Simplified nutritional screening tools for patients on maintenance hemodialysis[1–3]

Kohsuke Yamada, Ryuichi Furuya, Takako Takita, Yukitaka Maruyama, Yuri Yamaguchi, Sakae Ohkawa, and Hiromichi Kumagai

ABSTRACT

Background: Malnutrition is a prevalent complication in patients on maintenance hemodialysis. Nutritional screening tools may be useful to identify those patients at nutritional risk from among hundreds of hemodialysis patients in a large facility.

Objective: We tested several simplified nutritional screening tools on hemodialysis patients to validate the potential application of the tools.

Design: The simplified nutritional screening tools were chosen from references published between 1985 and 2005. Nutritional assessments, including history taking, and anthropometric and biochemical measurements were performed on 422 hemodialysis patients. These results were applied to obtain the score of each nutritional screening tool and the malnutrition-inflammation score (MIS), a comprehensive nutritional assessment tool, as the reference standard. The usefulness of each nutritional screening tool for identifying nutritional risk was assessed by comparison with the MIS value and various individual nutritional measures.

Results: Five reliable nutritional screening tools were found by the literature search. Among them, the geriatric nutritional risk index (GNRI) was considered to be the most accurate in identifying hemodialysis patients at nutritional risk, because the area under the receiver operating characteristic curve generated with the MIS value was the largest. The GNRI showed a significantly negative correlation with the MIS ($r = -0.67$, $P < 0.0001$), and the most accurate GNRI cutoff to identify a malnourished patient according to the MIS was <91.2. The GNRI's sensitivity, specificity, and accuracy of <91.2 in predicting malnutrition according to the MIS were 0.730, 0.819, and 0.787, respectively.

Conclusion: The GNRI was the simplest and most accurate risk index for identifying hemodialysis patients at nutritional risk according to the MIS.   *Am J Clin Nutr* 2008;87:106–13.

KEY WORDS   Geriatric nutritional risk index, hemodialysis, nutritional assessment, nutritional screening, malnutrition-inflammation score, nutritional risk

INTRODUCTION

Protein-energy malnutrition is one of prevalent complications appearing in patients undergoing hemodialysis (1, 2). Because protein-energy malnutrition is associated with poor prognosis, nutritional management has been recognized as an important therapeutic approach for patients on maintenance hemodialysis (3–5). Nutritional assessment is an essential and introductory clinical procedure in nutritional management, and the Dialysis Outcome Quality Initiative (DOQI) guideline recommends regular nutritional assessment for all dialysis patients (6). The reliable assessment of nutritional status requires multidisciplinary procedures, including anthropometric measurements, body composition measurements, biochemical measurements, functional assessments, dietary assessments, and subjective assessments. However, most of these procedures are time-consuming and cumbersome, even when a skillful dietitian is involved.

Nutritional screening is a feasible alternative for identifying patients at risk of malnutrition. Many nutritional screening tools have been developed for general purposes and for such specific subjects as the elderly, children, hospitalized patients, community patients, elderly in nursing homes, patients with cancer or HIV infection, and those with swallowing difficulties (7, 8). Among them, the subjective global assessment (SGA) is a validated clinical tool for screening nutrition at risk (9). This tool is based on medical history and clinical findings, and it is now used in a wide variety of the health care settings. The SGA has also been used as a reference standard for developing other nutritional screening tools for use in patients with chronic renal disease (10). Kalantar-Zadeh et al (11) developed the malnutrition-inflammation score (MIS), which involves 7 components from the SGA and the 3 additional non-SGA components of body mass index (BMI; in kg/m^2), serum albumin, and total iron–binding capacity (TIBC). The MIS has been validated as a better nutritional indicator than the SGA, and it could also be used as a nutritional assessment tool for both maintenance hemodialysis and peritoneal dialysis patients (11, 12). However, because the MIS and the SGA require subjective assessment and judgment by the examiner, significant training is necessary to ensure consistent results among different examiners and different times.

On the other hand, there are some simpler nutritional screening tools that can be scored by well-defined rules or cutoffs. These tools use common measures and can be rapidly applied in a large-scale population. The tools named Mini Nutritional Assessment–Short Form (MNA-SF) (13), nutrition risk score (NRS) (14), Malnutrition Universal Screening Tool (MUST) (15), Malnutrition Screening Tool (MST) (16), and geriatric nutritional risk index (GNRI) (17) consist of 2–5 components and were developed for use in the elderly or hospitalized patients. Although these nutritional screening tools have been validated by more than one study, none were previously studied for use in dialysis patients. The current study validated these simple nutritional screening tools by comparing their results with the MIS and with various individual nutritional measures for maintenance hemodialysis patients.

SUBJECTS AND METHODS

Subjects

The subjects were recruited from both the morning- and evening-scheduled maintenance hemodialysis patients at Iwata City Hospital (Shizuoka, Japan) and Maruyama Hospital (Hamamatsu, Japan), both of which are outpatient facilities. The study inclusion criteria were ongoing hemodialysis therapy for >6 mo and a stable condition without such severe co-morbidity as cardiovascular disease, gastrointestinal disease, respiratory disease, mental disorder, or progressive malnutrition. Bed-bound patients were excluded because their muscles may have fallen into atrophy as a result of the lack of physical activity. Finally, 422 patients (275 M, 147 F) were enrolled in this study. The mean age was 63.8 ± 12.1 y, and the mean duration of dialysis was 11.9 ± 8.8 y. The prevalence of diabetes was 16.3% in all patients. Hemodialysis was performed 3 times/wk for 4.1 ± 0.4 h with the use of hollow-fiber dialyzers and a bicarbonate-buffered endotoxin-free dialysate (Kindaly AF-3P; Fuso, Osaka, Japan). The blood flow rate was 213.6 ± 38.2 mL/min (range: 160–300 mL/min), and the dialysate flow rate was 500 mL/min. The patients had been educated by dietitians to restrict their intake of sodium, potassium, and fluids and to ingest 35 kcal energy$\cdot$kg$^{-1}\cdot$d^{-1} and 1.2 g protein$\cdot$kg$^{-1}\cdot$d^{-1}; however, their actual energy and protein intakes generally were free.

