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Comparison of three nutritional screening tools for predicting mortality in maintenance hemodialysis patients

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ABSTRACT

Objectives: The aim of this study was to compare the effect of different nutritional screening tools on predicting the risk for mortality in patients on maintenance hemodialysis (MHD).
Methods: A cohort of 1025 patients on MHD were enrolled from eight hospitals. The malnutrition-inflammation score (MIS), objective score of nutrition on dialysis (OSND), and geriatric nutritional risk index (GNRI) were measured at baseline. All-cause mortality and cardiovascular (CV) mortality were the major study outcomes.
Results: The median follow-up duration was 28.1 mo. The MIS (per SD increase, hazard ratio [HR], 1.35; 95% confidence interval [CI], 1.18–1.55), the OSND (per SD decrease, HR, 1.24; 95% CI, 1.09–1.42), and the GNRI (per SD decrease, HR, 1.26; 95% CI, 1.10–1.43) were significantly associated with the risk for all-cause mortality. More importantly, the mortality predictability of the MIS appears similar to the GNRI ($P = 0.182$) and greater than the OSND (MIS versus OSND: $P = 0.001$; GNRI versus OSND: $P = 0.045$). Similar results were found for CV mortality.
Conclusions: Each of the three nutritional screening tools was significantly associated with an increased risk for all-cause and CV mortality. The mortality predictability of the MIS was similar to the GNRI and greater than the OSND.

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Introduction

Protein–energy wasting (PEW) refers to the multiple nutritional and catabolic alterations in patients with chronic kidney disease (CKD) [1]. Because PEW is highly prevalent and strongly associated with increased risk for morbidity and mortality, as well as for poor quality of life [2,3], it is important to detect it accurately and easily. There has been a great consensus that the key first step in the evaluation of nutritional status is to identify "at-risk" status by using validated screening tools [4–7].

Accordingly, many nutritional screening tools have been developed for nutritional risk assessment among patients on maintenance hemodialysis (MHD). The subjective global assessment (SGA) [8] is a valid diagnostic tool for assessing nutritional status [9–11]. A more comprehensive tool, the malnutrition-inflammation score (MIS), was proposed by Kalantar-Zadeh et al. [12]. The MIS correlates well with morbidity, mortality, and various nutritional variables [12–15]. However, the MIS requires a subjective assessment, which is time-consuming and cumbersome. As such, the objective screening nutrition dialysis (OSND) was developed as an alternative for the MIS in the assessment of the nutritional risk of patients on hemodialysis [16]. In fact, some simple, fully objective nutritional screening tools also can be used to assess the nutritional risk of patients on MHD [17]. The geriatric nutritional risk index (GNRI) was recommended as one of the simplest risk indexes for nutritional status assessment among patients on MHD [17]. However, the predictive effect of the GNRI on mortality remains in conclusive [18–24].

Among the screening tools just mentioned, the MIS has been validated as a better nutritional indicator than the SGA in a previous study [12]. Moreover, the predictive validity of the MIS was reported to be superior to the GNRI in a recent study [25]. More importantly, although the OSND has been validated as an effective nutritional screening tool [16], the predictive effects on mortality risk between the OSND and the MIS or the GNRI among patients on MHD have never been fully compared. Therefore, we aimed to compare the effect of the MIS, the OSND, and the GNRI on the predictability risk for all-cause and cardiovascular (CV) mortality in a Chinese MHD cohort. Of note, malnutrition refers to deficiencies, excesses, or imbalances in a person's intake of energy or nutrients [26]. The present study only focuses on undernutrition.

Materials and methods

Study design and participants

This was a multicenter, prospective cohort study conducted from January 2014 to December 2015 in eight outpatient dialysis centers (including Nanfang Hospital, Foshan First People's Hospital, Shenzhen Second People's Hospital, Guangzhou Huadu District People's Hospital, Foshan Nanhai District People's Hospital, Guangzhou Red Cross Hospital, Third Affiliated Hospital of Southern Medical University, and First Affiliated Hospital of Jinan University) in the Guangdong province of China.

Eligible participants were ≥18 y of age, had received MHD for >3 mo, and could eat normally. The exclusion criteria included a history of hyperthyroidism, acute infection, liver cirrhosis, active autoimmune disease, multiple organ failure, serious gastrointestinal disease, cognitive disorder, and advanced malignant tumor. Participants were followed up at each routine dialysis visit where vital signs and possible endpoint events were documented by trained research staff and physicians.

The Ethics Committee of Nanfang Hospital approved the study. All participants provided written informed consent.

Data collection

Baseline data were collected by trained research staff according to standard operating procedures. Interviews were conducted with each participant using a standardized questionnaire designed specifically for the present study.

