically significant predictors of dichotomized LOS (Table 6), the added predictive ability of these NIs in addition to the SGA is quite limited (Table 7). The NRS 2002 lost significance, shown in Table 6, when PA and food intake were added to the model (**Table 8**), yet the NRS 2002 was still predictive of LOS when modeled in combination with HGS (P = 0.04), and the addition of HGS improved the c-statistic (0.62 in Table 6 to 0.64 in Table 8). However, none of the NI combinations had a c-statistic that exceeded 0.70, considered by Hosmer and Lemeshow (28) as the level of acceptable discrimination.

The logistic analysis of SGA B/C compared with SGA A, dichotomized HGS, and food intake, given in **Table 9**, shows that these variables are independently significant. The sensitivity, specificity, positive predictive value (PPV), and negative predicted value (NPV) for SGA B/C compared with SGA A, HGS, food intake, and the multiple logistic model are given in **Table 10**. The sensitivity and specificity of the model, combining the 3 indicators, did not add to that seen with the SGA alone. Yet, the sensitivity, specificity, NPV, and PPV of any combination were below standards for clinical discrimination.

Readmission rate in relation to SGA and NRS 2002

The readmission rate was significantly associated with SGA status and HGS in univariate analyses, and thus only these were included in adjusted models controlling for age, sex, and CCI. There was no statistically significant predictive value of other individual NIs or the NRS 2002 (**Table 11**), and they were therefore not included in the adjusted model. Adjusted model

TABLE 9
Multiple logistic model combining 3 nutrition indicators to predict the outcome of length of stay <7 d vs. ≥7 d (n = 699)[1]

Variable	OR (95% CI)	P value
HGS continuous, kg	0.98 (0.97, 0.996)	0.01
SGA B/C vs. SGA A	1.51 (1.11, 2.05)	0.009
Food intake <50%	1.44 (1.04, 2.00)	0.03

[1]HGS, handgrip strength; SGA A, subjective global assessment, well nourished; SGA B, subjective global assessment, mildly/moderately malnourished; SGA C, subjective global assessment, severely malnourished.

TABLE 10
Sensitivity, specificity, PPV, NPV, and their exact 95% CIs for SGA B/C vs. SGA A, food intake <50%, dichotomized HGS, and multiple logistic model including all 3 predictors (HGS used as continuous predictor) for length of stay <7 d vs. ≥7 d (n = 699)[1]

	SGA B/C	Food intake <50%	HGS dichotomized within age, sex groups[2]	Multiple logistic model
Sensitivity	0.52 (0.46, 0.57)	0.36 (0.34, 0.41)	0.45 (0.41, 0.51)	0.54 (0.49, 0.59)
Specificity	0.61 (0.55, 0.66)	0.73 (0.68, 0.78)	0.62 (0.57, 0.68)	0.65 (0.59, 0.70)
PPV	0.60 (0.54, 0.65)	0.60 (0.53, 0.67)	0.58 (0.52, 0.63)	0.63 (0.58, 0.69)
NPV	0.53 (0.48, 0.58)	0.50 (0.46, 0.55)	0.50 (0.46, 0.55)	0.56 (0.51, 0.61)

[1]Values are ORs; 95% CIs in parentheses. HGS, handgrip strength; NPV, negative predictive value; PPV, positive predictive value; SGA A, subjective global assessment, well nourished; SGA B, subjective global assessment, mildly/moderately malnourished; SGA C, subjective global assessment, severely malnourished.
[2]HGS was dichotomized at an optimal cutoff point; see Statistical analysis in Methods.

c-statistic was only slightly lower for the SGA (0.60) than for the HGS (0.62), and SGA C increased the risk of readmission, whereas SGA B did not. As a result, a combination analysis of individual NIs in addition to the SGA for this outcome was not completed.

