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Malnutrition Universal Screening Tool and Patient-Generated Subjective Global Assessment Short Form and their predictive validity in hospitalized patients

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SUMMARY

Background and aims: Malnutrition screening is a first step in the nutrition care process for hospitalized patients, to identify those at risk of malnutrition and associated worse outcome, preceding further assessment and intervention. Frequently used malnutrition screening tools including the Malnutrition Universal Screening Tool (MUST) mainly screen for characteristics of malnutrition, while the Patient-Generated Subjective Global Assessment Short Form (PG-SGA SF) additionally includes risk factors for development of malnutrition, yielding a higher percentage of patients at risk. To investigate whether this translates into higher risk of worse outcome, we aimed to determine the predictive validity of MUST and PG-SGA SF for prolonged hospitalization >8 days, readmission, and mortality <6 months after hospital discharge.

Methods: In this observational study, MUST was performed according to university hospital protocol. Additional screening using PG-SGA SF was performed within 24 h of hospital admission (high risk: MUST $\geq$ 2, PG_SGA SF $\geq$ 9). Associations of MUST and PG-SGA SF with outcomes were analyzed by logistic- and Cox PH-regression.

Results: Of 430 patients analyzed (age 58 $\pm$ 16 years, 53% male, BMI 26.9 $\pm$ 5.5 kg/m^2), MUST and PG-SGA SF identified 32 and 80 at high risk, respectively. One-hundred-eight patients had prolonged hospitalization, 109 were readmitted and 20 died. High risk by MUST was associated with mortality (HR = 3.9; 95% CI 1.3–12.2, P = 0.02), but not with other endpoints. High risk by PG-SGA SF was associated with prolonged hospitalization (OR = 2.5; 95% CI 1.3–5.0, P = 0.009), readmission (HR = 1.9; 95% CI 1.1–3.2, P = 0.03), and mortality (HR = 34.8; 95% CI 4.2–289.3, P = 0.001), independent of age, sex, hospital ward and previous hospitalization <6 months. In the 363/430 patients classified as low risk by MUST, high risk by PG-SGA SF was independently associated with higher risk of readmission (HR = 1.9; 95% CI 1.0–3.5, P = 0.04) and mortality (HR = 19.5; 95% CI 2.0–189.4, P = 0.01).

Conclusions: Whereas high malnutrition risk by MUST was only associated with mortality, PG-SGA SF was associated with higher risk of prolonged hospitalization, readmission, and mortality. In patients considered as low risk by MUST, high malnutrition risk by PG-SGA SF was also predictive of worse outcome. Our findings support the use of PG-SGA SF in routine care to identify patients at risk of malnutrition and worse outcome, and enable proactive interventions.

Abbreviations: PG-SGA SF, Patient-Generated Subjective Global Assessment Short Form; MUST, Malnutrition Universal Screening Tool; NIS, Nutrition Impact Symptoms.

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1. Introduction

Disease-related malnutrition is common among hospitalized patients, and is associated with negative health outcomes, such as increased risk of pressure ulcers, length of hospital stay, and hospital readmission, leading to increased health care costs, and higher mortality risk [1–6]. To quickly identify patients at risk, malnutrition screening using validated screening instruments is the first crucial step in the nutrition care process, preceding further assessment for malnutrition diagnosis, intervention and monitoring [7]. Importantly, as mentioned by ESPEN in their guidelines on clinical nutrition terminology, risk of malnutrition determined by validated screening tools is regarded as a condition in itself, and is also associated with worse clinical outcomes [8–12].

The Malnutrition Universal Screening Tool (MUST) is a widely used screening tool to detect malnutrition risk in adults across all health care settings [13,14]. The MUST is quick and easy to use in daily clinical practice, and has likely contributed to better care for patients at risk of malnutrition [15]. However, in this screening tool, BMI and unplanned weight loss are prominent items, strongly contributing to the total risk score, while factors contributing to development of malnutrition, including reduced food intake, nutrition impact symptoms (NIS, e.g. nausea, dysgeusia, pain) are not deliberately included. As a consequence, the MUST mainly identifies patients with characteristics of existing malnutrition, rather than those who are at risk for future development of malnutrition and may benefit most from early, preventive interventions.

Including risk factors for malnutrition, such as NIS, in current malnutrition screening practices may facilitate a more proactive and preventive approach to counteracting malnutrition, particularly in patients not (yet) identified by critical weight loss [16–18]. As an alternative screening tool for clinical practice, the Patient-Generated Subjective Global Assessment Short Form (PG-SGA SF) combines evaluation of present characteristics and important risk factors for development of malnutrition, scoring both recent weight loss, as well as food intake, NIS, and activities and function [19]. The PG-SGA SF can be used separately from the full PG-SGA for malnutrition risk screening, triage and identification of intervention targets. Also, it is suitable for self-completion by the patient, with most patients being able to complete the PG-SGA SF in less than 5 min [20,21]. Thus far, the PG-SGA SF has been validated against the full PG-SGA in cancer outpatients receiving chemotherapy [22,23], and has been associated with a higher risk of post-operative complications in vascular surgery patients independent of other characteristics such as age, sex, and BMI [24].