Anthropometric measurements

Body mass index (BMI), midarm circumference (MAC), and triceps skinfold (TSF) were obtained during physical examination. All measurements were conducted after dialysis when the patient was at dry weight according to the Kidney Disease Outcomes Quality Initiative guideline recommendations [9]. BMI was calculated as weight/height squared (kg/m^2). To evaluate midarm muscle circumference (MAMC). MAC was measured to the nearest cm with a firm, nonstretchable tape (Deli, Shanghai, China) on the right arm without arterio-venous fistula, at half distance between the acromion and the olecranon [9]. TSF thickness was measured to the nearest cm on the right arm using a skinfold caliper (Xinman Shanghai, China) in the standard manner [9]. Triplicate measurements on the same arm were taken, and the mean TSF of the three independent measures were used in analysis. MAMC was calculated from MAC and TSF using the DB Jelliffe formula [27]:

$$\mathrm{MAMC} = \mathrm{MAC(cm)} - (3.1415/10) \times \mathrm{TSF(cm)}.$$

Laboratory evaluation

Fasting venous blood samples were obtained from each participant before the hemodialysis session at baseline. Serum lipids, albumin, hemoglobin, C-reactive protein (CRP), calcium, phosphate levels, and total carbon dioxide (TCO_2) were measured using automatic clinical analyzers following the same standard protocol at each local dialysis center. Serum transferrin was measured by enzyme-linked immunosorbent assay. Kt/V (single pool) were calculated by using urea kinetic modeling formulas:

$$\mathrm{Kt/v} = -\ln(\mathrm{R} - 0.008 \times \mathrm{t}) + [(4 - 3.5 \times \mathrm{R}) \times \mathrm{UF/W}]$$

where R is the ratio of postdialysis to predialysis serum urea nitrogen; t is time of dialysis in hours; UF is the amount of ultrafiltration (in L), and W is postdialysis weight (in kg).

Study outcomes

The primary outcome of this study was all-cause mortality, which was defined as deaths due to any reasons. The secondary outcome was death from cardiovascular disease (CVD), which included sudden cardiac death, myocardial infarction, heart failure, stroke, CV hemorrhage, and death due to other known vascular causes. Evidence for death included death certificates from hospitals or reports from investigator visits.

Major definitions

Malnutrition-inflammation score

Previous studies have reported the MIS correlated well with morbidity, mortality, dialysis outcome, inflammation, anemia, and various nutrition-related markers, and was superior to conventional SGA [12,28–31].

The MIS has four sections (medical history, physical examination, BMI, and laboratory values) and 10 components. Each component has four levels of severity, from 0 (*normal*) to 3 (*severely abnormal*). The sum of all 10 MIS components can range from 0 (*normal*) to 30 (*severely malnourished*). A higher score reflects a more severe degree of malnutrition and inflammation [14]. Medical history consists of five components including dry weight change from the previous 6 mo, dietary intake, gastrointestinal symptoms, functional capacity and comorbid including dialysis vintage. Two physical examinations including fat and muscle stores were assessed according to the conventional SGA guidelines [8]. Other sections of the MIS include BMI, serum albumin, and serum transferrin.

Geriatric nutritional risk index

The GNRI was validated as a significant predictor of morbidity and mortality and correlated with various nutrition-related markers in some of the previous studies [17,18,20–24].

The GNRI was calculated using the equation developed by Bouillanne et al. [23] for geriatric patients as follows:

$$\mathrm{GNRI} = [14.89 \times \mathrm{albumin(g/dL)}] + [41.7 \times (\mathrm{bodyweight/idealbodyweight})].$$

The body weight/ideal body weight (IBW) was set to 1 when the patient's actual body weight exceeded the IBW. IBW was calculated from the patient's height and a BMI of 22 because of its validity [32], instead of the value calculated with the Lorentz formula used in the original GNRI equation [23]. IBW of BMI 22 was also reported to be associated with lowest morbidity [33–35].

Objective score of nutrition on dialysis

The OSND has been validated as a comprehensive scoring system with significant associations with prospective hospitalization and mortality, as well as measures of nutrition and inflammation, in patients on MHD [16].

The OSND was calculated by combining anthropometric measurements (the change in end-dialysis dry weight in the previous 6 mo, BMI, TSF, and MAC) with

three laboratory tests for albumin, transferrin, and cholesterol levels. Serum cholesterol scoring rules differ between patients treated with and without statins. The change in the dry weight in the previous 6 mo, BMI, TSF, MAC, and serum transferrin were scored by 1 (*normal*), 2 (*moderate abnormal*), and 4 (*severely abnormal*); The serum albumin and transferrin were scored by 6 (*normal*), 3 (*moderate abnormal*), and 0 (*severely abn*ormal). The sum of the seven components results in a score from 5 (*severely malnourished*) to 32 (*normal*) [16].

Statistical analysis

We assumed that the annual mortality rate of patients on MHD was 20% [36], the hazard ratio (HR) of the MIS, the GNRI, and the OSND between quartile 4 and quartile 1 was about 1.26, 1.12, and 1.2, respectively [16,25], with an α of 0.05; 160, 630, and 188 MHD patients followed up for 2 y would have a power of 80%, respectively. On the basis of these assumptions, 1025 MHD participants followed up for 2 y would have ≥90% power to detect this effect size.