The multiple logistic analysis of SGA, HGS, and food intake for readmission rate is given in **Table 12**. It shows that when SGA B/C compared with SGA A is part of the model, only HGS is independently significant. If SGA C compared with SGA B/A is used in the model, SGA C (P = 0.03) and HGS (P = 0.004) are independently significant. The sensitivity, specificity, PPV, and NPV for SGA B/C compared with SGA A; dichotomized HGS; food intake; and the multiple logistic model, including all 3 predictors, are given in **Table 13**. The sensitivity of the model derived from dichotomization at the optimal point for these 3 predictors was better than SGA by using B/C compared A alone but at cost of specificity. Although sensitivity and NPV were high, specificity and PPV were low. PPV depends not only on the sensitivity of the measure but also on the specificity and the prevalence of disease. PPV is defined as the proportion of patients having a disease out of those who tested positive. If we have low specificity, many patients test positive who do not actually have the condition, and they are included when we calculate PPV. PPV is also related to prevalence of condition, which in this context is the proportion of all admitted patients who are readmitted, which was relatively low.

DISCUSSION

To be clinically useful, assessment of nutritional status in an acute care setting needs to be efficient and predict adverse outcomes such as lengthened hospital stay and increased propensity to be readmitted, because increased time spent in the hospital adds to health costs and affects quality of life. Nutritional status is the balance between requirements modulated by activity and disease (requirements), on one hand, and nutrient intake altered by absorption (intake), on the other. The obvious effects of an imbalance between intake and requirements, as defined above, is a change in body composition with wasting of muscles and loss of body fat when intake is insufficient to meet requirements. If the imbalance continues, a critical stage is reached with increased infirmity; susceptibility to infection, especially pneumonia; and delayed healing, all of which are considered complications that lengthen hospital stay and promote readmission.

Most NIs—specifically, anthropometric measurements, body composition, and serum protein levels—reflect current status and are only a snapshot in time. If a patient is defined as being "malnourished" based on these criteria but is able to resume sufficient food intake (e.g., a patient with a benign esophageal stricture is dilated endoscopically and can eat), then a future health outcome—namely, prolonged hospital stay, readmission, or mortality—may be avoided. Hence, it is necessary to be able to predict the future course of nutritional status during hospitalization

TABLE 11
Logistic regression models: single nutrition indicator predicts 30-d readmission (n = 661)[1]

	Unadjusted models			Adjusted models[2]		
Variable	OR (95% CI)	P value	c-statistic (95% CI)	OR (95% CI)	P value	c-statistic (95% CI)
SGA		0.02	0.56 (0.51, 0.61)		0.03	0.60 (0.55, 0.66)
SGA B	1.20 (0.80, 1.82)	0.4		1.17 (0.77, 1.77)	0.5	
SGA C	2.24 (1.27, 3.94)	0.006		2.21 (1.24, 3.93)	0.007	
NRS 2002 "at risk"	1.27 (0.87, 1.89)	0.2	0.53 (0.48, 0.57)			
BW, kg	1.00 (0.99, 1.01)	0.6	0.52 (0.46, 0.58)			
MAC, cm	0.98 (0.95, 1.01)	0.2	0.54 (0.48, 0.60)			
CC, cm	0.99 (0.96, 1.02)	0.6	0.53 (0.47, 0.58)			
HGS, kg	0.97 (0.95, 0.99)	0.002	0.58(0.53, 0.63)	0.96 (0.94, 0.98)	0.0008	0.62 (0.57, 0.68)
PA, g/L	1.02 (0.98, 1.05)	0.4	0.53 (0.47, 0.58)			
Food intake <50%	0.90 (0.60, 1.37)	0.6	0.51 (0.47, 0.55)			

[1]ORs for continuous predictors are given per unit change. BW, body weight; CC, calf circumference; HGS, handgrip strength; MAC, midarm circumference; NRS, Nutrition Risk Screening; PA, plasma albumin; SGA B, subjective global assessment, mildly/moderately malnourished; SGA C, subjective global assessment, severely malnourished.
[2]Controlled for age ≥65 y, sex, and Charlson Comorbidity Index.