Observational studies in hospital patients and patients with chronic kidney disease have previously shown that the PG-SGA SF identifies a considerably larger percentage of patients at risk compared with the MUST [25–27]. This is consistent with a recent cross-sectional analysis from our hospital, in which we found an approximately 2.5-fold higher percentage of patients at risk according to the PG-SGA SF, compared with MUST [28]. However, whether this difference in classification, particularly the larger yield of the PG-SGA SF, has important clinical consequences, i.e., whether it also translates into corresponding higher risk of worse outcomes, has yet to be investigated. In the current study, we therefore determined the predictive validity of the MUST and the PG-SGA SF for prolonged hospitalization, hospital readmission, and mortality, respectively, up to 6 months after discharge.

2. Materials and methods

2.1. Patient population

This prospective observational cohort study was conducted at the University Medical Center Groningen (UMCG), a single academic center. Details on study design, inclusion and exclusion criteria have been described previously [28,29]. In short, adult patients (≥18 years) admitted to two surgical wards and two medical wards between March 2016 and July 2017, were asked to participate. This resulted in a convenience sample of a mixed university hospital population, for which we did not perform a power analysis before the start of the study. Demographic, anthropometric and other clinical data were retrieved from the medical records. This study was performed in accordance with the declaration of Helsinki and was approved by the local medical ethics committee (METc UMCG 2016/106).

2.2. Malnutrition risk screening

According to standard care at the UMCG, malnutrition screening was performed using the MUST within 24 h of hospital admission by a nurse or nutrition assistant [30]. The MUST score is based on three items regarding BMI (score 0–2), weight loss (score 0–2) and no nutritional intake due to acute disease (score 0–2) [13]. Details on the scoring of the MUST are provided in Supplemental Table 1a. Based on the MUST score, patients were categorized as having a low risk (MUST score 0), medium risk (MUST score 1) or high risk (MUST score ≥2) of malnutrition [13].

In addition, malnutrition screening was performed using the Dutch version [31] of the PG-SGA SF [32], which was filled out by the patient, with support from trained nurses or researchers when necessary. The PG-SGA SF comprises the first four boxes of the full PG-SGA, which addresses weight history (score 0–5), food intake (score 0–4), NIS (score 0–24), and activities/functioning (score 0–3) [19]. The PG-SGA SF thereby generates a score ranging from 0 to 36. Based on the PG-SGA SF score, patients were categorized as having low risk (PG-SGA SF score 0–3), medium risk (PG-SGA SF score 4–8), or high risk (PG-SGA SF score ≥9) of malnutrition [24].

Malnutrition care as usual was provided during the data collection period, as indicated in regular care protocols based on national guidelines [30]. This involved provision of additional snacks and an information brochure by the ward's nutrition assistant in case of medium malnutrition risk (MUST score 1), and a dietetic referral and intake monitoring in case of high malnutrition risk (MUST score ≥2). Irrespective of the malnutrition screening result by MUST, dietetic referral could be instructed by the doctor. There was no nutritional protocol in place based on the PG-SGA SF screening result, but a weekly overview of scores was provided to the ward's head nurse to enable start of interventions if needed. An overview of the nutritional care activities during this study was previously published [29].

2.3. Endpoints

The endpoints of this study included prolonged hospitalization, hospital readmission, and mortality after discharge within 6 months follow-up after discharge. In absence of a well-established definition of prolonged hospitalization, we defined prolonged hospitalization as a hospital stay that lasted longer than the 75th percentile of the total population [33], similar to previous research on hospital outcomes [34]. Data on study endpoints were retrieved from electronical patient records.

2.4. Statistical analyses

For this study we used data from patient hospitalizations with complete data on PG-SGA SF screening at admission ($n = 643$) and excluded those with missing or incomplete MUST data ($n = 213$), resulting in 430 cases eligible for analyses. Data are presented as means with standard deviations (SD) for normally distributed data, medians with interquartile range (IQR) for non-normally distributed data, and numbers with percentages for categorical data. Chi-square tests for categorical variables, ANOVA for normally distributed variables and Kruskal–Wallis tests for skewed distributed or ordinal data were performed to determine differences in baseline characteristics between risk groups as determined by the MUST and PG-SGA SF. Agreement between MUST and PG-SGA SF in classification of malnutrition risk was assessed by weighted kappa (κ) with values ≤ 0 as indicating no agreement, 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement [35].

To study whether MUST and PG-SGA SF were associated with prolonged hospitalization, we performed logistic regression analyses. Kaplan–Meier curves were used to visualize the association of MUST and PG-SGA SF risk groups with risk of hospital readmission and mortality. Cox proportional hazard regression analyses then were performed to further study this association. For both logistic and Cox proportional hazard regression, we first performed univariate analyses (model 1), after which we further adjusted for age, sex, hospital ward and previous hospitalization within 6 months prior to study baseline in addition (model 2). To account for different patient populations admitted to one hospital ward, we repeated all analyses with medical condition in the multivariate model instead of hospital ward. Patients were censored at time of death or loss to follow-up, when applicable. The same regression analyses for investigating the association of the PG-SGA SF with outcomes were performed in patients with low risk of malnutrition according to the MUST, and vice versa, to further study the clinical implications of the difference in classification of malnutrition risk between both instruments.

All statistical analyses were performed using SPSS version 23.0 (SPSS Inc. Chicago, Il). For all analyses, a two-tailed P-value < 0.05 was considered statistically significant.