Written informed consent was obtained from all participants. The study protocol was approved by the ethics committees of Iwata City Hospital, Maruyama Hospital, and the University of Shizuoka.

Nutritional assessment and screening tools

We evaluated MIS and several simple nutritional screening tools (**Table 1**) that were selected from references published between 1985 and 2005 by the criterion that validation studies had been performed with appropriate methods by ≥ 2 independent groups. These references were identified by searching all records in the PubMed database. Nutritional assessments were conducted on all patients from April to July of 2005. History taking, physical examinations, anthropometric measurements, and blood analyses were performed in the same week for each patient. The data from these assessments were then applied to the various nutritional screening tools. Of the cutoff scores for malnutrition defined by the original studies, only the MIS was used in the present study.

Malnutrition-inflammation score

The MIS developed by Kalantar-Zadeh et al (11) is based on the 7 components of the conventional or modified SGA method combined with the 3 additional components of BMI, serum albumin, and serum TIBC. The conventional SGA elements were scored according to both the medical history and physical examination. The medical history comprised 5 components: weight loss during the preceding 6 mo, gastrointestinal symptoms, food intake, functional capacity, and co-morbidity including the duration of hemodialysis. The physical examination comprised 2 components: loss of subcutaneous fat and muscle wasting. (Because extracellular fluid volume is essentially controlled by ultrafiltration during hemodialysis, the presence of edema or ascites, the third component of the original SGA physical examination, could not be ascribed as nutritional indexes in maintenance hemodialysis patients.) Each MIS component had 4 levels of severity from 0 (normal) to 3 (very severe); the sum of all 10 components ranged from 0 (normal) to 30 (severely malnourished). The cutoff score for malnutrition was defined as 6 in this study, because the screening tool should be able to identify most of the patients at nutritional risk.

Mini Nutritional Assessment–Short Form

The MNA-SF has been recommended for use by the European Society of Parenteral and Enteral Nutrition guidelines to detect the risk of undernutrition among the elderly (8). The MNA has 2 procedures (18): the MNA-SF is used to screen for risk of malnutrition (13), and the full MNA is used to assess nutritional status. We used the MNA-SF for nutritional screening in the present study. The MNA-SF comprises 6 components: declining

TABLE 1
Comparison of the various nutritional screening tools[1]

Variable	MIS	MNA-SF	NRS	MUST	MST	GNRI
Weight loss or BMI (or both)	√	√	√	√	√	√
Dietary intake	√	√	√		√	
Gastrointestinal symptoms	√					
Comorbidity	√	√	√	√		
Physical function	√	√	√			
Signs of muscle or fat loss	√					
Psychological problems		√				
Serum albumin	√					√
Total iron–binding capacity	√					

[1] MIS, malnutrition inflammation score; MNA-SF, Mini Nutritional Assessment–Short Form; NRS, nutritional risk score; MUST, Malnutrition Universal Screening Tool; MST, Malnutrition Screening Tool; GNRI, geriatric nutritional risk index. The checkmark indicates that the screening tool assesses a particular variable.

food intake over 3 mo (score: 0–2), weight loss during the past 3 mo (score: 0–3), mobility (score: 0–2), psychological stress or acute disease in the past 3 mo (score: 0–2), neuropsychological problems (score: 0–2), and BMI (score: 0–3). The total score range is from 0 to 14.

Nutritional risk score

The NRS has been developed for hospitalized patients by Reilly et al (14); it has 5 components: unintentional weight loss in the past 3 mo, BMI, appetite, ability to eat or retain food (or both), and clinical or medical (or both) stress factors. Each component is scored from 0 to 3; the total score ranges from 0 to 15.

Malnutrition Universal Screening Tool

The MUST for adults has been developed for multidisciplinary use by the Malnutrition Advisory Group of the British Association for Parenteral and Enteral Nutrition (15). The MUST consists of 3 independent components: current weight status measured by BMI (score: 0 to –2), unintentional weight loss (score: 0 to –2), and acute disease effect producing no nutritional intake for >5 d (score: 0 or 2). The sum of these 3 scores was calculated.

Malnutrition Screening Tool

The MST developed by Ferguson et al (16) has been used for acute hospital patients; it incorporates 3 components: weight loss (score: 0 or 2), amount of weight lost (score: 1–4), and poor food intake or poor appetite (score: 0 or 1). The total score was calculated for each patient.

Geriatric nutritional risk index

The GNRI was developed by modifying the nutritional risk index (NRI) for elderly patients (17). This index is calculated from the serum albumin and body weight by using the following equation:

$$\text{GNRI} = [1.489 \times \text{albumin (g/dL)}]$$
$$+ [41.7 \times (\text{body wt/ideal body wt})] \quad (1)$$

Body weight or ideal body weight was set to 1 when the patient's body weight exceeded the ideal body weight. The ideal body weight in the present study was defined as the value calculated from the height and a BMI of 22, because of its validity (19), instead of the value calculated with the Lorentz formula used in the original GNRI equation. We compared GNRI scores calculated by both formulae and found that there was little difference between the values (**Figure 1**).