Baseline characteristics are presented as means ± SD or medians (25th–75th) for continuous variables and percentages for categorical variables. Differences in baseline characteristics between patients who died and those who survived at the end of follow-up were compared using the Student's *t* test or the Mann–Whitney U test for continuous variables and the χ^2 test for categorical variables.

Cox proportional hazards models were used to estimate the HRs and 95% confidence intervals (CI) for the risk for all-cause, CVD, and non-CVD mortality associated with three nutritional screening tools as a continuous variable and as quartiles or categories based on clinical definition, without and with adjustments for age, sex, dialysis centers, income, history of diabetes and CVD, vitamin D supplementation (1,25-dihydroxyvitamin D_3), systolic blood pressure, diastolic blood pressure, hemoglobin, TCO_2, dialysis vintage, Kt/V, and total cholesterol (TC; the TC is a component of the OSND, which was not included in the models related with the OSND). Harrell's C statistic was calculated for every test to assess discrimination [37]. The Harrell's C statistic, proposed by Harrell, is a measure of concordance between a predictive biomarker and the right-censored survival outcome. We also tested the difference among these C statistics based on a one-shot nonparametric approach [38] in R compare packages. Comparing with the reclassification measures for the evaluation of prediction models such as the net reclassification improvement and integrated discrimination improvement, the C statistic/area under the curve of receiver operating characteristic is more robust and stable and literatures have indicated some methodological errors in the calculation of net reclassification improvement [39,40].

A two-tailed $P < 0.05$ was considered statistically significant. All data analyses were performed by GraphPad Prism version 7 (GraphPad Software Inc., La Jolla, CA, USA), Empower(R) (www.empowerstats.com; X&Y Solutions, Inc., Boston, MA, USA), and R software, version 3.4.3 (http://www.r-project.org).

Results

Baseline characteristics of the participants

We included 1025 participants in the final analysis (Supplementary Fig. 1). The baseline characteristics of the study population between patients who died and those who survived at the end of follow-up are shown in Table 1. The patients who died during the follow-up period were older and had a higher prevalence of diabetes, hypertension, and CVDs, along with higher MIS, TC levels, and CRP levels and lower OSND, GNRI, TSF, albumin, and transferrin compared with patients who were still alive at follow-up.

Associations of the three nutritional screening tools with study outcomes

All-cause and CV mortality occurred in 226 (22%) and 136 (13.3%) participants during the follow-up, respectively.

Table 1
Baseline characteristics of the study participant*

Variables	Total (N = 1025)	Alive (n = 799)	Deceased (n = 226)	*P*-value
Demographic				
Age, y	53.93 ± 15.06	51.04 ± 14.56	64.11 ± 12.12	<0.001
Male, n (%)	588 (57.37)	460 (57.57)	128 (56.64)	0.802
Mid- to high-level income, n (%)	574 (56)	349 (43.68)	102 (45.13)	0.698
Clinical parameters				
Diabetes, n (%)	276 (26.93)	171 (21.40)	105 (46.46)	<0.001
History of CVD, n (%)	210 (20.49)	138 (17.27)	72 (31.86)	<0.001
Vitamin D supplementation, n (%)	371 (36.2)	289 (36.17)	82 (36.28)	0.975
Dialysis age, mo†	24.50 (12.30–51.10)	24.50 (12.10–52.50)	25.00 (13.15–48.22)	0.622
Systolic blood pressure, mm Hg	144.65 ± 20.66	144.08 ± 20.68	146.65 ± 20.51	0.098
Diastolic blood pressure, mm Hg	84.29 ± 13.05	85.05 ± 12.96	81.59 ± 13.04	<0.001
Kt/V	1.32 ± 0.44	1.34 ± 0.45	1.28 ± 0.39	0.056
Nutrition screening tools				
MIS	8.12 ± 3.60	7.69 ± 3.34	9.62 ± 4.09	<0.001
OSND	21.98 ± 4.51	22.23 ± 4.39	21.11 ± 4.83	<0.001
GNRI	95.01 ± 6.85	95.63 ± 6.43	92.80 ± 7.78	<0.001
Anthropometrical indicators				
BMI, kg/m^2	21.25 ± 3.40	21.27 ± 3.42	21.19 ± 3.37	0.736
MAMC, cm	19.82 ± 2.71	19.9 ± 2.8	19.5 ± 2.5	0.066
TSF, cm	1.21 ± 0.62	1.23 ± 0.63	1.11 ± 0.59	0.012
Waist circumference, cm	80.28 ± 1.06	79.55 ± 10.25	82.86 ± 11.23	<0.001
Biochemistry				
Albumin, g/L	38.05 ± 3.78	38.46 ± 3.60	36.59 ± 4.05	<0.001
Hemoglobin, g/L	107.46 ± 20.89	108.11 ± 20.28	105.18 ± 22.84	0.062
Transferrin, g/L	1.63 ± 0.41	1.65 ± 0.40	1.57 ± 0.44	0.014
CRP, mg/L†	2.74 (1.00–7.41)	2.19 (0.84–6.14)	4.90 (2.02–10.45)	<0.001
Total cholesterol, mmol/L	4.15 ± 1.13	4.09 ± 1.05	4.36 ± 1.33	0.002
Creatinine, μmol/L	1088.17 ± 320.14	1127.42 ± 317.08	949.59 ± 291.70	<0.001
TCO_2, mmol/L	19.81 ± 4.35	19.75 ± 4.43	20.00 ± 4.04	0.436
Calcium, mmol/L	2.16 ± 0.26	2.16 ± 0.26	2.18 ± 0.26	0.25
Phosphate, mmol/L	2.14 ± 0.65	2.15 ± 0.65	2.11 ± 0.64	0.359

