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Prospective validation of five malnutrition screening and assessment instruments among medical inpatients: *Secondary analysis of a randomized clinical trial*

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Abstract

Background: Screening for malnutrition upon hospital admission is the first crucial step for proper nutritional assessment and treatment. While several nutritional screening and assessment instruments exist, there is a lack of head-to-head validation of these instruments. We studied the ability of five different nutrition screening and assessment instruments to predict 1-year mortality and response to nutritional treatment in participants of the EFFORT randomized trial.

Methods: In this secondary analysis of a Swiss-wide multicenter, randomized clinical trial comparing individualized nutritional support with usual care nutrition in medical inpatients, we prospectively classified patients as low, intermediate, and high risk based on five nutritional screening and assessment instruments (NRS 2002, SGA, SNAQ, MNA and MUST).

Results: Overall mortality at 1-year in the 1866 included patients was 30.4%. There were significant correlations and concordance between all instruments with r-values ranging from 0.23 to 0.55 and kappa values ranging from 0.10 to 0.36. While high nutritional risk was associated with higher mortality in all instruments, SGA and MNA showed the strongest association with adjusted odds ratios of 3.17 (95%CI, 2.18 to 4.61, p<0.001) and 3.45 (95%CI, 2.28 to 5.22, p<0.001). There were some differences regarding response to nutritional treatment among instruments, with NRS 2002 and SGA showing the most pronounced relationship between the severity of malnutrition and reduction in mortalit as a response to nutritional support.

Conclusion: Among all five screening and assessment instruments, higher nutritional risk was associated with higher risk for mortality and adverse clinical outcome, but not with more or less treatment response from nutritional support with differences among scores. Adding more specific parameters to these instruments is important when using them for deciding for or against nutritional support interventions.

Trial registration: ClinicalTrials.gov NCT02517476

1. Introduction

Today, most parts of the world are affected by disease-related malnutrition [1]. In fact, with a prevalence of around 30%, disease-related malnutrition is frequent among hospitalized patients and represents a major risk factor for adverse clinical outcomes and mortality [2-9]. While achieving a consensus definition for disease-related malnutrition has been challenging due to the lack of a true gold standard, many experts recommend that malnutrition should be diagnosed in a two-phased approach. In a first step, nutritional screening is recommended to identify patients at risk of malnutrition. In a second step, more specific criteria should be applied to confirm the diagnosis of malnutrition [1,10]. Importantly, in the last few years, several trials and meta-analyses of such trials, have provided evidence that nutritional support among patients at risk of malnutrition significantly reduces the negative clinical outcomes associated with malnutrition [11,12].

Today, several screening and assessment instruments can be used to identify the risk for malnutrition upon admission of a patient to hospital [1,4,6,13-18]. The most widely used instruments in the hospital setting include the Nutritional Risk Screening 2002 (NRS 2002) [6], the Subjective Global Assessment (SGA) [14], the Short nutritional assessment questionnaire (SNAQ) [13], the Mini Nutritional Assessment (MNA) [15] and the Malnutrition Universal Screening Tool (MUST) [6]. For the selection of the appropriate instrument, it is important to identify whether the instrument has been validated for the patient population (e.g., age and health status) and setting (e.g., hospital, institution, or community) in question [1,10]. In addition, screening instruments should be easy to use, fast to perform, economical, standardized and validated. Furthermore, nutritional screening instruments should be both sensitive and specific, correlate with severity and adverse clinical outcomes, and optimally should predict response to nutritional therapy [4].

While several nutrition screening and assessment instruments are available currently, there is a lack of comparison and head-to-head validation of these tools regarding their ability to identify patients at higher medical risk and patients responding to nutritional interventions. Herein, using data from patients included in the randomized Effect of early nutritional therapy on Frailty, Functional Outcomes, and Recovery of malnourished medical inpatients Trial (EFFORT) [19], our aim was to study the ability of five different nutrition screening and assessment instruments, namely NRS 2002, SGA, SNAQ, MNA and MUST to predict 1-year mortality and response to nutritional treatment.

2. Methods

2.1 Study design, setting and participant sample

This is a secondary analysis of participants included in EFFORT [19], a prospective, investigator-initiated, multicenter randomized clinical trial that was performed in eight Swiss hospitals from April 2014 to February 2018. The main aim of the trial was to assess the effects of early nutritional therapy on outcomes in a medical inpatient setting. The trial protocol [20], the main results [19] as well as results regarding long-term outcomes [21], cost outcomes [22] and results of secondary analyses [23-30] have been published previously. The Ethics Committee of Northwestern Switzerland (EKNZ; 2014_001) approved the trial, which was registered at ClinicalTrials.gov (https://clinicaltrials.gov/ct2/show/NCT02517476). EFFORT enrolled adult participants (≥18 years) at nutritional risk with a total NRS 2002 score of at least 3 points [5], with an expected hospital stay ≥5 days if they were willing to provide informed consent. Exclusion criteria were initial admission to an intensive care or surgical unit, inability to ingest food orally, already established nutritional support at admission, terminal illness, gastric bypass, anorexia nervosa, acute pancreatitis, acute liver failure, cystic fibrosis, stem cell transplantation or contraindications for nutritional support and previous inclusion in the trial. Patients were randomly assigned (1:1) either to the intervention group, receiving individualized nutritional support, or the control group receiving standard hospital food. All participants in the intervention group received individualized nutritional support within 48 hours of admission to reach protein and energy goals according to a previously published consensus protocol [31] and in accordance with recent international guidelines [32]. Individualized energy and protein goals were defined for each individual patient upon admission to hospital by a registered dietician. We used the weight-adjusted Harris-Benedict equation to estimate energy requirements [33]. Daily protein intake goals were set at 1.2–1.5 g/kg body weight/day with lower targets of 0.8 g/kg body weight for participants with renal failure [34]. To reach these goals, an individualized nutritional plan was developed by a registered dietician for each participant based initially on oral nutrition provided by the hospital kitchen and oral nutritional supplements [35,36]. A further increase in nutritional support to enteral tube feeding or parenteral feeding was recommended if at least 75% of energy and protein targets could not be reached through oral feeding within 5 days.