Anthropometric measurements

Body weight was measured before and after each dialysis session, with the postdialysis body weight used as the dry weight. BMI was calculated (in kg/m²) from the dry weight. Midarm circumference (MAC) and triceps skinfold thickness (TSF) were measured by using Harpenden skinfold calipers (Holtain, Crymych, United Kingdom) on the limb not being used for vascular access.

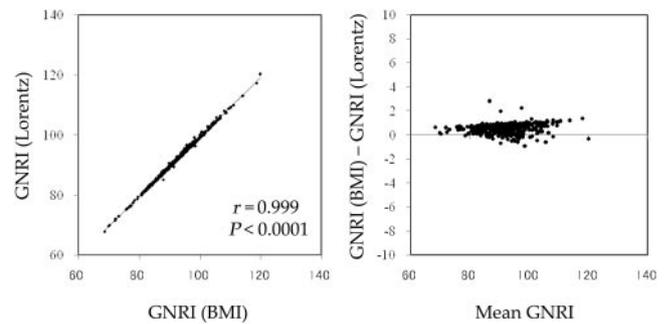The midupper arm muscular area (MAMA) was calculated by using the following equation:

FIGURE 1. Left) Correlation between the geriatric nutritional risk index (GNRI) calculated from the ideal BMI of 22 and that calculated by the Lorentz formula ($r = 0.999$, $P < 0.0001$). Right) A Bland-Altman plot for the GNRI calculated from the ideal BMI of 22 and that calculated by the Lorentz formula. The mean difference in the GNRI between both methods was only 0.6 ± 0.4.

$$\text{MAMA} = (\text{MAC} - 31.4 \times \text{TSF})^2/12.56 \quad (2)$$

where MAMA, MAC, and TSF were measured in cm.

Body composition measurements

The muscle area of the thigh was measured by using X-ray computed tomography (CT). An axial CT image of the thigh was obtained at the midpoint of a line extending from the superior border of the patella to the greater trochanter of the femur. Each patient was examined in the supine position with the thigh muscles relaxed. The thickness of a slice was 10 mm. The radiographic image was digitally scanned for analysis by a personal computer. The adipose tissue–free thigh muscle area (TMA) and thigh bone area (TBA) were quantified by using NIH IMAGE, a public-domain planimetry program (version 1.61; written by Wayne Rasband, US National Institutes of Health). TMA standardized by TBA [ie, the ratio of TMA to TBA (TMA/TBA)] is a verified muscle mass index that avoids any need to adjust for body size, age, and sex; hemodialysis patients with a TMA/TBA of <10 are considered malnourished (2020). Percentage body fat was measured by using bioelectrical impedance analysis on a BC-552 instrument (Tanita, Tokyo, Japan) with the frequency of 50 kHz and current of 50 μA.

Laboratory procedures

Serum albumin, creatinine, urea nitrogen, total cholesterol, triacylglycerol, TIBC, hematocrit, and lymphocyte count were measured by standard laboratory techniques with the use of an automatic analyzer. Serum prealbumin and high-sensitivity C-reactive protein were quantified by laser nephelometry. The hemodialysis dose was calculated by the following equation:

$$Kt/V\text{urea} = -\text{Ln} (R - 0.008 \times t)$$
$$+ [4 - (3.5 \times R)] \times \text{UF}/W \quad (3)$$

where Kt/V is single-pool Kt/V, R is the ratio of postdialysis to predialysis serum urea nitrogen, t (in h) is the duration of dialysis, UF (L) is the ultrafiltrate, and W (kg) is the postdialysis body weight (6). The measure of dietary protein intake was the normalized protein equivalent of nitrogen appearance (nPNA), which was calculated by using the equation published by the K/DOQI Hemodialysis Adequacy Working Group (6):

$$\text{nPNA}(g \cdot kg^{-1} \cdot d^{-1})$$
$$= C_0/[36.3 + 5.48 (Kt/V) + 53.5/(Kt/V)] + 0.168 \quad (4)$$

where C_O (mg/dL) is the predialysis concentration of serum urea nitrogen. The data collected during a dialysis session at the beginning of the week were used for these calculations.

Statistical analysis

Each variable is presented as the mean ± SD. Differences among groups were evaluated by performing an analysis of variance or a nonparametric analysis for data having skewed distribution and subsequent Bonferroni test. A simple regression analysis was used to examine the relations between variables; $P < 0.05$ was considered statistically significant.