3. Results

3.1. Baseline characteristics

Malnutrition risk screening using both the MUST and PG-SGA SF were performed at hospital admission in 430 consecutive patients. Mean age was 58 ± 16 years, 228 (53%) were male, and mean BMI was 26.9 ± 5.5 kg/m^2. Out of the 430 included patients, 241 (56%) patients were included from surgical wards and 189 (44%) patients from medical wards. During admission, 274 (64%) patients underwent surgery. The most common medical conditions for which patients were admitted to the hospital were neoplasms including malignancies (25%) and kidney failure (18%), followed by other conditions in the head or neck area (15%), trauma or arthrosis (12%) and sepsis or other (systemic) infections (11%). In total, 7 (1.6%) patients were excluded from prospective analyses because of death during hospitalization ($n = 2$) or missing data on hospital readmission or mortality ($n = 5$), resulting in 423 patients eligible for prospective analyses. Baseline characteristics of the patients according to categories of the PG-SGA SF and MUST are shown in Table 1.

Based on the MUST, 363 (84%) patients at hospital admission were classified as low risk, 35 (8%) patients as medium risk, and 32 (7%) patients as high risk of malnutrition. Patients with low risk of malnutrition according to the MUST were more often male, taller, had a higher weight and BMI, when compared with the high risk of malnutrition group. Based on the PG-SGA SF, in the same population, 248 (58%) patients were classified as having low risk, 102 (24%) patients as medium risk, and 80 (19%) patients as high risk of malnutrition. Patients with high risk of malnutrition according to the PG-SGA SF had significantly higher scores on all items compared with low or medium risk patients. The difference was most pronounced for the items on nutrition impact symptoms (median score 0 vs. 3 vs. 8 points for low, medium and high risk, respectively) and activities/functioning (median score 0 vs. 1 vs. 2 points for low, medium and high risk, respectively). Additional results regarding the item scores of the PG-SGA SF are provided in Supplemental Table 1b. Patients with low risk of malnutrition according to the PG-SGA SF were younger, more often male, taller, had a higher weight, were less often hospitalized in the 6 months before study baseline, when compared with the group with high risk for malnutrition according to PG-SGA SF. For both the MUST and the PG-SGA SF, patients with medium and high risk of malnutrition were more often admitted to a medical ward when compared with patients with low risk of malnutrition. Compared with patients who underwent surgery during admission, patients who did not undergo surgery during admission were older, were more often hospitalized in the past 6 months, were more often at medium or high risk of malnutrition according to both the MUST and the PG-SGA SF, and had a longer length of stay (Supplemental Table 2).

A comparison between the malnutrition risk classification according to the MUST and the PG-SGA SF is shown in Table 2. Agreement between the MUST and the PG-SGA SF was fair ($\kappa = 0.210$, $P < 0.001$). Overall, 229 (53%) patients were classified as having low risk of malnutrition, 8 (2%) patients as medium risk, and 17 (4%) patients as high risk according to both the MUST and the PG-SGA SF. On the one hand, 19/248 (8%) patients that were classified as low risk of malnutrition according to the PG-SGA SF were classified as having a medium or high risk of malnutrition according to the MUST. On the other hand, 134/363 (37%) of patients that were classified as low risk of malnutrition according to the MUST were classified as medium or high risk of malnutrition based on the PG-SGA SF.

3.2. Association between malnutrition risk according to MUST and PG-SGA SF and clinical outcomes

Median length of hospital stay was 5 [2–8] days and 104 (24%) patients had a hospital stay of >8 days. Results of the logistic regression analyses are shown in Table 3. Medium or high malnutrition risk classified by the MUST was not associated with risk of prolonged hospitalization (medium risk: OR 1.6; 95% CI 0.8–3.4, $P = 0.23$, high risk: OR 2.1; 95% CI 1.0–4.5, $P = 0.06$). However, similar analyses of malnutrition risk classified by the PG-SGA SF showed that high malnutrition risk was associated with higher risk of prolonged hospitalization (OR 3.0; 95% CI 1.7–5.2, $P < 0.001$), and this association remained after adjustment for age, sex, hospital ward and hospitalization within 6 months prior to study baseline (OR 2.5; 95% CI 1.3–5.0, $P = 0.009$). Including medical condition in the multivariate model instead of hospital ward did not materially alter these results (Supplemental Table 3a).

During follow-up of 6 months after hospital discharge, 109 (25%) patients were readmitted to the hospital and 20 (5%) patients died. Kaplan–Meier survival curves of the association between MUST and PG–SGA SF and risk of hospital readmission and mortality respectively, are shown in Fig. 1, and results of the Cox proportional hazard regression analyses are shown in Table 4. The Cox proportional hazards analyses showed that neither

Table 1
Patient characteristics at hospital admission according to nutritional screening by MUST and PG-SGA SF.