CVD, cardiovascular diseases; BMI, body mass index; CRP, C-reactive protein; GNRI, geriatric nutritional risk index; MAMC, midarm muscle circumference calculated; MIS, malnutrition-inflammation score; OSND, objective score of nutrition on dialysis; TCO_2, total carbon dioxide; TSF, triceps skinfold
*Data expressed as mean ± SD.
†Data expressed as median with interquartile range (Q1–Q3).

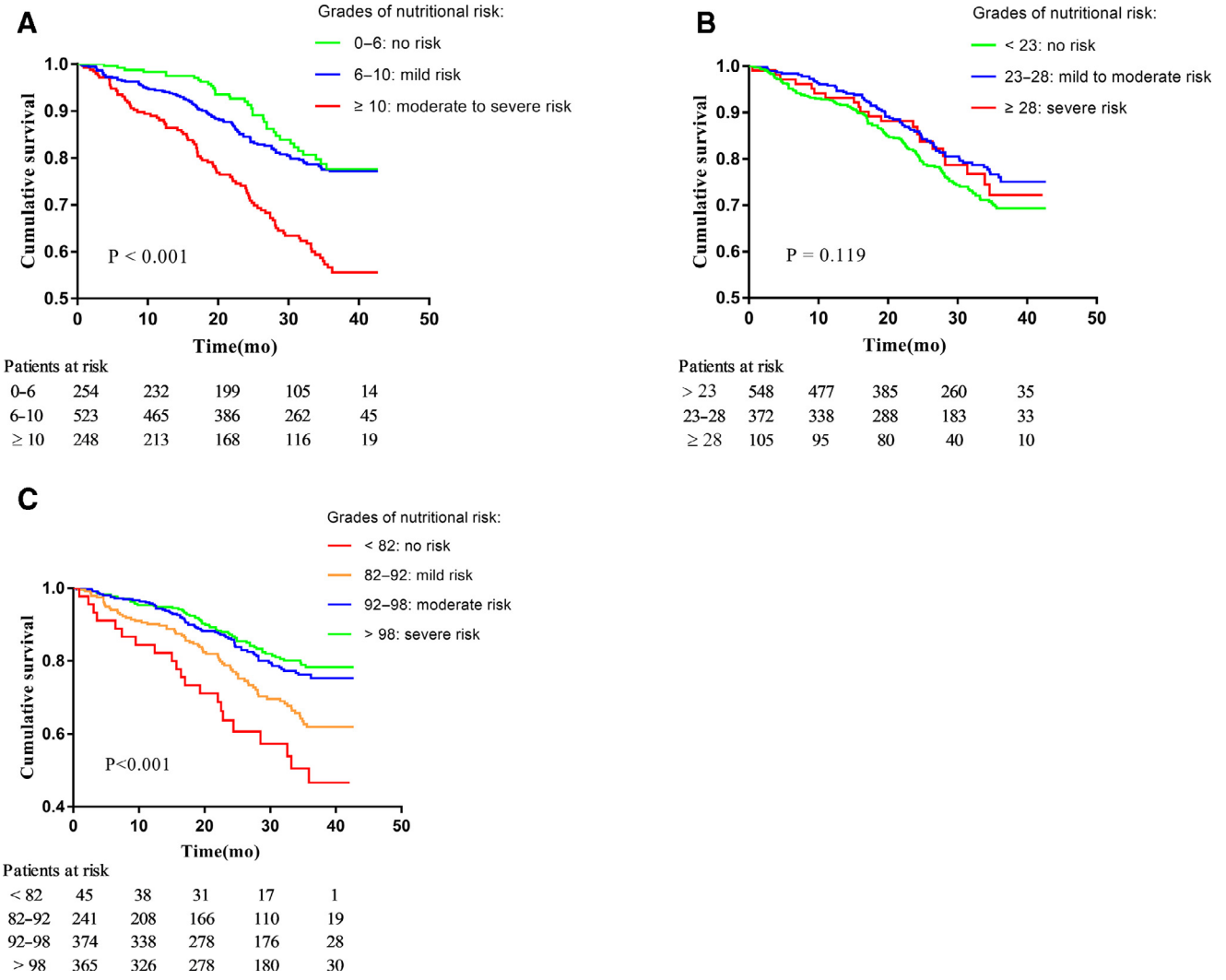

Fig. 1. Kaplan–Meier survival curves of the malnutrition-inflammation score (**A**), the objective score of nutrition on dialysis (**B**), and the geriatric nutritional risk index (**C**) categories.