With the use of the MIS as the reference standard, a receiver operating characteristic (ROC) curve was generated for each nutritional screening tool (21); the area under the ROC curve (AUC) indicated the probability of discriminating a nutritional risk. The cutoff risk point of nutrition for each tool was then defined from the highest sensitivity $-$ (1 $-$ specificity) value in the ROC curve. A contingency table was made to analyze the relation between each nutritional screening tool and various nutritional variables or the MIS. These tables were used to determine the sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV) according to the following equations:

Sensitivity

$$= \text{true positives}/(\text{true positives} + \text{false negatives}) \quad (5)$$

Specificity

$$= \text{true negatives}/(\text{true negatives} + \text{false positives}) \quad (6)$$

Accuracy

$$= (\text{true positives} + \text{true negatives})/\text{total numbers} \quad (7)$$

$$\text{PPV} = \text{true test positives}/\text{all test positives} \quad (8)$$

and

$$\text{NPV} = \text{true test negatives}/\text{all test negatives} \quad (9)$$

To determine posttest probability, the positive likelihood ratio (LR+) and negative likelihood ratio (LR−) were calculated as follows (22):

$$\text{LR}+ \; = \text{sensitivity}/(1 - \text{specificity}) \quad (10)$$

and

$$\text{LR}- \; = (1 - \text{sensitivity})/\text{specificity} \quad (11)$$

All statistical analyses were performed with GB-STAT (version 10; Dynamic Microsystems, Silver Spring, MD) and JMP (version 6.0; SAS Institute, Cary, NC) software.

RESULTS

The patients were classified into 3 groups according to the MIS score: normal nutrition (score: 0–5), mild malnutrition (6–10), and moderate-to-severe malnutrition (≥11) (**Table 2**). Most of the individual nutritional indexes, including the anthropometric and biochemical indexes, were significantly ($P < 0.05$) lower in the patients with a high MIS score than in those with a low MIS score. Furthermore, such a nutrition-related index as C-reactive protein was significantly ($P < 0.0001$) higher in the high-MIS group than in the low-MIS group. These results indicated that the MIS was considered reasonable as a reference standard for evaluating the nutritional screening tools in this study.

The scores for the various nutritional screening tools examined in this study were compared in the 3 MIS groups (**Table 3**). All of these scores differed significantly ($P < 0.0001$) between the lowest and the highest MIS group. However, the ability to discriminate the nutritional risk differed between these screening tools. With malnutrition defined by an MIS score of ≥6, the ROC AUC was largest with the GNRI and decreased in the order of NRS, MNA-SF, MUST, and MST (**Figure 2**). This result suggested that the GNRI would have the best ability to discriminate the nutritional risk.

The cutoffs for the most accurate discrimination of nutritional risk were derived from these ROC AUCs (Figure 2). These cutoff points were used to calculate the sensitivity, specificity, and accuracy of each nutritional screening tool in predicting abnormal values of the various biochemical and anthropometric nutritional indexes (**Table 4**). The GNRI showed the highest sensitivity, specificity, and accuracy for predicting hypoalbuminemia among these nutritional screening tools. The GNRI also had higher diagnostic values for the other clinical nutritional indexes.

The GNRI showed a significantly negative correlation with MIS ($r = -0.67$, $P < 0.0001$; **Figure 3**); the values for sensitivity, specificity, and accuracy with a GNRI of <91.2 in predicting malnutrition based on the MIS were 0.730, 0.819, and 0.787, respectively. PPV (0.717) and NPV (0.787) also had high scores. The posttest probability of true malnutrition in the patients at risk according to the GNRI was examined by the likelihood ratios. LR+ and LR− for the GNRI were 4.03 and 0.330, respectively, which suggests that the MIS generated only a small change in probability for the diagnosis of nutritional risk made by the GNRI. The application of the GNRI to the maintenance hemodialysis patients in the current study found significant ($P < 0.05$) differences in the various nutrition-related indexes between the group with a GNRI > 91.2 and that with a GNRI ≤ 91.2 (**Table 5).**

DISCUSSION

Although the numbers of dialysis patients worldwide have been increasing annually, the number of health professionals such as dietitians has not increased to meet the greater demand of patients. The result has been an increase in the number of dialysis patients per dietitian, from 34.9 in 1995 to 50.3 in 2005; 83% of dietitians in Japan work parttime (23, 24). The mean number of dialysis patients for each dietitian working as a full-time equivalent has been reported to be as high as 124 in the United States (25) and as high as 128 in the United Kingdom (26). In the face of the problem of a limited number of dietitians in a renal care unit, nutritional screening tools have become vitally important to identify those patients at nutritional risk from the hundreds of maintenance hemodialysis patients in a large facility.

We used the MIS as a reference standard in order to examine the usefulness of simple nutritional screening tools. The MIS, a comprehensive nutritional assessment tool developed by Kalantar-Zadeh et al (11), is a practical and reproducible measure for assessing malnutrition and inflammation in maintenance hemodialysis patients. It is a quantitative nutritional assessment based on the SGA, and it comprises some non-SGA objective

TABLE 2
Clinical variables for patients on maintenance hemodialysis as classified by malnutrition-inflammation score[1]