2.2 Malnutrition screening and assessment instruments and risk categories

We prospectively calculated NRS 2002, SGA, SNAQ, MNA and MUST scores at hospital admission In all patients. While NRS 2002, SNAQ, and MUST are screening instruments, SGA and MNA represent assessment instruments for malnutrition. The MNA-SF, a short form of the MNA, is a screening version of this instrument [4,15,16]. In our work, we examined the long form of the MNA (MNA-LF). More details of the different screening and assessment instruments are presented in the **Appendix (eTable 1)**. As recommended, we categorized risk for malnutrition according to three risk groups: low-, intermediate-, and high-risk for malnutrition among all instruments. The low-risk group for malnutrition was defined as a NRS 2002 score of 3, a SNAQ score of 0 or 1, a MUST score of 0, a MNA score between 24 and 30, and a SGA level of A. The intermediate-risk group for malnutrition was defined as a NRS 2002 score of 4, a SNAQ score of 2, a MUST score of 1, a MNA score between 17 and 23, and a SGA level of B. The high-risk group was defined as a NRS 2002 score of 5 or 6, a SNAQ score of 3 to 5, a MUST score of 2 to 4, a MNA score between 0 and 16, and a SGA level of C.

While EFFORT included a total of 2,028 participants, for this secondary analysis we only included 1866 participants with complete data on all the investigated instruments outlined above (**eFigure 1**).

Primary and secondary endpoints

The primary endpoint was all-cause mortality after one year. The main secondary endpoints were rehospitalisation, length of hospital stay (LOS) and adverse outcome (a composite endpoint defined as all-cause mortality, admission to the intensive care unit from the medical ward, non-elective hospital readmission after discharge, and major complications or a decline in functional status all within day 30 measured). Detailed information on endpoints are presented in the **Appendix**. To verify outcome, we performed structured telephone interviews with all participants of the EFFORT trial at 30 days and 1 year. Finally, we studied te ability of each tool to predict response to nutritional therapy.

Statistical analysis

Continuous data are expressed as mean with standard deviations (SD) or median with interquartile range (IQR), while binary and categorical variables are shown as frequency with percentages.

The correlation of the different screening and assessment instruments was investigated by calculation of Spearman’s rank correlation with reporting of Spearman's rank correlation coefficient rho. We additionally presented concordance tables between instruments. Further, univariable and multivariable logistic regression models were used to examine the association of the different instruments and clinical

outcomes. Odds ratios (OR) and coefficients, including the corresponding 95% confidence intervals (CI) were reported as a measure of association. We adjusted the analyses for the following predefined covariates: age, sex, main diagnosis (cancer, cardiovascular diseases and infections), comorbidities (cancer, renal failure, congestive heart failure, coronary heart disease and diabetes mellitus), randomization group, and study center. The area under the receiver-operator-curve (ROC-AUC) was used to evaluate the discrimination of the different instruments. Kaplan Meier curves were used to compare mortality according to the different instruments. To investigate whether prognostic significance differed among different subgroups, we performed subgroup analysis for the different instruments by age, BMI, cancer, and cardiovascular disease.

Finally, we investigated the ability of the different screening and assessment instruments to predict treatment response by comparing patients receiving nutritional support with control patients stratified according to the instruments specific risk of patients. More specifically, we compared 30-day mortality of patients in the nutritional intervention arm of the EFFORT trial with control group patients independently among those classified as low-, intermediate-, and high-risk for malnutrition. We then calculated interaction analysis to investigate whether the reduction in mortality would be more pronounced in high compared to lower risk within each instrument.

A two-sided p-value of <0.05 was considered significant. Statistical analyses were performed using STATA 17.0 (STATA Corp., College Station, TX).

3. Results

3.1 Baseline characteristics

While the EFFORT study included a total of 2028 participants, within this secondary analysis we had complete data for 1866. Baseline characteristics of the overall cohort and stratified according to the primary endpoint are shown in **Table 1**. Of the total 1866 included participants, 568 (30.4%) died within 1 year. The median age was 72.5 years and 975 (52.3%) were men. The most common main diagnoses were infectious diseases (30.4%, n=567) and cancer (18.6%, n=348).

3.2 Correlation and concordance of the five different screening and assessment instruments

Overall, correlation analysis showed a significant correlation between all instruments with r-values ranging from 0.23 to 0.55 (**Table 2**). The strongest correlation was observed between MUST and SNAQ (r=0.55, p<0.001). We also present the concordance between instruments in concordance tables

(**eTable 2 – 12**). Agreement between instruments was in the range of 31% to 62% resulting in Kappa values of between 0.10 and 0.36.

3.3 Prognostic significance of the screening and assessment instruments for one-year mortality

Across all screening and assessment instruments, non-survivors were more likely to be classified as high-risk for malnutrition compared with survivors (NRS 2002: 227 [40.0%] *vs.* 338 [26.0%]; SGA: 140 [24.6%] *vs.* 161 [12.4%]; SNAQ: 274 [48.2%] *vs.* 470 [36.2%]; MNA: 170 [29.9%] *vs.* 250 [19.3%]; MUST: 213 [37.5%] *vs.* 332 [25.6%]).