MUST	Low risk (score 0)	Medium risk (score 1)	High risk (score ≥2)	*P*-value
N	363	35	32	
Age, years	60 [47–69]	65 [52–76]	63 [53–70]	0.19
Male sex, *n* (%)	201 (55.4)	16 (45.7)	11 (34.4)	0.05
Height, cm	174 ± 9	173 ± 11	170 ± 8	0.03
Weight, kg	84.3 ± 17.5	67.9 ± 13.4	63.4 ± 16.5	<0.001
BMI, kg/m^2	27.8 ± 5.1	22.6 ± 4.8	22.1 ± 5.8	<0.001
Previous hospitalization within 6 months, *n* (%)	73 (20.1)	10 (28.6)	10 (31.3)	0.20
Hospital ward, *n* (%)				0.001
Surgical ward (*n* = 241)	217 (59.8)	13 (37.1)	11 (34.4)	
Medical ward (*n* = 189)	146 (40.2)	22 (62.9)	21 (65.6)	
Underwent surgery, *n* (%)	247 (68.0)	16 (45.7)	11 (34.4)	<0.001
Medical condition, *n* (%)				<0.001
Neoplasms, incl. malignancies and complications thereof (*n* = 106)	92 (25.3)	7 (20.0)	7 (21.9)	
Trauma, arthrosis (*n* = 54)	50 (13.8)	2 (5.7)	2 (6.3)	
Other conditions in the head or neck area (*n* = 75)	65 (17.9)	7 (20.0)	3 (9.4)	
Other conditions of the skin or connective tissue (*n* = 23)	17 (4.7)	5 (14.3)	1 (3.1)	
Kidney failure and complications thereof (*n* = 89)	79 (21.8)	6 (17.1)	4 (12.5)	
Sepsis, gastro-enteritis and other (systemic) infections (*n* = 59)	47 (12.9)	5 (14.3)	7 (21.9)	
Other (*n* = 24)	13 (3.6)	3 (8.6)	8 (25.0)	
Length of hospital stay, days	5 [2–8]	7 [2–9]	7 [4–13]	0.07
PG-SGA SF	Low risk (score 0–3)	Medium risk (score 4–8)	High risk (score ≥9)	*P*-value
N	248	102	80	
Age, years	59 [47–69]	59 [44–68]	65 [55–73]	0.009
Male sex, *n* (%)	150 (60.5)	45 (44.1)	33 (41.3)	0.001
Height, cm	175 ± 9	172 ± 9	170 ± 9	<0.001
Weight, kg	84.9 ± 17.6	77.0 ± 16.6	76.4 ± 20.5	<0.001
BMI, kg/m^2	27.5 ± 5.1	26.0 ± 5.5	26.3 ± 6.3	0.04
Previous hospitalization within 6 months, *n* (%)	40 (16.1)	27 (26.5)	26 (32.5)	0.003
Hospital ward, *n* (%)				<0.001
Surgical ward (*n* = 241)	173 (69.8)	47 (46.1)	21 (26.3)	
Medical ward (*n* = 189)	75 (30.2)	55 (53.9)	59 (73.8)	
Underwent surgery, *n* (%)	195 (78.6)	61 (59.8)	18 (22.5)	<0.001
Medical condition, *n* (%)				<0.001
Neoplasms, incl. malignancies and complications thereof (*n* = 106)	63 (25.4)	24 (23.5)	19 (23.8)	
Trauma, arthrosis (*n* = 54)	41 (16.5)	9 (8.8)	4 (5.0)	
Other conditions in the head or neck area (*n* = 75)	58 (23.4)	12 (11.8)	5 (6.3)	
Other conditions of the skin or connective tissue (*n* = 23)	8 (3.2)	10 (9.8)	5 (6.3)	
Kidney failure and complications thereof (*n* = 89)	50 (20.2)	26 (25.5)	13 (16.3)	
Sepsis, gastro-enteritis and other (systemic) infections (*n* = 59)	21 (8.5)	17 (16.7)	21 (26.3)	
Other (*n* = 24)	7 (2.8)	4 (3.9)	13 (16.3)	
Length of hospital stay, days	4 [1–8]	6 [2–9]	8 [5–13]	<0.001

Data are reported as mean ± SD, median [IQR] or numbers (%) within malnutrition risk category for categorical variables. Differences were tested by ANOVA or Kruskal–Wallis for normally distributed continuous and skewed or ordinal variables, and χ^2-test for categorical variables. MUST: Malnutrition Universal Screening Tool, PG-SGA SF: Patient-Generated Subjective Global Assessment Short Form, BMI: body mass index.

Table 2
Classification according to the MUST and PG-SGA SF at hospital admission.

		MUST			
		Low risk (score 0)	Medium risk (score 1)	High risk (score ≥2)	Total
PG–SGA SF	Low risk (score 0–3)	229	15	4	248
	Medium risk (score 4–8)	83	8	11	102
	High risk (score ≥9)	51	12	17	80
	Total	363	35	32	430

MUST: Malnutrition Universal Screening Tool, PG-SGA SF: Patient-Generated Subjective Global Assessment Short Form.

medium nor high malnutrition risk classified by the MUST was associated with risk of hospital readmission (medium risk: HR 1.1; 95% CI 0.5–2.1, $P = 0.86$, high risk: HR 1.5; 95% CI 0.8–2.8, $P = 0.20$). However, both medium and high malnutrition risk according to the MUST were associated with higher risk of mortality after discharge (medium risk: HR 3.7; 95% CI 1.2–11.6, $P = 0.03$, high risk: HR 5.4; 95% CI 1.9–15.6, $P = 0.002$), but only high malnutrition risk according to the MUST remained significantly associated with higher risk of mortality after further adjustment for age, sex, hospital ward and hospitalization within 6 months prior to study baseline (HR 3.9; 95% CI 1.3–12.2, $P = 0.02$). Similar analyses of malnutrition risk classified by the PG-SGA SF showed that high malnutrition risk was associated with higher risk of hospital readmission (HR 2.2; 95% CI 1.4–3.4, $P = 0.001$), and this association remained statistically significant after adjustment for age, sex, hospital ward and hospitalization within 6 months prior to study baseline (HR 1.9; 95% CI 1.1–3.2, $P = 0.03$). Both medium and high malnutrition risk according to the PG-SGA SF were associated with higher risk of mortality after discharge (medium risk: HR 14.7; 95% CI 1.8–121.9, $P = 0.01$, high

Table 3
Association between malnutrition risk and prolonged hospitalization in 430 patients.