| | All patients | Malnutrition-inflammation score | | | p[2] |
		0–5	6–10	≥11	
Patients (male/female), n	422 (275/147)	259 (169/90)	152 (101/51)	11 (5/6)	
Age (y)	63.8 ± 12.1[3]	60.8 ± 11.7[a,4]	68.5 ± 11.0[b]	67.4 ± 12.8[b]	<0.0001
Duration of dialysis (y)	11.9 ± 8.9	10.5 ± 8.3[a]	14.1 ± 9.3[b]	16.6 ± 8.3[b]	<0.0001
BMI (kg/m^2)	20.4 ± 2.8	21.4 ± 2.7[a]	19.0 ± 2.3[b]	17.3 ± 2.7[b]	<0.0001
TSF (mm)	8.2 ± 4.9	9.3 ± 5.0[a]	6.6 ± 4.0[b]	4.2 ± 3.2[b]	<0.0001
MAMA (cm^2)	38.1 ± 10.4	41.3 ± 10.1[a]	33.8 ± 8.5[b]	23.1 ± 5.1[c]	<0.0001
nPCR (g·kg^{-1}·d^{-1})	1.02 ± 0.19	1.03 ± 0.18	1.01 ± 0.20	0.91 ± 0.22	0.06
Kt/V urea	1.47 ± 0.26	1.43 ± 0.26[a]	1.54 ± 0.22[b]	1.62 ± 0.39[b]	<0.0001
Blood analysis					
Albumin (g/dL)	3.62 ± 0.32	3.73 ± 0.28[a]	3.48 ± 0.31[b]	3.25 ± 0.33[c]	<0.0001
Prealbumin (mg/dL)	30.0 ± 7.6	32.1 ± 7.1[a]	27.1 ± 7.1[b]	21.1 ± 7.4[c]	<0.0001
Urea nitrogen (mg/dL)	69.5 ± 14.7	71.2 ± 14.2[a]	67.2 ± 14.8[b]	59.3 ± 16.7[b]	<0.0001
Creatinine (mg/dL)	11.7 ± 2.8	12.3 ± 2.8[a]	11.0 ± 2.5[b]	8.7 ± 1.4[c]	<0.0001
Total cholesterol (mg/dL)	149.1 ± 33.4	151.0 ± 32.3	146.4 ± 35.7	144.1 ± 26.1	NS
Triacylglycerol (mg/dL)	113.6 ± 72.4	120.9 ± 70.7[a]	102.4 ± 75.4[b]	95.5 ± 47.4[b]	0.03
TIBC (mg/dL)	231.9 ± 52.9	247.8 ± 50.1[a]	207.7 ± 45.8[b]	180.3 ± 63.0[b]	<0.0001
C-reactive protein (mg/dL)	0.35 ± 0.95	0.24 ± 0.65[a]	0.45 ± 1.16[a]	1.63 ± 2.17[b]	<0.0001
Hematocrit (%)	31.9 ± 3.4	32.3 ± 3.5[a]	31.5 ± 3.0[a]	28.7 ± 4.1[b]	<0.001
rHuEPO dose (U/wk)	4781 ± 2972	4419 ± 3035[a]	5210 ± 2766[b]	7364 ± 2270[b]	<0.001
Computed tomographic data					
TMA (cm^2)	79.9 ± 21.5	85.0 ± 21.2[a]	72.5 ± 19.6[b]	57.8 ± 10.2[b]	<0.0001
TMA/TBA	11.4 ± 2.9	12.2 ± 2.6[a]	10.2 ± 2.8[b]	8.3 ± 2.3[b]	<0.0001
Bioelectrical impedance analysis					
Percentage body fat (%)	21.9 ± 7.3	23.0 ± 6.9[a]	20.1 ± 7.6[b]	11.6 ± 6.2[c]	<0.0001

[1] TSF, triceps skinfold thickness; MAMA, midarm muscle area; nPCR, normalized protein catabolic rate; TIBC, total iron–binding capacity; rHuEPO, recombinant human erythropoietin; TMA, thigh muscle area; TBA, thigh bone area.
[2] ANOVA.
[3] $\bar{x}$ ± SD (all such values).
[4] Values with different superscript letters differ significantly, $P < 0.05$.

components including BMI, serum albumin, and TIBC. The MIS value has been reported to correlate with morbidity, mortality, various nutritional variables, inflammation, anemia, and erythropoietin hyporesponsiveness in maintenance hemodialysis patients (27). As shown in Table 2, we also found that a high MIS value was associated with the deterioration of many individual nutritional measures. We believe, therefore, that the MIS is the most reasonable choice to use as the reference standard for evaluating nutritional screening tools.

The GNRI was considered to be the most accurate screening tool for predicting malnutrition when the MIS was used as the reference standard. The GNRI is calculated by a very simple equation in which only 3 nutritional variables—serum albumin, height, and body weight—are involved. This nutritional score uses only objective information, and any subjective assessments and judgments by the examiner can therefore be avoided. Furthermore, the equation can be handled by a computer, and the patients at high risk of malnutrition can be referred to by numbers.

TABLE 3
Scores for the nutritional screening tools classified by malnutrition-inflammation score[1]

| | All patients ($n = 422$) | Malnutrition-inflammation score | | | P |
		0–5 ($n = 259$)	6–10 ($n = 152$)	≥11 ($n = 11$)	
MNA-SF	11.9 ± 1.3[3]	12.3 ± 1.2[a,4]	11.3 ± 1.1[b]	10.1 ± 1.4[c]	<0.0001
NRS	3.1 ± 1.1	2.7 ± 0.8[a]	3.5 ± 1.1[b]	5.5 ± 1.0[c]	<0.0001
MUST	0.8 ± 0.9	0.5 ± 0.7[a]	1.2 ± 0.9[b]	1.7 ± 0.8[b]	<0.0001
MST	0.4 ± 0.6	0.3 ± 0.6[a]	0.4 ± 0.6[a]	1.3 ± 0.9[b]	<0.0001
GNRI	92.7 ± 7.5	96.0 ± 6.2[a]	87.9 ± 6.0[b]	81.1 ± 7.1[c]	<0.0001