Table 3 shows the prognostic significance of the instruments regarding one-year mortality. In all instruments, high risk patients were significantly associated with mortality, both in unadjusted and adjusted models. Patients classified into the high risk category by the SGA or MNA showed the strongest association with outcome with an adjusted OR of 3.17; 95% CI, 2.18 to 4.61, p<0.001 for SGA and an adjusted OR of 3.45; 95% CI, 2.28 to 5.22, p<0.001 for MNA. We also investigated discrimination among scores in regard to the area under the curve (AUC). Discrimination tended to be better for SGA and MNA with an AUC of 0.61 and 0.60, respectively, compared with the other instruments (MUST: 0.57, NRS 2002: 0.58, and SNAQ: 0.59).

These results were also confirmed in Kaplan Meier analyses, where we found a higher likelihood for mortality among patients categorized at high risk by all scores but the SNAQ, and results were most notably for the SGA and MNA (**Figure 1**).

3.4 Subgroup analyses for the primary endpoint

Subgroup analyses for the different screening and assessment instruments showed that the SGA appeared to have particularly good prognostic significance in participants with BMI ≥26 kg/m^2 (adjusted OR, 6.62; 95% CI, 2.69 to 16.28, p<0.001). Further, similar findings were observed for the SNAQ in participants with cancer (adjusted OR, 6.47; 95% CI, 1.80 to 23.29; p=0.004). The MNA showed this property in participants with BMI ≤20 kg/m^2, in participants with BMI ≥26 kg/m^2, and in those with cancer (adjusted OR, 6.56; 95% CI, 0.72 to 59.40; p=0.094; adjusted OR, 6.29; 95% CI, 2.91 to 13.58; p<0.001; adjusted OR, 7.25; 95% CI, 2.90 to 18.13; p<0.001). All subgroup analyses are presented in the **Appendix** (**eFigure 2 – 6**).

3.5 Prognostic significance of the screening and assessment instruments for secondary endpoints

In addition to mortality, we also investigated the association of the different instruments with risk of rehospitalisation, length of hospital stay (LOS) and adverse outcome all within a 30 day time window (**Table 4**). For rehospitalisation, SGA showed the strongest association and was significant in both, univariate and multivariate analyses, while overall the prognostic ability of the instruments were only moderate. For adverse outcome, all instruments were associated with higher risk in both, uni- and multivariable analyses. In addition, NRS 2002, SGA and MNA predicted longer LOS.

3.6 Prediction of therapeutic response by the screening and assessment instruments

To understand whether the instruments could predict response to nutritional therapy, we compared outcome among intervention and control group patients within the different risk categories (**Figure 2**). Regarding response to nutritional treatment, NRS 2002 and SGA showed the best separation of responders and non-responders, however, without significant results in interaction analyses.

4. Discussion

The main findings of this secondary analysis from a multicenter trial are two-fold. First, our results indicate that all five screening and assessment instruments showed significant associations between the severity of malnutrition and one-year mortality. These associations remained robust after multivariable adjustment demonstrating that higher severity of malnutrition is associated with mortality in the longer term. Also, significant asociations were found for most secondary endpoints including rehospitalization risk, adverse outcome and length of hospital stay (LOS). Second, there were some differences regarding the response to nutritional treatment among instruments, with NRS 2002 and SGA showing the most pronounced relationship between malnutrition severity and response to nutritional support.

A 2021 comparative effectiveness review from the Agency for Healthcare Research and Quality (AHRQ) concluded that there is evidence of an association between malnutrition and increased mortality and prolonged length of hospital stay among malnourished hospitalized patients, yet the strength of this association varied depending on patient population and the tool used to identify malnutrition with an overall lack of large-scale validation studies [37]. The report also highlighted that there is now convincing evidence that malnutrition-focused hospital-initiated interventions are more likely to reduce mortality compared with usual care among patients diagnosed with malnutrition, but further research is needed to assess the clinical utility of measurement tools for malnutrition. Herein, our study provides important

information about the validity of five screening and assessment instruments regarding outcome prediction and response to nutritional treatment. Only a few other studies have rigorously compared different screening and assessment instruments or examined the association between nutritional risk and clinical outcomes. However, most of them focused on specific patient groups and compared only individual instruments [8,38-48]. In 2010, a Brazilian study investigated three screening instruments (NRS 2002, MNA-SF, and MUST) in hospitalized patients regarding their ability to predict adverse clinical outcomes [49]. In the analysis, MUST did not perform well in predicting unfavorable clinical outcomes compared with NRS 2002 and MNA-SF. Our results are consistent with these findings, also showing that MNA and NRS 2002 performed better compared with MUST predicting one-year morality, although, unlike in our study, the MNA-SF was used.

Our results are also consistent with those of an international multicenter study (EuroOOPS study), involving 5,000 patients, that demonstrated an association between nutritional risk assessed by the NRS 2002 and clinical outcome [50]. Whether the differences found in our and previous studies are clinically meaningful is unclear. Ease of use and experience with the instrument may be more important to achieve high adherence in the hospital.

In our report, SGA and the MNA showed slightly superior results compared to other instruments. It is interesting to note that both, the SGA and the MNA are assessment instruments and not screening instruments for malnutrition, which may explain the superior performance regarding the prediction of adverse clinical outcomes.