TABLE 12
ORs (95% CIs) in multiple logistic model combining 3 nutrition indicators to predict 30-d readmission (n = 661)[1]

Variable	OR (95% CI)	P value
HGS continuous, kg	0.97 (0.96, 0.99)	0.003
SGA B/C vs. SGA A	1.31 (0.89, 1.92)	0.2
Food intake <50%	0.83 (0.55, 1.27)	0.4

[1]HGS, handgrip strength; SGA A, subjective global assessment, well nourished; SGA B, subjective global assessment, mildly/moderately malnourished; SGA C, subjective global assessment, severely malnourished.

rather than the just the current picture. On the basis of the above considerations, the SGA, which attends to not only the current status but also the interacting factors of food intake, gastrointestinal status, effect of disease on nutrient requirements, and the continued direction of change (not absolute value) in body strength and mass, is most likely to predict nutrition-related outcomes rather than single measurements on admission.

In the current analyses, when adjusted for age, sex, and number of diagnoses, SGA C and the NRS 2002 were significantly predictive of LOS, whereas SGA B was not. Although the general direction of weight, anthropometric measurements, PA, HGS, and food intake in the hospital followed the SGA categories (Table 3), in contrast to the SGA, weight and anthropometric measurements, when adjusted for covariates, were not significant predictors of LOS (Table 6). In a recent study, body muscle mass measured by computed tomography in patients with respiratory failure did not correlate with the SGA, yet the SGA clearly discriminated between patients who went to rehabilitation and those who went to a hospice or died. Hence, muscle mass alone as measured by computed tomography did not correlate with outcome (29). Other studies have confirmed the inability of BMI to predict LOS (30) and/or hospital complications (31). On the other hand, PA, HGS, and food intake in the hospital remain predictors even when adjusted. The next question is whether adding another NI, shown to predict LOS, to the SGA or NRS 2002—namely, PA, HGS, or in-hospital food intake—can improve the ability of the SGA or NRS 2002 to predict LOS or 30-d readmission.

When multiple logistic regression adjusted for age, sex, and number of diagnoses was performed, the SGA remained an independent predictor (Table 7) with all combinations of relevant NIs. On the other hand, when so combined, PA was no longer an independent predictor. Hence, PA should not be used as an additional variable of nutritional status if the SGA has been evaluated. Furthermore, PA and other acute phase proteins are known to be influenced by inflammation, and C-reactive protein can demonstrate this influence. In a large multicenter study where C-reactive protein and prealbumin were measured in addition to the SGA, the conclusion was that the SGA was the best predictor of mortality and adequately discriminated among the range of values of other nutritional indexes (32).

In contrast, HGS and food intake in the hospital remain independent additional variables of LOS, indicating the possibility that HGS and observation of food intake in the hospital may add information to the assessment of nutritional status by the SGA. In contrast, another widely used technique of nutritional assessment, the NRS 2002, does not remain an independent variable when combined with PA or food intake, indicating that the NRS 2002 does not provide sufficient additional information to predict LOS when PA or food intake is used. Again, HGS remains an independent predictor together with the NRS 2002. The 30-d readmission rate adjusted for age, sex, and comorbidity based on the CCI was significant only for SGA C and HGS. The NRS 2002 was not predictive of 30-d readmission. It is possible that if the NRS 2002 was redesigned to show grades of malnutrition, a higher degree might predict readmission. The difference in the significance between moderate and severe malnutrition as defined by the SGA could possibly be attributed to the fact that in the hospital, nutritional support during a short stay influenced those with mild to moderate malnutrition but was not sufficiently long enough for those with severe malnutrition to recover. Clearly, more controlled data during refeeding of patients with different SGA classes should be undertaken in the future.