Kaplan–Meier curves for mortality of the clinical categories of the MIS, the OSND, and the GNRI are shown in Figure 1. The association between the three nutritional screening tools and all-cause mortality is plotted in Figure 2. Overall, after the adjustment of potential confounders, an SD change in each nutritional screening tool was associated with a 35%, 24%, and 26% increment in the risk for all-cause mortality in the MIS, the OSND, and the GNRI, respectively (MIS: HR, 1.35; 95% CI, 1.18–1.55; OSND: HR, 1.24; 95% CI, 1.09–1.42; GNRI: HR, 1.26; 95% CI, 1.10–1.43; Table 2). Consistently, when the three nutritional screening tools were assessed as quartiles, a significantly higher risk for all-cause mortality was found in participants in quartile 4 of the MIS (versus quartile 1; HR, 1.93; 95% CI, 1.29–2.91), and quartile 1 of the OSND (versus quartile 4; HR, 1.80; 95% CI, 1.22–2.65) or GNRI (versus quartile 4; HR, 2.05; 95% CI, 1.36–3.10). Similar trends were found when clinical definitions were used for all three tools (Supplementary Table 1).

Accordingly, similar results were found for CV mortality (Supplementary Table 2); however, the association between the three nutritional screening tools and non-CV mortality was not significant except for the OSND (Supplementary Table 3).

Stratified analyses

Stratified analyses were performed to assess the association between the three nutritional screening tools (per 1 SD change) and the risk for all-cause mortality in various subgroups. None of these variables, including age, sex, diabetes, history of CVD, and dialysis age significantly modified the associations between the three nutritional screening tools and the risk for all-cause mortality ($P_{interaction} > 0.05$ for all comparisons; Supplementary Figs. 2–4).

Discrimination tests

The discrimination of each nutritional screening tool was evaluated by Harrell's C statistic. The Harrell's C statistics of the MIS and GNRI were significantly higher than the OSND (MIS versus OSND: $P = 0.001$; GNRI versus OSND: $P = 0.045$), and there was no significant difference between the MIS and the GNRI in the values of the Harrell's C statistic ($P = 0.182$; Table 3). Similar results were founded in CV mortality; however, there were no significant differences among the three nutritional screening

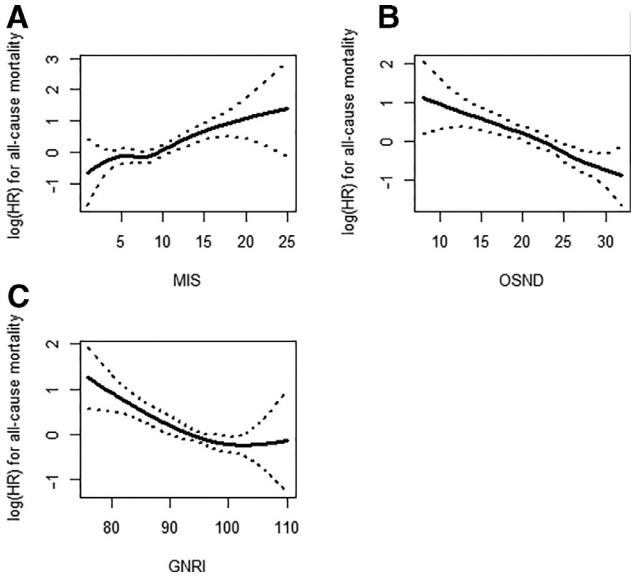

Fig. 2. The relationship between the MIS (**A**), the OSND (**B**), and the GNRI (**C**) and all-cause mortality. All adjusted for sex, age, centers, income, history of diabetes and cardiovascular disease, systolic BP, diastolic BP, dialysis vintage, vitamin D supplementation, hemoglobin quartiles, Kt/V, total carbon dioxide, and TC (TC is a component of the OSND, which was not included in the models related with the OSND); BP, blood pressure; GNRI, geriatric nutritional risk index; MIS, malnutrition-inflammation score; OSND, objective score of nutrition on dialysis; TC, total cholesterol.

tools in the values of the Harrell's C statistic for non-CV mortality (Table 3).

Discussion

The present study demonstrated that each of the three nutritional screening tools was significantly associated with an increased risk for all-cause, CV, and non-CV mortality in Chinese patients on MHD. Furthermore, the all-cause and CV mortality predictability of the MIS appears similar to the GNRI and greater than the OSND.

Consistently, previous studies found that the MIS [12,16,28–31] and the OSND [16] were associated with all-cause mortality in patients on MHD. However, the relationship between the GNRI and all-cause mortality remains uncertain. Studies have reported that the GNRI is a significant predictor of mortality in Japanese [18,20], Korean [21], European [22], and Israeli [24] patients on MHD. However, Ilia Beberashvili et al. did not find any relationship between the GNRI and all-cause mortality among 75 patients on MHD in a period of 46.8 mo follow-up [19]. The conflicting results may partly be explained by differences in population characteristics, sample size, and the method of controlling for confounders. The present study, with its large sample size and a comprehensive adjustment for the related covariates, suggested an inverse association between the GNRI and all-cause mortality in patients on MHD.