A special feature of the MNA is that physical and psychological aspects are assessed, in addition to the nutritional evaluation. Since these aspects often influence the nutritional status of the elderly, MNA is particularly recommended for the assessment of malnutrition in this group [5,6,15,51-53]. However, physical and psychological aspects may also influence the nutritional status of younger people, which in turn could explain the good results of MNA in our work. In the SGA tool, a subjective grading of the patient is performed by the examiner, with data extracted from the medical history and physical examination [6,14]. Thus, through this subjective assessment by the examiner, physical and psychological components of the patient may influence the SGA as well. This, in turn, could again explain the good results of the SGA in our study. These results are also in line with another prospective multicenter study where SGA was showen to be a simple and useful tool to predict the risk of long-term mortality in patients receiving total parenteral nutrition [56].. SGA may allow detection of malnutrition earlier, before body composition has changed or, for example, even in the presence of obesity.

Interestingly, this is what was shown in our analysis, with the SGA appearing to have particularly good prognostic power in patients with a BMI ≥26. The same was also seen with the MNA, which again could be explained by the fact that it is an assessment and not a screening instrument. With regard to MNA, two further studies focusing on nursing home residents also came to the same conclusion that MNA, MNA-SF, MUST and NRS 2002 are associated with prediction of mortality at 1-year [54,55]. Again, the MNA showed the best predictive value.

Importantly, there is a lack of prospective studies investigating which screening instrument is helpful in identifying patients who would or would not benefit from nutritional therapy. Herein, our secondary analysis of a large randomized trial is novel and important. Still, a retrospective analysis investigating the utility of the NRS 2002 to predict treatment response in 128 randomized clinical trials found this screening system to be able to identify patients who are likely to benefit from nutritional support [5]. This analysis is, thus, in line with results of the initial EFFORT study and the current secondary analysis suggesting that NRS 2002 is a valuable instrument to stratify patients regarding nutritional interventions [19].

MUST did not perform well in our analysis regarding treatment response. Importantly, MUST was initially developed for use in the community, and later expanded to other health care settings, including hospitals. Possibly, this could be explained by the fact that MUST is a screening instrument (not an assessment instrument) for malnutrition and does not include severity of the disease - as opposed to NRS 2002 [6].

This study has several strengths and limitations. To the best of our knowledge, this is the first analysis from a prospective randomized trial comparing five screening and assessment instruments in parallel regarding treatment response. However, an important limitation of our work related to the underlying trial is the fact that we only included patients at nutritional risk based on NRS and thus did not have a control group without nutritional risk (NRS of 0-2). Validation of our finding in such patients in the near future would be important. Other limitations include the focus on only Swiss medical inpatients limiting generalizability to surgical and other populations, the lack of blinding of patients and dietitians, and some variation in adherence to the dietary protocol. We also had to exclude some patients from the EFFORT trial due to incomplete study data.

5. Conclusion

Based on this secondary analysis of a randomized trial, all five screening and assessment instruments identified patients with severe malnutrition and high 1-year mortality, but identification of patients with more or less benefit from nutritional support was only moderate with differences among scores. Adding more specific parameters to these instruments is important when guiding nutritional support interventions.

ARTICLE INFORMATION

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The funders had no rule in the design and conduct of this study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Author Contributions:

Prof Schuetz had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Table 1: Baseline characteristics

	Overall	Survivors	Non-survivors	p value
N	1866	1298	568	
Sociodemographics				
Age, mean (SD) years	72.5 (14.1)	71.3 (14.7)	75.2 (12.0)	<0.001
Male sex	975 (52.3%)	631 (48.6%)	344 (60.6%)	<0.001
Nutrional assessment				
BMI, mean (SD) kg/m^2	24.7 (5.3)	25.0 (5.4)	24.2 (4.7)	0.001
BMI				
≤*20* kg/m^2	408 (21.9%)	281 (21.7%)	127 (22.4%)	0.037
***21-25* kg/m^2**	742 (39.9%)	495 (38.3%)	247 (43.6%)	
≥*26* kg/m^2	711 (38.2%)	518 (40.0%)	193 (34.0%)	
Weight at admission, mean (SD) kg	70.8 (16.6)	71.1 (16.8)	70.0 (16.1)	0.22
Height, mean (SD) cm	167.7 (9.3)	167.5 (9.3)	168.1 (9.3)	0.24
NRS 2002 score, mean (SD)	4.0 (0.9)	4.0 (0.8)	4.2 (0.9)	<0.001
NRS 2002 subgroups				
low risk	584 (31.3%)	438 (33.7%)	146 (25.7%)	<0.001
intermediate risk	717 (38.4%)	522 (40.2%)	195 (34.3%)	
high risk	565 (30.3%)	338 (26.0%)	227 (40.0%)	
SGA score, mean (SD)	1.9 (0.6)	1.8 (0.6)	2.1 (0.6)	<0.001
SGA Subgroups				
low risk	461 (24.7%)	377 (29.0%)	84 (14.8%)	<0.001
intermediate risk	1104 (59.2%)	760 (58.6%)	344 (60.6%)	
high risk	301 (16.1%)	161 (12.4%)	140 (24.6%)	
SNAQ score, mean (SD)	2.0 (1.5)	1.9 (1.4)	2.4 (1.5)	<0.001
SNAQ Subgroups				
low risk	1025 (54.9%)	771 (59.4%)	254 (44.7%)	<0.001
intermediate risk	97 (5.2%)	57 (4.4%)	40 (7.0%)	
high risk	744 (39.9%)	470 (36.2%)	274 (48.2%)	
MNA score, mean (SD)	19.7 (4.0)	20.1 (4.0)	18.7 (3.9)	<0.001
MNA Subgroups				
low risk	292 (15.6%)	242 (18.6%)	50 (8.8%)	<0.001
intermediate risk	1154 (61.8%)	806 (62.1%)	348 (61.3%)	
high risk	420 (22.5%)	250 (19.3%)	170 (29.9%)	
MUST score, mean (SD)	0.9 (1.1)	0.8 (1.0)	1.1 (1.1)	<0.001
MUST Subgroups				
low risk	939 (50.3%)	698 (53.8%)	241 (42.4%)	<0.001
intermediate risk	382 (20.5%)	268 (20.6%)	114 (20.1%)	
high risk	545 (29.2%)	332 (25.6%)	213 (37.5%)	
Admission diagnosis				