[1] MNA-SF, Mini Nutritional Assessment–Short Form; NRS, nutritional risk score; MUST, Malnutrition Universal Screening Tool; MST, Malnutrition Screening Tool; GNRI, geriatric nutritional risk index.
[2] ANOVA.
[3] $\bar{x}$ ± SD (all such values).
[4] Values with different superscript letters differ significantly, $P < 0.05$.
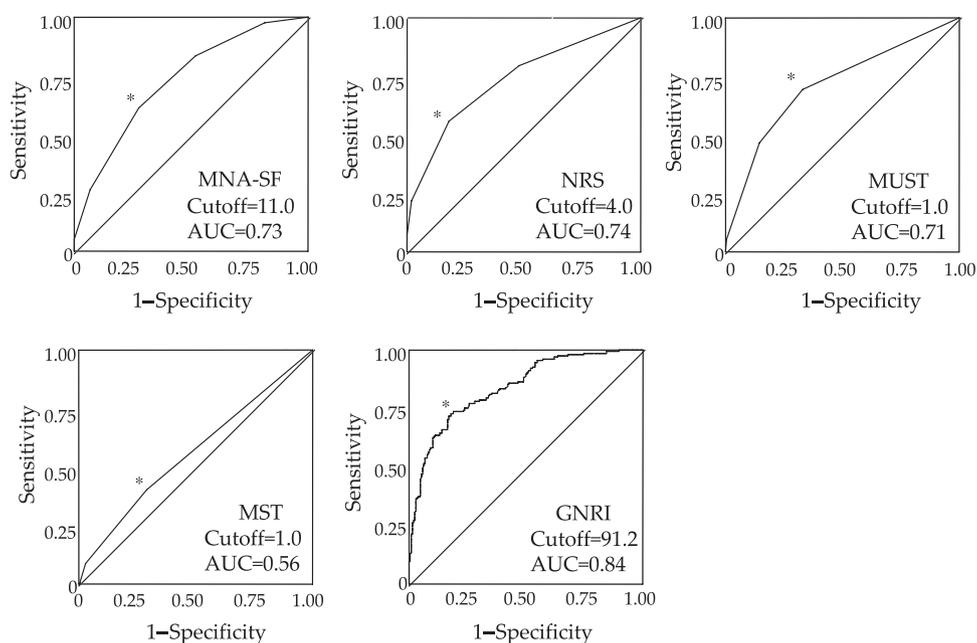
FIGURE 2. Receiver operating characteristic (ROC) curves generated for each nutritional screening tool and the malnutrition-inflammation score. The area under the ROC curve (AUC) indicates the probability for discriminating nutritional risk. The cutoff risk point of nutrition (∗) for each tool is defined by the highest Sensitivity − (1 − Specificity) value on the ROC AUC. MNA-SF, Mini Nutritional Assessment–Short Form; NRS, nutritional risk score; MUST, Malnutrition Universal Screening Tool; MST, Malnutrition Screening Tool; GNRI, geriatric nutritional risk index.

The GNRI was developed by Bouillanne et al (17) to identify those elderly hospitalized patients at nutritional risk according to the NRI described by Buzby et al (28, 29), which scored the severity of the risk in young postoperative patients. The GNRI has been reported to be a reliable prognostic indicator of nutrition-related morbidity and mortality in elderly hospitalized

TABLE 4
Diagnostic values for the simple nutritional screening tools relative to various nutritional and inflammation variables[1]

	MNA-SF (≤11.0)[2]	NRS (>4.0)	MUST (>1.0)	MST (>1.0)	GNRI (≤91.2)
Albumin <3.5 g/dL					
Sensitivity	0.441	0.387	0.514	0.315	0.811
Specificity	0.605	0.695	0.547	0.659	0.756
Accuracy	0.562	0.614	0.538	0.569	0.770
Prealbumin <30 mg/dL					
Sensitivity	0.480	0.395	0.547	0.309	0.543
Specificity	0.668	0.745	0.617	0.638	0.770
Accuracy	0.568	0.558	0.580	0.463	0.649
Total cholesterol <150 mg/dL					
Sensitivity	0.407	0.315	0.506	0.315	0.436
Specificity	0.591	0.657	0.580	0.641	0.663
Accuracy	0.486	0.462	0.538	0.455	0.533
BMI (in kg/m^2) <18.5					
Sensitivity	1.000	0.835	1.000	0.391	0.800
Specificity	0.814	0.863	0.730	0.687	0.759
Accuracy	0.865	0.855	0.803	0.607	0.770
TMA/TBA <10					
Sensitivity	0.653	0.542	0.708	0.417	0.639
Specificity	0.678	0.763	0.612	0.691	0.757
Accuracy	0.670	0.692	0.643	0.603	0.719
C-reactive protein ≥0.6 mg/dL					
Sensitivity	0.385	0.365	0.538	0.288	0.404
Specificity	0.595	0.683	0.548	0.658	0.617
Accuracy	0.569	0.643	0.547	0.612	0.590

[1] MNA-SF, Mini Nutritional Assessment–Short Form; NRS, nutritional risk score; MUST, Malnutrition Universal Screening Tool; MST, Malnutrition Screening Tool; GNRI, geriatric nutritional risk index; TMA, thigh muscle area; TBA, thigh bone area.
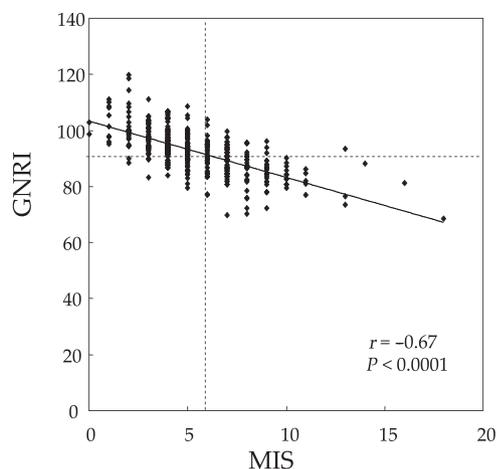[2] The cutoff is indicated for each nutritional index.