Moreover, the MIS and the GNRI had similar discrimination to predict mortality and were superior to the OSND in predicting all-cause and CV mortality in the present study. However, a longitudinal study with 489 patients on MHD and a median follow-up of 2.89 y reported that the MIS was superior to the GNRI because the 95% CI of Harrell's C statistics between the MIS and the GNRI did not overlap (MIS: C statistic = 0.68; 95% CI, 0.66–0.70; GNRI: C statistic = 0.64; 95% CI, 0.62–0.66) [25]. This inconsistent finding might be due to the differences in sample size, dialysis vintage, or population characteristics. More importantly, this study used the Lorentz formula based on height to calculate the IBW [23], which might be another reason contributing to the discrepancy. The present findings and hypotheses warrant further confirmation.

Table 3
Results of Harrell's C statistic

Variables	Harrell's C statistic (95% CI)	*P*-value	
All-cause mortality			
MIS	0.62 (0.58–0.66)	Ref.	0.001
OSND	0.56 (0.52–0.60)	0.001	Ref.
GNRI	0.6 (0.56–0.64)	0.182	0.045
CV mortality			
MIS	0.62 (0.58–0.67)	Ref.	0.001
OSND	0.55 (0.50–0.60)	0.001	Ref.
GNRI	0.6 (0.55–0.65)	0.226	0.035
Non-CV mortality			
MIS	0.62 (0.55–0.68)	Ref.	0.304
OSND	0.59 (0.52–0.65)	0.304	Ref.
GNRI	0.6 (0.53–0.67)	0.532	0.673

CV, cardiovascular; GNRI, geriatric nutritional risk index; MIS, malnutrition-inflammation score; OSND, objective score of nutrition on dialysis.

Table 2
Associations of the three nutritional screening tools with all-cause, CV, and non-CV mortality in continuous models

Exposure	Crude		Adjusted*	
	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
All-cause mortality				
MIS, per SD increase	1.51 (1.34–1.71)	<0.001	1.35 (1.18–1.55)	<0.001
OSND per SD decrease	1.24 (1.09–1.41)	0.001	1.24 (1.09–1.42)	0.001
GNRI per SD decrease	1.39 (1.23–1.56)	<0.001	1.26 (1.10–1.43)	<0.001
CV mortality				
MIS, per SD increase	1.56 (1.33–1.82)	<0.001	1.39 (1.17–1.66)	<0.001
OSND per SD decrease	1.19 (1.00–1.41)	0.044	1.20 (1.01–1.42)	0.038
GNRI per SD decrease	1.39 (1.19–1.63)	<0.001	1.25 (1.06–1.48)	0.008
Non-CV mortality				
MIS, per SD increase	1.45 (1.19–1.76)	<0.001	1.29 (1.04–1.61)	0.019
OSND per SD decrease	1.33 (1.08–1.63)	0.007	1.32 (1.07–1.62)	0.01
GNRI per SD decrease	1.37 (1.14–1.66)	0.001	1.27 (1.03–1.56)	0.025

BP, blood pressure; CV, cardiovascular; GNRI, geriatric nutritional risk index; MIS, malnutrition-inflammation score; OSND, objective score of nutrition on dialysis; TC, total cholesterol; TCO_2, total carbon dioxide

*Adjusted for sex, age, centers, income, history of diabetes or CVD, systolic BP, diastolic BP, dialysis vintage, vitamin D supplementation, hemoglobin quartiles, Kt/V, TCO_2, and TC (TC is a component of the OSND, which was not included in the models related with the OSND).

A nutritional screening tool should be easy to use, quick to administer, have good reproducibility (intra- and interrater reliability), and have a sufficient discrimination. Although the MIS and the GNRI had similar discrimination to predict mortality, and previous studies [19] had reported that the MIS and the GNRI had an almost perfect intra- and interrater reliability, the MIS requires assessment by a well-trained staff and is much more time-consuming, whereas the GNRI is calculated using a very simple equation. As such, the GNRI appears to be an easier and faster tool to risk stratify in patients on MHD.

Some limitations should be considered in the present study. First, longitudinal changes in nutritional status (including nutritional screening tools and nutritional markers) were not evaluated during the follow-up, which limits further analysis of correlation between the three nutritional screening tools and changes in nutritional markers. Second, the nutritional status of this population is mainly mild to moderate undernutrition; few participants had severe malnutrition. Third, the study population was mainly from southern China and its generalizability to general population or other ethnic group remains to be verified. Due to these limitations, more additional studies are required to confirm our results.