Infection	567 (30.4%)	456 (35.1%)	111 (19.5%)	<0.001
Cancer	348 (18.6%)	135 (10.4%)	213 (37.5%)	<0.001
Cardiovascular disease	180 (9.6%)	116 (8.9%)	64 (11.3%)	0.12
Failure to thrive	182 (9.8%)	142 (10.9%)	40 (7.0%)	0.009
Lung disease	112 (6.0%)	77 (5.9%)	35 (6.2%)	0.85
Gastrointestinal disease	155 (8.3%)	116 (8.9%)	39 (6.9%)	0.14
Neurological disease	88 (4.7%)	79 (6.1%)	9 (1.6%)	<0.001
Renal disease	61 (3.3%)	45 (3.5%)	16 (2.8%)	0.47
Metabolic disease	57 (3.1%)	50 (3.9%)	7 (1.2%)	0.002
Other	47 (2.5%)	30 (2.3%)	17 (3.0%)	0.39
Comorbidities				
Hypertension	1019 (54.6%)	698 (53.8%)	321 (56.5%)	0.27
Malignant disease	616 (33.0%)	292 (22.5%)	324 (57.0%)	<0.001
Chronic kidney disease	584 (31.3%)	369 (28.4%)	215 (37.9%)	<0.001
Coronary heart disease	527 (28.2%)	354 (27.3%)	173 (30.5%)	0.16
Diabetes mellitus	394 (21.1%)	262 (20.2%)	132 (23.2%)	0.14
Congestive heart failure	317 (17.0%)	194 (14.9%)	123 (21.7%)	<0.001
Chronic obstructive pulmonary disease	278 (14.9%)	182 (14.0%)	96 (16.9%)	0.11
Peripheral arterial disease	170 (9.1%)	101 (7.8%)	69 (12.1%)	0.003
Cerebrovascular disease	150 (8.0%)	106 (8.2%)	44 (7.7%)	0.76
Dementia	64 (3.4%)	43 (3.3%)	21 (3.7%)	0.67

Abbreviations: BMI, body mass index; NRS 2002, Nutritional Risk Screening 2002; SGA, Subjective Global Assessment; SNAQ, Short Nutritional Assessment Questionnaire; MNA, Mini Nutritional Assessment; MUST, Malnutrition Universal Screening Tool; SD, standard deviation. The subgroups divided into low risk, intermediate risk, and high risk refer to the risk for malnutrition.

Table 2: Spearman rank correlation of different screening and assessment instruments

Malnutrition Screening Tool	NRS 2002	SGA	SNAQ	MNA
SGA	r=0.35, p <0.001			
SNAQ	r=0.23, p <0.001	r=0.32, p <0.001		
MNA	r=0.26, p <0.001	r=0.52, p <0.001	r=0.46, p <0.001	
MUST	r=0.25, p <0.001	r=0.44, p <0.001	r=0.55, p <0.001	r=0.51, p <0.001

Abbreviations: r, Spearman correlation coefficient; NRS 2002, Nutritional risk screening 2002; SGA, Subjective global assessment; SNAQ, short Nutritional Assessment Questionnaire; MNA, Mini Nutritional Assessment; MUST, Malnutrition Universal Screening Tool.

Table 3: Prognostic value of different screening and assessment instruments for 1-year-mortality

Overall 1-year-mortality					
	NRS 2002	**SGA**	**SNAQ**	**MNA**	**MUST**
Unadjusted regression analysis, OR (95% CI), p-value					
Low risk	*reference*	*reference*	*reference*	*reference*	*reference*
Intermediate risk	1.12 (0.87, 1.44), p=0.37	2.03 (1.55, 2.66), p<0.001	2.13 (1.39, 3.27), p=0.001	2.09 (1.5, 2.91), p<0.001	1.23 (0.95, 1.6), p=0.121
High risk	2.01 (1.57, 2.59), p<0.001	3.9 (2.81, 5.41), p<0.001	1.77 (1.44, 2.17), p<0.001	3.29 (2.29, 4.72), p<0.001	1.86 (1.48, 2.33), p<0.001
Discrimination statistics					
AUC	0.58	0.61	0.59	0.60	0.57
Adjusted[a] regression analysis, OR (95% CI), p-value					
Low risk	*reference*	*reference*	*reference*	*reference*	*reference*
Intermediate risk	1.15 (0.87, 1.53), p=0.314	1.81 (1.34, 2.44), p<0.001	1.79 (1.09, 2.94), p=0.021	1.92 (1.34, 2.77), p<0.001	1.08 (0.8, 1.46), p=0.61
High risk	1.63 (1.22, 2.18), p=0.001	3.17 (2.18, 4.61), p<0.001	1.53 (1.21, 1.93), p<0.001	3.45 (2.28, 5.22), p<0.001	1.61 (1.24, 2.1), p<0.001