For any method of nutritional assessment to be clinically useful, it should be able to indicate increased risk of poor outcome in patients identified as malnourished. However, based purely on the c-statistic, sensitivity, specificity, PPV, and NPV, none of the NIs, including the SGA, can be used as a tool to predict LOS or readmission. Yet, malnutrition as measured with the SGA was independently associated with prolonged LOS and readmission when tested in a multivariate analysis, including other influential covariates for these outcomes. These are important health utilization outcomes and indicate that malnutrition, as judged by the SGA, increases the odds of potentially greater costs and prolonged disability through increased LOS and readmission rate. Because nutrition is only one of many factors that influence LOS and readmission, it therefore was expected that the SGA would not have a high predictive value for these outcomes. Yet, the SGA, compared with other NIs, is a stronger independent identifier of the risk of increased LOS and readmission as malnutrition progresses from SGA A to SGA C. In the

TABLE 13
Sensitivity, specificity, PPV, NPV for food intake, SGA, and dichotomized HGS and multiple logistic model including all 3 predictors (HGS continuous) for 30-d readmission rate outcome (n = 661)

	SGA B/C	Food intake <50%	HGS dichotomized within age, sex groups	Multiple logistic model with 3 NIs
Sensitivity	0.52 (0.44, 0.61)	0.30 (0.22, 0.38)	0.55 (0.46, 0.64)	0.82 (0.74, 0.88)
Specificity	0.56 (0.52, 0.61)	0.68 (0.64, 0.72)	0.58 (0.53, 0.62)	0.37 (0.33, 0.41)
PPV	0.24 (0.19, 0.29)	0.20 (0.15, 0.26)	0.25 (0.21, 0.31)	0.25 (0.22, 0.30)
NPV	0.82 (0.77, 0.86)	0.79 (0.75, 0.82)	0.83 (0.79, 0.87)	0.88 (0.84, 0.92)

[1]Values are ORs; 95% CIs in parentheses. HGS, handgrip strength; NI, nutrition indicator; NPV, negative predictive value; PPV, positive predictive value; SGA B, subjective global assessment, mildly/moderately malnourished; SGA C, subjective global assessment, severely malnourished.

hospital setting, these findings confirm the clinical utility of this tool to identify patients who need the attention of scarce dietitian resources as well as nutritional support. To support the value of the SGA, a prior controlled trial indicates that when patients are identified as malnourished by the SGA and nutritional support is instituted, there is a reduced readmission rate (33).

The strengths of our study are its prospective nature; the large, diverse, and multicenter population of patients; and the concurrent use of different nutritional assessment techniques, which made this analysis possible. A specific weakness of this analysis is the effect of disease, which interacts with nutrition, causing similar effects; we attempted to control for this effect by modeling CCI or number of diagnoses. In prior research, when 101 patients classified as malnourished by SGA were randomly allocated oral nutritional support or dietary counseling (33), those receiving oral nutritional support showed a significantly lower readmission rate and better change in muscle function. This indicates that the SGA can identify those patients who would benefit from nutritional support and that nutrition treatment improves outcome, irrespective of disease state. The current study supports the concept that SGA does identify patients likely to develop nutrition-related complications. Previous work has also shown that the SGA identifies patients who continue to benefit from long-term oral nutritional support after discharge from the hospital (34). In other studies, the SGA has been shown to predict other nutrition-related complications, including mortality (35) increased infection rate (36), and ICU- related outcomes (36, 37). A potential weakness of the SGA is that it requires training to perform accurately and in a reproducible manner. Another weakness in our study is that we did not include all types of hospital patients, such as those in the ICU; however, other studies have shown that the SGA predicts outcome in ICU patients (36, 37).

In summary, the SGA and HGS appear to be the most robust indicators of increased risk of prolonged LOS and hospital readmission. Further studies to evaluate the improvement of nutritional assessment by combining the SGA with HGS and in-hospital food intake should be considered. In addition, a definitive large study in medical and surgical patients demonstrating that nutritional treatment of patients at risk improves recovery and reduces readmission is needed.

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