Prolonged hospitalization >8 days						
MUST	Low risk		Medium risk		High risk	
Event, *n* (%)	81 (22)		11 (31)		12 (38)	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Model 1	Reference	–	1.6 (0.8–3.4)	0.23	2.1 (1.0–4.5)	0.06
Model 2	Reference	–	1.2 (0.5–2.7)	0.72	2.1 (0.9–5.0)	0.09
PG-SGA SF	Low risk		Medium risk		High risk	
Event, *n* (%)	45 (18)		27 (26)		32 (40)	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Model 1	Reference	–	1.6 (0.9–2.8)	0.08	3.0 (1.7–5.2)	<0.001
Model 2	Reference	–	1.4 (0.8–2.6)	0.27	2.5 (1.3–5.0)	0.009

Logistic regression analyses were performed to assess the association of the PG-SGA SF and MUST with risk of prolonged hospitalization. Model 1: crude analyses. Model 2: adjusted for age, sex, hospital ward and previous hospitalization within 6 months prior to study baseline. MUST: Malnutrition Universal Screening Tool, PG-SGA SF: Patient-Generated Subjective Global Assessment Short Form.

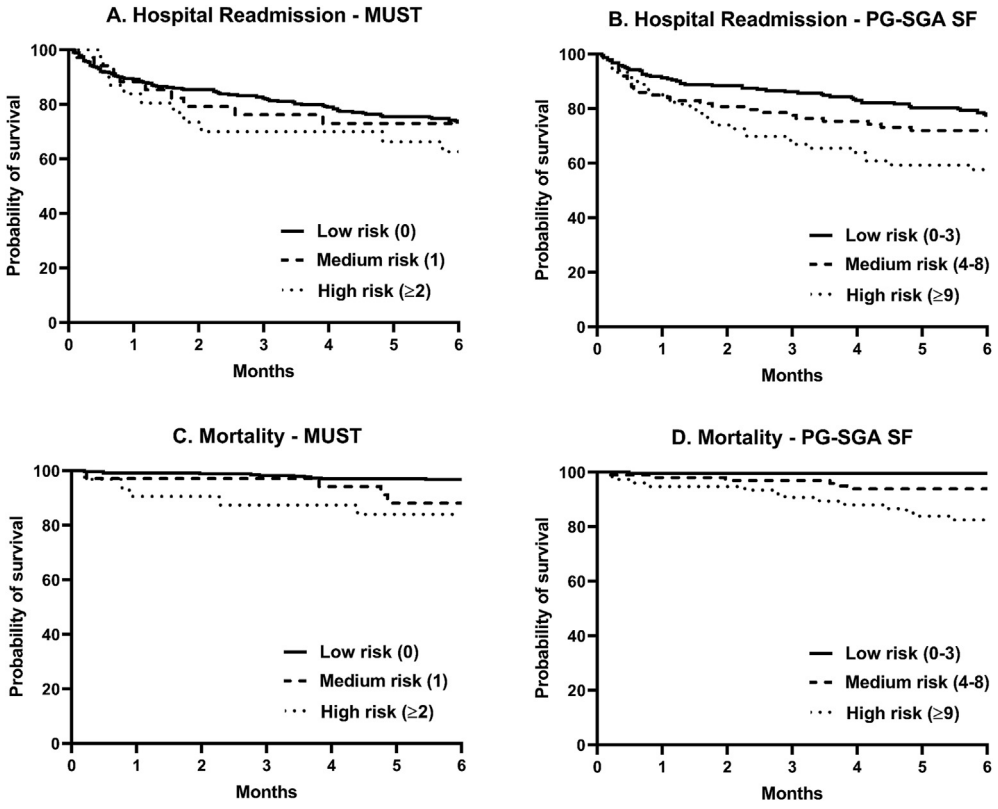

Fig. 1. Kaplan–Meier curves illustrating the association of A) MUST and hospital readmission, B) PG-SGA SF and hospital readmission, C) MUST and mortality, and D) PG-SGA SF and mortality. MUST: Malnutrition Universal Screening Tool, PG-SGA SF: Patient-Generated Subjective Global Assessment Short Form.

risk: HR 43.7; 95% CI 5.7–334.1, $P < 0.001$), and these associations also remained statistically significant after further adjustment for age, sex, hospital ward and hospitalization within 6 months prior to study baseline (medium risk: HR 13.7; 95% CI 1.6–115.5, $P = 0.02$, high risk: HR 34.8; 95% CI 4.2–289.3, $P = 0.001$). Inclusion of medical condition in the multivariate model instead of hospital ward did not materially alter the association of high risk according to the PG-SGA SF with hospital readmission (Supplemental Table 3b). Multivariate prospective analyses adjusted for medical condition were not reported for mortality as an endpoint, as due to the smaller number of events, events were lacking in some subgroups, which made it not possible to establish a reliable model.