Abbreviations: SD, standard deviation; OR, odds ratio; 95% CI, 95% confidence interval; AUC, area under the curve; NRS 2002, Nutritional Risk Screening 2002; SGA, Subjective Global Assessment; SNAQ, Short Nutritional Assessment Questionnaire; MNA, Mini Nutritional Assessment; MUST, Malnutrition Universal Screening Tool; SD, standard deviation. The subgroups divided into low risk, intermediate risk, and high risk refer to the risk for malnutrition.

a: Adjusted for age, sex, main diagnosis, comorbidities, randomization, and study center

Table 4: Prognostic value of different screening and assessment instruments for secondary endpoints

	NRS	SGA	SNAQ	MNA	MUST
Rehospitalization within 30 days					
Unadjusted regression analysis, OR (95% CI), p-value					
Low risk	*reference*	*reference*	*reference*	*reference*	*reference*
Intermediate risk	0.96 (0.65, 1.42), p=0.829	1.74 (1.12, 2.71), p=0.015	1.93 (1.03, 3.63), p=0.04	1.85 (1.08, 3.18), p=0.025	1.08 (0.71, 1.64), p=0.707
High risk	1.25 (0.84, 1.85), p=0.277	2.42 (1.43, 4.07), p=0.001	1.48 (1.07, 2.06), p=0.019	1.82 (1, 3.31), p=0.051	1.16 (0.8, 1.67), p=0.434
Discrimination statistics					
AUC	0.52	0.57	0.55	0.55	0.52
Adjusted[a] regression analysis, OR (95% CI), p-value					
Low risk	*reference*	*reference*	*reference*	*reference*	*reference*
Intermediate risk	1.01 (0.67, 1.5), p=0.972	1.73 (1.09, 2.72), p=0.019	1.78 (0.94, 3.37), p=0.078	1.75 (1, 3.04), p=0.048	1.03 (0.67, 1.57), p=0.904
High risk	1.24 (0.81, 1.89), p=0.314	2.3 (1.33, 3.96), p=0.003	1.38 (0.98, 1.94), p=0.069	1.72 (0.92, 3.22), p=0.091	1.05 (0.72, 1.54), p=0.791
Adverse outcome[b] within 30 days					
Unadjusted regression analysis, OR (95% CI), p-value					
Low risk	*reference*	*reference*	*reference*	*reference*	*reference*
Intermediate risk	1.09 (0.84, 1.42), p=0.508	1.5 (1.14, 1.98), p=0.004	1.57 (0.99, 2.49), p=0.055	1.75 (1.25, 2.47), p=0.001	1.08 (0.82, 1.43), p=0.584
High risk	1.32 (1.01, 1.74), p=0.042	2.23 (1.59, 3.14), p=<0.001	1.33 (1.07, 1.66), p=0.01	2.02 (1.38, 2.95), p<0.001	1.19 (0.93, 1.52), p=0.165
Discrimination statistics					
AUC	0.53	0.56	0.56	0.56	0.52
Adjusted[a] regression analysis, OR (95% CI), p-value					