Conclusion

In Chinese patients on MHD, all three nutritional screening tools—MIS, OSND, and GNRI—were significantly associated with an increased risk for all-causes and CV mortality. The mortality predictability of the MIS was similar to the GNRI and greater than the OSND. The present findings provided further evidence for the choice of the nutritional screening tool to predict mortality in patients on MHD. If further confirmed, GNRI may be used to identify patients on MHD who are at high risk for mortality. By targeting these high-risk patients and implementing early intensive multiple interventions, we may help reduce their risk.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.nut.2019.06.013.

References

[1] Fouque D, Kalantar-Zadeh K, Kopple J, Cano N, Chauveau P, Cuppari L, et al. A proposed nomenclature and diagnostic criteria for protein–energy wasting in acute and chronic kidney disease. Kidney Int 2008;73:391–8.
[2] Ikizler TA, Cano NJ, Franch H, Fouque D, Himmelfarb J, Kalantar-Zadeh K, et al. Prevention and treatment of protein energy wasting in chronic kidney disease patients: a consensus statement by the International Society of Renal Nutrition and Metabolism. Kidney Int 2013;84:1096–107.
[3] De Mutsert R, Grootendorst DC, Axelsson J, Boeschoten EW, Krediet RT, Dekker FW. Excess mortality due to interaction between protein-energy wasting, inflammation and cardiovascular disease in chronic dialysis patients. Nephrol Dial Transplant 2008;23:2957–64.
[4] Cederholm T, Jensen GL, Correia MITD, Gonzalez MC, Fukushima R, Higashiguchi T, et al. GLIM criteria for the diagnosis of malnutrition—a consensus report from the global clinical nutrition community. Clin Nutr 2019;38:1–9.
[5] Kondrup J, Allison SP, Elia M, Vellas B, Plauth M. Educational and Clinical Practice Committee. European Society of Parenteral and Enteral Nutrition (ESPEN). ESPEN guidelines for nutrition screening 2002. Clin Nutr 2003;22:415–21.
[6] Skipper A, Ferguson M, Thompson K, Castellanos VH, Porcari J. Nutrition screening tools: an analysis of the evidence. JPEN J Parenter Enteral Nutr 2012;36:292–8.
[7] van Bokhorst-de van der Schueren MA, Guaitoli PR, Jansma EP, de Vet HC. Nutrition screening tools: does one size fit all? A systematic review of screening tools for the hospital setting. Clin Nutr 2014;33:39–58.
[8] Detsky AS, McLaughlin JR, Baker JP, Johnston N, Whittaker S, Mendelson RA, et al. What is subjective global assessment of nutritional status? JPEN J Parenter Enteral Nutr 1987;11:8–13.
[9] Kopple JD. National kidney foundation K/DOQI Clinical practice guidelines for nutrition in chronic renal failure. Am J Kidney Dis 2000;35(suppl 2):S1–140.
[10] Steiber A, Leon JB, Secker D, McCarthy M, McCann L, Serra M, et al. Multicenter study of the validity and reliability of subjective global assessment in the hemodialysis population. J Ren Nutr 2007;17:336–42.
[11] De Mutsert R, Grootendorst DC, Boeschoten EW, Brandts H, van Manen JG, Krediet RT, et al. Subjective global assessment of nutritional status is strongly associated with mortality in chronic dialysis patients. Am J Clin Nutr 2009;89:787–93.
[12] Kalantar-Zadeh K, Kopple JD, Block G, Humphreys MH. A malnutrition-inflammation score is correlated with morbidity and mortality in maintenance hemodialysis patients. Am J Kidney Dis 2001;38:1251–63.
[13] Santin F, Rodrigues J, Brito FB, Avesani CM. Performance of subjective global assessment and malnutrition inflammation score for monitoring the nutritional status of older adults on hemodialysis. Clin Nutr 2018;37:604–11.
[14] Borges MCC, Vogt BP, Martin LC, Caramori JCT. Malnutrition inflammation score cut-off predicting mortality in maintenance hemodialysis patients. Clin Nutr ESPEN 2017;17:63–7.
[15] Jagadeswaran D, Indhumathi E, Hemamalini AJ, Sivakumar V, Soundararajan P, Jayakumar M. Inflammation and nutritional status assessment by malnutrition inflammation score and its outcome in pre-dialysis chronic kidney disease patients. Clin Nutr 2019;38:341–7.
[16] Beberashvili I, Azar A, Sinuani I, Yasur H, Feldman L, Averbukh Z, et al. Objective score of nutrition on dialysis (OSND) as an alternative for the malnutrition–inflammation score in assessment of nutritional risk of haemodialysis patients. Nephrol Dial Transplant 2010;25:2662–71.
[17] Yamada K, Furuya R, Takita T, Maruyama Y, Yamaguchi Y, Ohkawa S, et al. Simplified nutritional screening tools for patients on maintenance hemodialysis. Am J Clin Nutr 2008;87:106–13.