3.3. Clinical outcomes in patients with discrepant results on MUST and PG-SGA SF

We subsequently analyzed the association between malnutrition risk according the PG-SGA SF and study endpoints in the 363 patients that were classified as low risk of malnutrition by the MUST (Table 5). In these patients high malnutrition risk according to the PG-SGA SF was associated with higher risk of prolonged hospitalization (OR 2.7; 95% CI 1.4–5.3, $P = 0.003$), but this association lost statistical significance after adjustment for age, sex, hospital ward and hospitalization within 6 months prior to study baseline (OR 1.9; 95% CI 0.9–4.2, $P = 0.12$). However, high malnutrition risk according to the PG-SGA SF was associated with higher

Table 4
Association between malnutrition risk and hospital readmission and mortality after discharge in 423 patients.

Hospital readmission <6 months						
MUST	Low risk		Medium risk		High risk	
Event, *n* (%)	89 (25)		9 (26)		11 (34)	
	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Model 1	Reference	–	1.1 (0.5–2.1)	0.86	1.5 (0.8–2.8)	0.20
Model 2	Reference	–	0.9 (0.4–1.8)	0.90	1.4 (0.7–2.7)	0.35
PG-SGA SF	Low risk		Medium risk		High risk	
Event, *n* (%)	52 (21)		27 (27)		30 (40)	
	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Model 1	Reference	–	1.4 (0.9–2.2)	0.18	2.2 (1.4–3.4)	0.001
Model 2	Reference	–	1.2 (0.7–1.9)	0.46	1.9 (1.1–3.2)	0.03
Mortality <6 months						
MUST	Low risk		Medium risk		High risk	
Event, *n* (%)	11 (3)		4 (11)		5 (16)	
	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Model 1	Reference	–	3.7 (1.2–11.6)	0.03	5.4 (1.9–15.6)	0.002
Model 2	Reference	–	1.9 (0.6–6.4)	0.30	3.9 (1.3–12.2)	0.02
PG-SGA SF	Low risk		Medium risk		High risk	
Event, *n* (%)	1 (0.4)		6 (6)		13 (17)	
	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Model 1	Reference	–	14.7 (1.8–121.9)	0.01	43.7 (5.7–334.1)	<0.001
Model 2	Reference	–	13.7 (1.6–115.5)	0.02	34.8 (4.2–289.3)	0.001

Cox-regression analyses were performed to assess the association of the PG-SGA SF and MUST with risk of hospital readmission and mortality. Model 1: crude analyses. Model 2: adjusted for age, sex, hospital ward and previous hospitalization within 6 months prior to study baseline. MUST: Malnutrition Universal Screening Tool, PG-SGA SF: Patient-Generated Subjective Global Assessment Short Form.

risk of hospital readmission (HR 2.5; 95% CI 1.5–4.1, $P = 0.001$), and remained so after further adjustment in the multivariate model (HR 1.9; 95% CI 1.0–3.5, $P = 0.04$). Also, both medium and high malnutrition risk according to the PG-SGA SF were associated with higher mortality risk (medium risk: HR 13.7; 95% CI 1.6–116.9, $P = 0.02$, high risk: HR 23.8; 95% CI 2.8–204.1, $P = 0.004$), also after adjustment for age, sex, hospital ward and hospitalization within 6 months prior to study baseline (medium risk: HR 12.2; 95% CI 1.4–106.4, $P = 0.02$, high risk: HR 19.5; 95% CI 2.0–189.4, $P = 0.01$). Including medical condition in the multivariate model instead of hospital ward did not materially alter these results. Again, analyses for mortality could not be performed (Supplemental Table 4).

Likewise, we analyzed the association between the MUST and study endpoints in the 248 patients that were classified as low risk of malnutrition by the PG-SGA SF. In these analyses, neither medium nor high risk according to the MUST was associated with risk of prolonged hospitalization (medium risk: HR 1.1; 95% CI 0.3–4.2, $P = 0.84$, high risk: HR 1.5; 95% CI 0.2–15.1, $P = 0.72$). Similarly, we observed no association between medium malnutrition risk according to the MUST and risk of hospital readmission (HR 1.3; 95% CI 0.5–3.5, $P = 0.66$), and due to the absence of hospital readmission in the high malnutrition risk group, the association between high malnutrition risk according to the MUST and hospital readmission could not be studied. Moreover, of these patients only one patient died after hospital discharge, and therefore we were unable to perform Cox regression analyses on mortality after discharge.

4. Discussion

This study showed that categorization of high malnutrition risk was 2.5 times higher using the PG-SGA SF compared with the MUST, which translated into a higher risk of worse clinical outcomes. Whereas high risk of malnutrition according to the MUST was only associated with higher risk of mortality, high malnutrition risk according to the PG-SGA SF was independently associated with all study endpoints, i.e., higher risk of prolonged hospitalization, hospital readmission and mortality after discharge. Moreover, in patients categorized as low risk by the MUST, high malnutrition risk by the PG-SGA SF was also associated with higher risk of readmission and mortality, while this was not the case for the MUST when analyzed in low risk patients classified by the PG-SGA SF. Our findings suggest that the difference in categorization between both instruments, particularly the larger yield of the PG-SGA SF, may have important clinical consequences, and stresses the importance of a more proactive approach to malnutrition risk through identification of patients that are at high risk of future malnutrition by the PG-SGA SF. It should be noted that, in this study, we assessed malnutrition risk using two screening instruments, not malnutrition itself using gold standard assessment techniques. Considering the role of malnutrition screening as a first step in the nutrition care process to identify patients at risk, these findings on the association of malnutrition risk with outcomes are relevant for clinical practice.