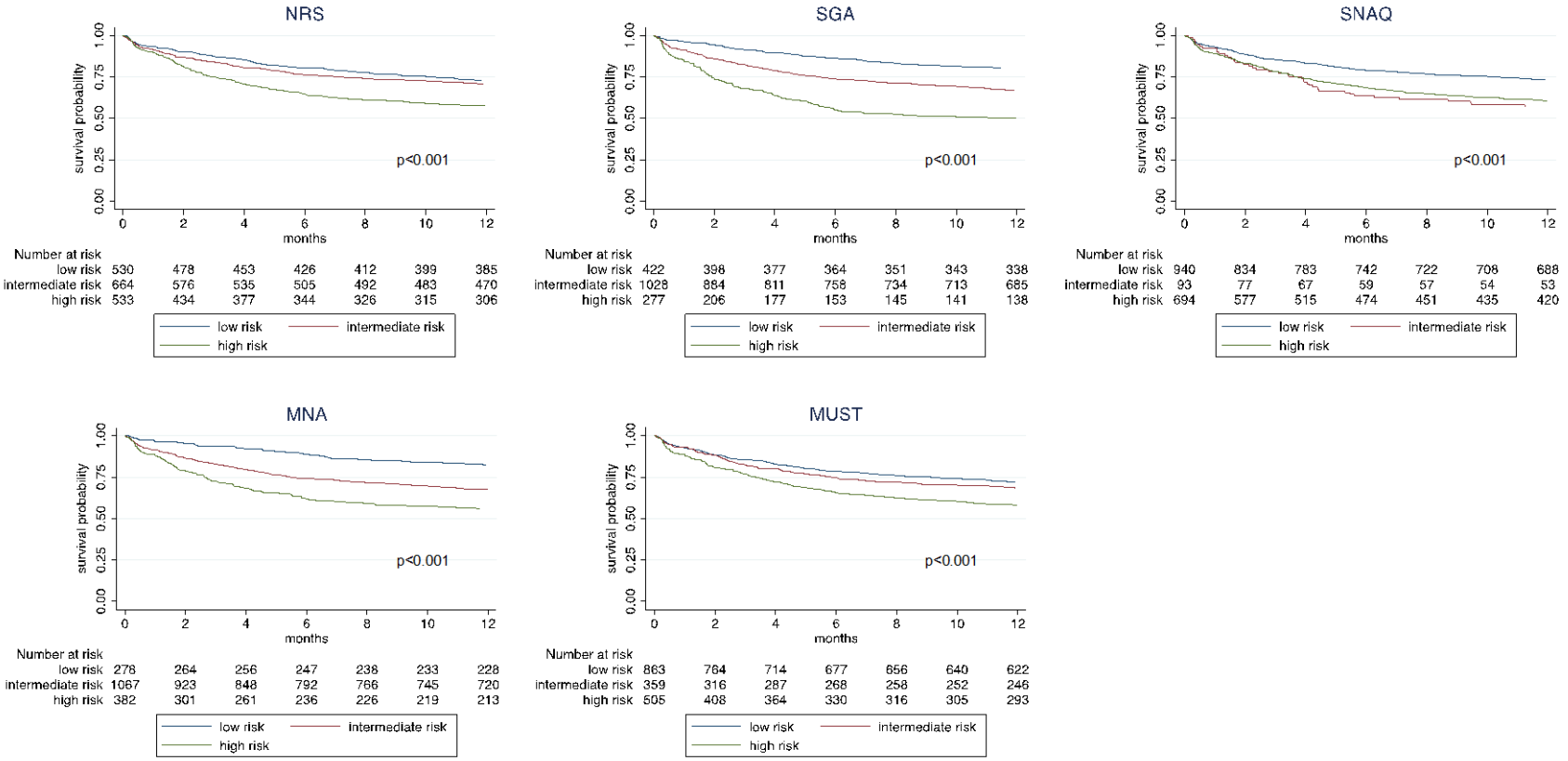
Low risk	*reference*	*reference*	*reference*	*reference*	*reference*
Intermediate risk	1.13 (0.86, 1.49), p=0.37	1.45 (1.09, 1.94), p=0.012	1.45 (0.9, 2.33), p=0.127	1.71 (1.2, 2.44), p=0.003	1.04 (0.78, 1.4), p=0.769
High risk	1.18 (0.88, 1.57), p=0.273	2.02 (1.41, 2.9), p<0.001	1.27 (1, 1.61), p=0.046	1.97 (1.31, 2.96), p=0.001	1.1 (0.85, 1.43), p=0.474
Length of hospital stay (LOS)					
Unadjusted regression analysis, Coefficient (95% CI), p-value					
Low risk	*reference*	*reference*	*reference*	*reference*	*reference*
Intermediate risk	0.89 (0.18, 1.6), p=0.014	0.79 (0.09, 1.5), p=0.028	1.77 (0.41, 3.12), p=0.01	0.76 (-0.07, 1.59), p=0.072	-0.76 (-1.54, 0.01), p=0.053
High risk	1.1 (0.35, 1.85), p=0.004	1.73 (0.79, 2.68), p<0.001	0.2 (-0.41, 0.81), p=0.522	2.49 (1.52, 3.45), p<0.001	0.14 (-0.54, 0.83), p=0.681
Adjusted[a] regression analysis, Coefficient (95% CI), p-value					
Low risk	*reference*	*reference*	*reference*	*reference*	*reference*
Intermediate risk	0.91 (0.19, 1.62), p=0.013	0.75 (0.03, 1.47), p=0.042	1.94 (0.58, 3.29), p=0.005	0.91 (0.06, 1.75), p=0.036	-0.77 (-1.54, 0.01), p=0.054
High risk	1.26 (0.47, 2.04), p=0.002	1.68 (0.71, 2.66), p=0.001	0.08 (-0.55, 0.71), p=0.802	2.64 (1.63, 3.65), p<0.001	0.05 (-0.66, 0.77), p=0.882

Abbreviations: SD, standard deviation; OR, odds ratio; 95% CI, 95% confidence interval; AUC, area under the curve; NRS 2002, Nutritional Risk Screening 2002; SGA, Subjective Global Assessment; SNAQ, Short Nutritional Assessment Questionnaire; MNA, Mini Nutritional Assessment; MUST, Malnutrition Universal Screening Tool; SD, standard deviation. The subgroups divided into low risk, intermediate risk, and high risk refer to the risk for malnutrition.

a: Adjusted for age, sex, main diagnosis, comorbidities, randomization, and study center

b: a composite endpoint defined as all-cause mortality, admission to the intensive care unit from the medical ward, non-elective hospital readmission after discharge, and major complications or a decline in functional status