[18] Kobayashi I, Ishimura E, Kato Y, Okuno S, Yamamoto T, Mori K, et al. Geriatric nutritional risk index, a simplified nutritional screening index, is a significant predictor of mortality in chronic dialysis patients. Nephrol Dial Transplant 2010;25:3361–5.
[19] Beberashvili I, Azar A, Sinuani I, et al. Comparison analysis of nutritional scores for serial monitoring of nutritional status in hemodialysis patients. Clin J Am Soc Nephrol 2013;8:443–51.
[20] Takahashi H, Inoue K, Shimizu K, Hiraga K, Takahashi E, Otaki K, et al. Comparison of nutritional risk scores for predicting mortality in Japanese chronic hemodialysis patients. J Ren Nutr 2017;27:201–6.
[21] Park JH, Kim SB, Shin HS, Jung YS, Rim H. Geriatric nutritional risk index may be a significant predictor of mortality in Korean hemodialysis patients: a single center study. Ther Apher Dial 2012;16:121–6.
[22] Panichi V, Cupisti A, Rosati A, Di Giorgio A, Scatena A, Menconi O, et al. Geriatric nutritional risk index is a strong predictor of mortality in hemodialysis patients: data from the Riscavid cohort. J Nephrol 2014;27:193–201.
[23] Bouillanne O, Morineau G, Dupont C, Coulombel I, Vincent JP, Nicolis I, et al. Geriatric nutritional risk index: a new index for evaluating at-risk elderly medical patients. Am J Clin Nutr 2005;82:777–83.
[24] Beberashvili I, Azar A, Sinuani I, Shapiro G, Feldman L, Sandbank J, et al. Geriatric nutritional risk index, muscle function, quality of life and clinical outcome in hemodialysis patients. Clin Nutr 2016;35:1522–9.
[25] De Roij van Zuijdewijn CLM, ter Wee PM, Chapdelaine I, Bits ML, Blankenstijn PJ, van den Dorpel MA, et al. A comparison of 8 nutrition-related tests to predict mortality in hemodialysis patients. J Ren Nutr 2015;25:412–9.
[26] Stenvinkel P, Heimbürger O, Lindholm B. Wasting, but not malnutrition, predicts cardiovascular mortality in end-stage renal disease. Nephrol Dial Transplant 2004;19:2181–3.
[27] Jelliffe DB. The assessment of the nutritional status of the community; with special reference to field surveys in developing regions of the World (WHO Monograph 53). Geneva, Switzerland: World Health Organization; 1966.
[28] Santin FG, Bigogno FG, Dias Rodrigues JC, Cuppari L, Avesani CM. Concurrent and predictive validity of composite methods to assess nutritional status in older adults on hemodialysis. J Ren Nutr 2016;26:18–25.
[29] González-Ortiz AJ, Arce-Santander CV, Vega-Vega O, Correa-Rotter R, Espinosa-Cuevas Mde L. Assessment of the reliability and consistency of the "malnutrition inflammation score" (MIS) in Mexican adults with chronic kidney disease for diagnosis of protein-energy wasting syndrome (PEW). Nutr Hosp 2015;31:1352–8.
[30] Kalantar-Zadeh K, Kopple JD, Humphreys MH, Block G. Comparing outcome predictability of markers of malnutrition–inflammation complex syndrome in haemodialysis patients. Nephrol Dial Transplant 2004;19:1507–19.
[31] Rambod M, Bross R, Zitterkoph J, Benner D, Pithia J, Colman S, et al. Association of malnutrition-inflammation score with quality of life and mortality in hemodialysis patients: a 5-year prospective cohort study. Am J Kidney Dis 2009;53:298–309.
[32] Shah B, Sucher K, Hollenbeck CB. Comparison of ideal body weight equations and published height-weight tables with body mass index tables for healthy adults in the United States. Nutr Clin Pract 2006;21:312–9.
[33] Bray GA. What is ideal body weight? J Nutr Biochem 1998;9:489–92.
[34] Matsuzawa Y, Tokunaga K, Kotani K, Keno Y, Kobayashi T, Tarui S. Simple estimation of ideal body weight from body mass index with the lowest morbidity. Diabetes Res Clin Pract 1990;10(suppl 1):S159–64.

[35] Examination Committee of Criteria for 'Obesity Disease' in Japan and Japan Society for the Study of Obesity. New criteria for 'obesity disease' in Japan. Circ J 2002;66:987–92.
[36] US Renal Data System. Excerpts from the USRDS 2006. Annual data report. Am J Kidney Dis Suppl 2007;49:S1–296.
[37] Pencina MJ, D'Agostino Sr RB, Song L. Quantifying discrimination of Framingham risk functions with different survival C statistics. Stat Med 2012;31:1543–53.
[38] Kang L, Chen W, Petrick NA, Gallas BD. Comparing two correlated C indices with right-censored survival outcome: a one-shot nonparametric approach. Statistics Med 2015;34:685–703.
[39] Pepe MS, Janes H, Li CI. Net risk reclassification P values: valid or misleading? JNCI J Natl Cancer Inst 2014;106:Dju041.
[40] Kerr KF, Wang Z, Janes H, McClelland RL, Psaty BM, Pepe MS. Net reclassification indices for evaluating risk-prediction instruments: a critical review. Epidemiology 2014;25:114–21.