To our knowledge, this is the first study to investigate the difference between the currently widely used MUST and the PG-SGA SF in their association with clinical outcomes. The main difference in content between these instruments is that the MUST mostly screens for present characteristics of malnutrition (i.e., low BMI, critical weight loss), while the PG-SGA SF includes a combination of characteristics and risk factors for development of malnutrition in the immediate future [19]. The MUST scores BMI, in addition to weight loss and absence of nutritional intake for more than 5 days, with all items theoretically contributing to one third of the maximum risk score. In contrast, the PG-SGA SF scores weight loss

Table 5
Association between malnutrition risk screening according to the PG-SGA SF and hospital outcomes in 363 patients[a] categorized as low risk of malnutrition by the MUST.

Prolonged hospitalization >8 days						
PG-SGA SF	Low risk		Medium risk		High risk	
Event, *n* (%)	41 (18)		21 (25)		19 (37)	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Model 1	Reference	–	1.5 (0.9–2.8)	0.15	2.7 (1.4–5.3)	0.003
Model 2	Reference	–	1.3 (0.7–2.5)	0.45	1.9 (0.9–4.2)	0.12
Hospital readmission <6 months						
PG-SGA SF	Low risk		Medium risk		High risk	
Event, *n* (%)	48 (21)		20 (24)		21 (45)	
	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Model 1	Reference	–	1.2 (0.7–2.1)	0.45	2.5 (1.5–4.1)	0.001
Model 2	Reference	–	1.1 (0.6–1.9)	0.70	1.9 (1.0–3.5)	0.04
Mortality <6 months						
PG-SGA SF	Low risk		Medium risk		High risk	
Event, *n* (%)	1 (0.4)		5 (6)		5 (11)	
	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Model 1	Reference	–	13.7 (1.6–116.9)	0.02	23.8 (2.8–204.1)	0.004
Model 2	Reference	–	12.2 (1.4–106.4)	0.02	19.5 (2.0–189.4)	0.01

Logistic regression analyses were performed to assess the association of the PG-SGA SF with risk of prolonged hospitalization. Cox-regression analyses were performed to assess the association of the PG-SGA SF with risk of hospital readmission and mortality. Model 1: crude analyses. Model 2: adjusted for age, sex, hospital ward and previous hospitalization within 6 months prior to study baseline. MUST: Malnutrition Universal Screening Tool, PG-SGA SF: Patient-Generated Subjective Global Assessment Short Form.

[a] $n = 7$ were excluded due to death during hospitalization or loss to follow-up, leaving $n = 356$ for prospective analyses on hospital readmission and mortality after discharge.

irrespective of BMI, as well as food intake, NIS and activities/functioning, of which the item on NIS contributed the most to the total risk score in our study population, followed by the item on activities/functioning. Importantly, our findings suggest that the additional risk factors that are included in the PG-SGA SF are predictive of clinical outcomes in hospital patients, in contrast to the scoring of BMI as included in the MUST. Specifically, presence of multiple NIS as determined by the PG-SGA SF seems to discriminate between patients with low and high risk of malnutrition and worse clinical outcome, consistent with previous literature on the prognostic value of NIS [16–18]. As a result, the PG-SGA SF yields a BMI-independent risk assessment, and through inclusion of potentially modifiable risk factors also provides specific target areas for proactive and interdisciplinary interventions.

Our results on the predictive validity of the PG-SGA SF for clinical outcomes in a mixed hospital population are consistent with previous studies conducted in patients with cancer. In patients with advanced lung or gastrointestinal cancer, high risk of malnutrition according to the PG-SGA SF (score ≥9 points) was associated with an average 12% greater hospitalization time and a 3.4 times higher mortality rate during follow-up [36]. Similarly, increased malnutrition risk according to the PG-SGA SF (score ≥5 points) was associated with an approximately 3.5 times higher 1-year mortality risk in ambulatory patients with cancer [37]. Of note, in the current study the hazard ratios for mortality in patients with high risk of malnutrition according to the PG-SGA SF were much larger, possibly due to differences in overall mortality rate due to differences in underlying diseases, and the fact that we only included hospitalized patients.

Several studies previously reported on the predictive value of the MUST for hospital outcomes. In our study, we did not find a significant association between the MUST and prolonged hospitalization. This is consistent with prior data in older hospital patients [38], although others reported an association between malnutrition risk according to the MUST and longer hospital stay in a mixed hospital population and elderly hospital patients [39–41]. Furthermore, we did not find an association between malnutrition risk according to the MUST and hospital readmission, which corresponds to previous studies in general hospital patients and older people with a hip fracture who underwent surgery [38,42]. However, our finding that malnutrition risk according to the MUST is predictive of mortality is consistent with findings of other studies [38–41].

Our finding that the PG-SGA SF categorizes a considerably larger amount of patients at increased malnutrition risk than the MUST is consistent with previous studies by us and other [25–28], differences ranging from 1.3-fold in patients with head and neck cancer [26] through 2.5-fold in the current study, to 3-fold in patients with chronic kidney disease [27]. The difference in magnitude is related to patient heterogeneity, as we included patients from both surgical and medical wards in the current study, and found a higher prevalence of malnutrition risk, and a larger difference in classification between PG-SGA SF and MUST in medical as compared to surgical wards. This indicates a higher prevalence of risk factors for malnutrition in patients admitted to medical wards, consistent with a previous multi-center study on Internal Medicine wards [43]. Our previous cross-sectional analysis of the current cohort, moreover, indicates that BMI is a major factor affecting differences in diagnostic properties of MUST as compared to PG-SGA SF, with the most pronounced difference in patients with an overweight or obese BMI [28]. This may be of particular and increasing relevance, in an ageing and increasingly obese society [44].