FIGURE 3. Correlation between the malnutrition-inflammation score (MIS) and the geriatric nutritional risk index (GNRI). Broken lines indicate cutoffs for the MIS and the GNRI.

patients. The GNRI formula consists of serum albumin and weight loss, both of which are strong independent risk factors for mortality in both elderly patients and maintenance hemodialysis patients.

A comparison of the ROC AUCs showed that, among the various nutritional screening tools for assessing the risk of malnutrition based on the MIS, the GNRI had the highest accuracy. The GNRI also had the highest accuracy in assessing the risks of

hypoalbuminemia and low muscle mass (TMA/TBA) in the maintenance hemodialysis patients in the current study when a cutoff of 91.2 was used. A GNRI of <91.2 had high scores for sensitivity, specificity, PPV, and NPV in predicting malnutrition based on the MIS value. Furthermore, the likelihood ratios suggested that the posttest probability was little different from the pretest probability. The results of these statistical analyses suggested that the reliability of the GNRI would be high enough for screening maintenance hemodialysis patients at nutritional risk.

The cutoff of 91.2 for GNRI determined from the ROC AUC in our study is lower than the original cutoff of 98 determined by Bouillanne et al (17), which may reflect a difference in the definition of nutritional risk. Whereas malnourished elderly patients are defined by the threshold values of Bouillanne et al (3.8 g albumin/dL and 95% of ideal body weight), these threshold values for maintenance hemodialysis patients are usually 3.5 albumin/dL and a BMI of 18.5.

The cutoff in the current study is defined by the highest Sensitivity − (1 − Specificity) value on the ROC AUC. This point means the best cutoff with the highest sensitivity and lowest 1 − specificity. If a nutritional screening tool were to be used only for screening and if it could be supported by a more detailed nutritional assessment, it is possible that an even higher cutoff for detecting nutritional risk may be chosen. This procedure would yield higher sensitivity, but at the expense of specificity. However, when the cutoff of 91.2 was used for the GNRI, the posttest probability of both PPV and NPV exhibited sufficiently high values, which suggested that further assessment may not be necessary.

TABLE 5
Clinical and nutritional variables for patients on maintenance hemodialysis as classified by the geriatric nutritional risk index (GNRI) score[1]

	GNRI		
	>91.2	≤91.2	P[2]
Patients (male/female), n	256 (181/75)	166 (94/72)	
Age (y)	61.0 ± 11.4[3]	67.9 ± 12.0	<0.0001
Duration of dialysis (y)	11.1 ± 8.3	13.1 ± 9.6	<0.02
BMI (kg/m^2)	21.7 ± 2.5	18.4 ± 1.9	<0.0001
TSF (cm)	8.9 ± 5.0	7.2 ± 4.4	<0.001
MAMA (cm^2)	42.2 ± 10.0	31.9 ± 7.5	<0.0001
nPCR (g·kg^{-1}·d^{-1})	1.04 ± 0.17	0.99 ± 0.21	0.01
Kt/V urea	1.42 ± 0.25	1.56 ± 0.26	<0.0001
Blood analysis			
Albumin (g/dL)	3.83 ± 0.27	3.44 ± 0.31	<0.0001
Prealbumin (mg/dL)	32.6 ± 7.2	26.1 ± 6.6	<0.0001
Urea nitrogen (mg/dL)	71.9 ± 13.5	65.7 ± 15.6	<0.0001
Creatinine (mg/dL)	12.6 ± 2.7	10.3 ± 2.5	<0.0001
Total cholesterol (mg/dL)	151.1 ± 33.3	146.0 ± 33.7	NS
Triacylglycerol (mg/dL)	123.3 ± 78.0	98.7 ± 59.9	<0.001
TIBC (mg/dL)	242.7 ± 51.5	215.2 ± 50.9	<0.0001
C-reactive protein (mg/dL)	0.30 ± 0.80	0.44 ± 1.14	NS
Hematocrit (%)	32.2 ± 3.5	31.4 ± 3.1	<0.001
rHuEPO dose (U/wk)	4417 ± 2918	5368 ± 2955	0.001
Computed tomographic data			
TMA (cm^2)	86.9 ± 21.0	67.9 ± 16.5	<0.0001
TMA/TBA	12.3 ± 2.6	9.9 ± 2.7	<0.0001
Bioelectrical impedance analysis			
Percentage body fat (%)	23.1 ± 7.1	19.9 ± 7.3	<0.0001

[1] TSF, triceps skinfold thickness; MAMA, midarm muscle area; nPCR, normalized protein catabolic rate; TIBC, total iron–binding capacity; rHuEPO, recombinant human erythropoietin; TMA, thigh muscle area; TBA, thigh bone area.
[2] ANOVA.
[3] $\bar{x}$ ± SD (all such values).