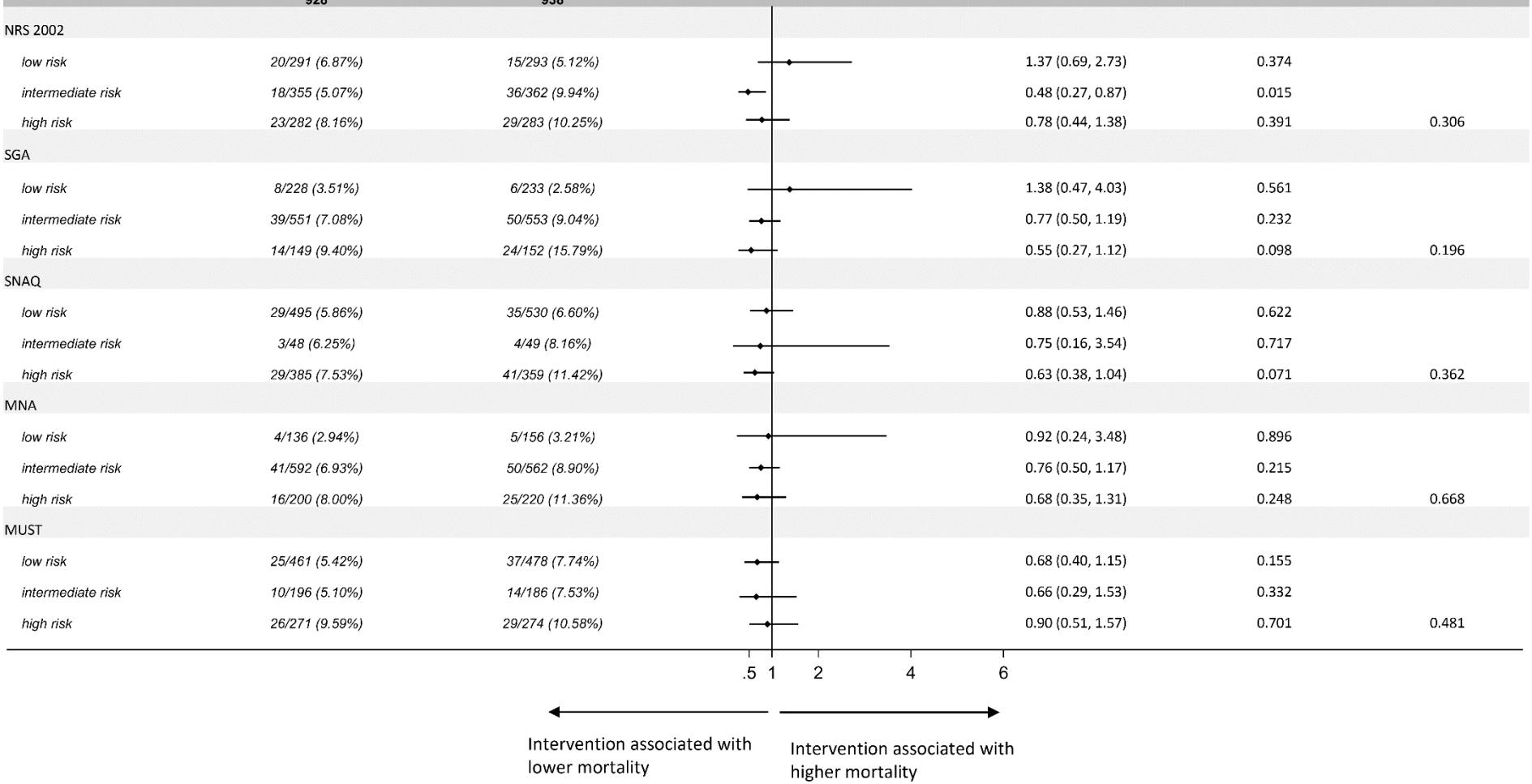
Figure 1: Kaplan Meier estimate of different screening and assessment instruments for time to death within 12 months



Abbreviations: NRS 2002, Nutritional Risk Screening 2002; SGA, Subjective Global Assessment; SNAQ, Short Nutritional Assessment Questionnaire; MNA, Mini Nutritional Assessment; MUST, Malnutrition Universal Screening Tool.

Figure 2: Forest plot for response to nutritional therapy according to screening and assessment instruments

Overall 30-day-mortality	Nutritional therapy	No nutritional therapy	OR (95% CI)	p-value	p for interaction
	928	938			
NRS 2002					
low risk	*20/291 (6.87%)*	*15/293 (5.12%)*	1.37 (0.69, 2.73)	0.374	
intermediate risk	*18/355 (5.07%)*	*36/362 (9.94%)*	0.48 (0.27, 0.87)	0.015	
high risk	*23/282 (8.16%)*	*29/283 (10.25%)*	0.78 (0.44, 1.38)	0.391	0.306
SGA					
low risk	*8/228 (3.51%)*	*6/233 (2.58%)*	1.38 (0.47, 4.03)	0.561	
intermediate risk	*39/551 (7.08%)*	*50/553 (9.04%)*	0.77 (0.50, 1.19)	0.232	
high risk	*14/149 (9.40%)*	*24/152 (15.79%)*	0.55 (0.27, 1.12)	0.098	0.196
SNAQ					
low risk	*29/495 (5.86%)*	*35/530 (6.60%)*	0.88 (0.53, 1.46)	0.622	
intermediate risk	*3/48 (6.25%)*	*4/49 (8.16%)*	0.75 (0.16, 3.54)	0.717	
high risk	*29/385 (7.53%)*	*41/359 (11.42%)*	0.63 (0.38, 1.04)	0.071	0.362
MNA					
low risk	*4/136 (2.94%)*	*5/156 (3.21%)*	0.92 (0.24, 3.48)	0.896	
intermediate risk	*41/592 (6.93%)*	*50/562 (8.90%)*	0.76 (0.50, 1.17)	0.215	
high risk	*16/200 (8.00%)*	*25/220 (11.36%)*	0.68 (0.35, 1.31)	0.248	0.668
MUST					
low risk	*25/461 (5.42%)*	*37/478 (7.74%)*	0.68 (0.40, 1.15)	0.155	
intermediate risk	*10/196 (5.10%)*	*14/186 (7.53%)*	0.66 (0.29, 1.53)	0.332	
high risk	*26/271 (9.59%)*	*29/274 (10.58%)*	0.90 (0.51, 1.57)	0.701	0.481



Abbreviations: OR, odds ratio; 95% CI, 95% confidence interval; NRS 2002, Nutritional Risk Screening 2002; SGA, Subjective global assessment; SNAQ, short Nutritional Assessment Questionnaire; MNA, Mini Nutritional Assessment; MUST, Malnutrition Universal Screening Tool. The subgroups divided into low risk, intermediate risk, and high risk refer to the risk for malnutrition