The results of the current study have various implications for clinical practice. Most importantly, our findings on its predictive validity for clinical outcomes support the use of the PG-SGA SF in routine care. The inclusion of important risk factors for the development of malnutrition in the PG-SGA SF enables a more proactive approach rather than reactive approach to malnutrition risk [19],

allowing for early initiation of nutritional and/or interdisciplinary interventions to help prevent or counteract adverse outcomes. From a feasibility perspective, patients consider the PG-SGA SF as comprehensible and easy to use, and the time needed for completion of this screening tool is comparable to screening by the MUST [20,21]. Moreover, self-completion of the PG–SGA SF by the patient may increase self-awareness of malnutrition risk, as shown in patients with head and neck cancer [20]. Additionally, the PG-SGA has potential to cover both steps in the nutrition care process, screening and assessment, because of its 4-in-1 design for screening, assessment, triaging and monitoring. In this scenario, the PG-SGA SF is used for initial risk screening, and the additional items of the full PG–SGA would be subsequently completed in patients identified as at risk. However, for actual implementation of such a procedure in clinical practice, additional research on efficacy and cost-effectiveness is needed.

To what extent the risk of worse clinical outcomes is modifiable by nutritional or interdisciplinary interventions in the patients classified as at risk of malnutrition, was not within the scope of the current study and warrants further investigation. In the EFFORT trial, medical inpatients at nutritional risk according to the NRS-2002 who received individualized nutritional support had significantly lower risk of 30-day mortality compared with the control group who received standard hospital food (adjusted OR 0.65; 95% CI 0.47–0.91) [45,46]. However, this effect was not sustained after 6 months follow-up [47]. In a previous systematic review and meta-analysis, which included the EFFORT trial, nutritional support in patients at nutritional risk was not found to be significantly associated with mortality, although there was a trend towards a lower risk of non-elective readmissions [48]. Based on these results, there is evidence that risk of malnutrition and associated worse outcomes are modifiable through adequate nutritional support, at least on the short term. Whether and to what extent nutritional or interdisciplinary interventions are effective in reducing risk of negative health outcomes in patients identified by the PG-SGA SF, has yet to be investigated.

Strengths of this study include that the data were obtained in the context of routine care, therefore being a good reflection of daily clinical practice, and yielding information directly relevant for the 'real life' situation. However, this approach could also be considered as a limitation, since unintentional exclusion of patients who underwent surgery, interventions, or diagnostic procedures prior to study inclusion could have led to selection bias. Another strength of the current study is that we collected data on different hospital wards with a variety of both surgical and medical admitting specialisms. Our findings are therefore applicable to and relevant for a wide range of hospital patients with different conditions and diseases.

Limitation of the current study is that there was no re-screening performed at 6 months follow-up to account for changes in malnutrition risk. Also, other complications during follow-up were not recorded, neither was the cause of readmission or cause of death. Therefore, differences in outcomes cannot conclusively be attributed to malnutrition risk alone, but may also be secondary to other factors as well. However, important prognostic factors such as age, sex and hospital ward were accounted for in the multivariate model. Furthermore, our results were not materially altered when adjusting for medical condition category instead of hospital ward, although it should be noted that our data did not allow for an in-depth analysis with highly differentiated medical conditions, and the association with mortality could not adequately be evaluated in this context. Another limitation of the current study is that we did not record whether and which interventions were provided as a result of the malnutrition screening result, which may have influenced study outcomes. However, in the group of patients with low risk of malnutrition according to the MUST we found an association between the PG-SGA SF and clinical outcomes, despite the fact that they did not receive protocolized nutritional interventions based on their screening result. Due to the nature of the study design, assessing malnutrition risk with screening tools only, and lacking data on intervention measures, our study cannot substantiate a causal relationship between malnutrition risk and patient outcomes.

In conclusion, the higher yield of patients with high malnutrition risk according to the PG-SGA SF compared with the MUST corresponds to a significantly higher risk of worse clinical outcome in these patients. Our findings support the use of the PG-SGA SF in routine hospital care to screen for patients at high risk of (developing) malnutrition and associated worse clinical outcome, facilitating a more proactive and preventive approach to counteract malnutrition risk.

Declaration of competing interest

A.W. Gomes Neto received research support from Danone Nutricia for contributing to this research. H. Jager-Wittenaar was co-developer of the Patient-Generated Subjective Global Assessment-based Pt-Global app/web tool. The remaining authors have nothing to disclose.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnesp.2021.08.015.

Statement of authorship

AWGN: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. IMYV: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. MCJO: Visualization, Writing – original draft, Writing – review & editing. MFCJ: Resources, Supervision, Writing – review & editing. SJLB: Resources, Supervision, Writing – review & editing. HJW: Conceptualization, Methodology, Resources, Supervision, Writing – review & editing. GJN: Conceptualization, Funding acquisition, Methodology, Supervision, Visualization, Writing – review & editing. All authors read and approved the final manuscript.

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