Compared with GNRI, the other simple nutritional screening tools appeared to be less accurate from the ROC AUCs for predicting malnutrition according to the MIS. One possible reason for this may be that such equivocal measures as appetite, dietary intake, and psychological stress are incorporated in those screening tools; the scoring of these measures is dependent on uncertain subjective complaints in the patient and on the skill of the examiner. Another reason may be the different patient populations used in these studies. Most of the nutritional screening tools have been developed for either hospitalized patients, postoperative patients, or elderly patients. Although the GNRI was also developed for elderly patients, both components of the GNRI—ie, serum albumin and BMI—have been proven to correlate with morbidity and mortality in hemodialysis patients (3, 4). Furthermore, these components have been shown to be representative of all aspects of nutrition, inflammation, and anemia in dialysis patients (11). It is, therefore, not surprising that the GNRI emerged as the most accurate nutritional screening tool in maintenance hemodialysis patients.

A limitation of this study is that the validation of these nutritional screening tools has not fully been examined on the basis of the risks of morbidity and mortality. One objective of nutritional screening is to identify those patients at nutritional risk who have a high risk of a clinical outcome. The results of the current study suggest that the GNRI has the highest accuracy with the MIS, which is known to be correlated with the prospective hospitalization and death of maintenance hemodialysis patients. This fact implies that the GNRI is a good predictor of a patient's prognosis. However, a larger-scale longitudinal study may be necessary to establish the significance of GNRI as a nutritional screening tool for maintenance hemodialysis patients.

In conclusion, the current study indicated GNRI to be the simplest and most accurate risk index for identifying maintenance hemodialysis patients with malnutrition according to the MIS among the various available nutritional screening tools. The introduction of GNRI would improve the efficiency and rationalization of nutritional assessment for patients undergoing hemodialysis.

REFERENCES

1. Ikizler TA, Hakim RM. Nutrition in end-stage renal disease. Kidney Int 1996;50:343–57.
2. Stenvinkel P, Heimburger O, Paultre F, et al. Strong association between malnutrition, inflammation, and atherosclerosis in chronic renal failure. Kidney Int 1999;55:1899–911.
3. Lowrie EG, Lew NL. Death risk in hemodialysis patients: the predictive value of commonly measured variables and an evaluation of death rate differences between facilities. Am J Kidney Dis 1990;15:458–82.
4. Pifer TB, McCullough KP, Port FK, et al. Mortality risk in hemodialysis patients and changes in nutritional indicators: DOPPS. Kidney Int 2002; 62:2238–45.
5. Mehrotra R, Kopple JD. Nutritional management of maintenance dialysis patients: why aren't we doing better? Annu Rev Nutr 2001;21:343–79.
6. National Kidney Foundation. Kidney Disease Outcomes Quality Initiative clinical practice guidelines for nutrition in chronic renal failure. Am J Kidney Dis 2000;35:S17–104.
7. Jones JM. The methodology of nutritional screening and assessment tools. J Hum Nutr Diet 2002;15:59–71.
8. Kondrup J, Allison SP, Elia M, Vellas B, Plauth M. ESPEN guidelines for nutrition screening 2002. Clin Nutr 2003;22:415–21.
9. Detsky AS, McLaughlin JR, Baker JP, et al. What is subjective global assessment of nutritional status? JPEN J Parenter Enteral Nutr 1987;11: 8–13.
10. Steiber AL, Kalantar-Zadeh K, Secker D, McCarthy M, Sehgal A, McCann L. Subjective global assessment in chronic kidney disease: a review. J Ren Nutr 2004;14:191–200.
11. 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.
12. Afsar B, Sezer S, Ozdemir FN, Celik H, Elsurer R, Haberal M. Malnutrition-inflammation score is a useful tool in peritoneal dialysis patients. Perit Dial Int 2006;26:705–11.
13. Rubenstein LZ, Harker JO, Salva A, Guigoz Y, Vellas B. Screening for undernutrition in geriatric practice: developing the short-form mini-nutritional assessment (MNA-SF). J Gerontol A Biol Sci Med Sci 2001; 56:M366–72.
14. Reilly HM, Martineau JK, Moran A, Kennedy H. Nutritional screening—evaluation and implementation of a simple Nutrition Risk Score. Clin Nutr 1995;14:269–73.
15. Stratton RJ, Hackston A, Longmore D, et al. Malnutrition in hospital outpatients and inpatients: prevalence, concurrent validity and ease of use of the 'malnutrition universal screening tool' ('MUST') for adults. Br J Nutr 2004; 92:799–808.
16. Ferguson M, Capra S. Bauer J, Banks M. Development of a valid and reliable malnutrition screening tool for adult acute hospital patients. Nutrition 1999;15:458–64.
17. Bouillanne O, Morineau G, Dupont C, et al. Geriatric Nutritional Risk Index: a new index for evaluating at-risk elderly medical patients. Am J Clin Nutr 2005;82:777–83.
18. Guigoz Y, Vellas B, Garry PJ. Assessing the nutritional status of the elderly: the Mini Nutritional Assessment as part of the geriatric evaluation. Nutr Rev 1996;54:S59–65.
19. 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.
20. Ohkawa S, Odamaki M, Yoneyama T, Hibi I, Miyaji K, Kumagai H. Standardized thigh muscle area measured by computed axial tomography as an alternate muscle mass index for nutritional assessment of hemodialysis patients. Am J Clin Nutr 2000;71:485–90.
21. Murphy JM, Berwick DM, Weinstein MC, Borus JF, Budman SH, Klerman GL. Performance of screening and diagnostic tests. Application of receiver operating characteristic analysis. Arch Gen Psychiatry 1987; 44:550–5.
22. Halkin A, Reichman J, Schwaber M, Paltiel O, Brezis M. Likelihood ratios: getting diagnostic testing into perspective. QJM 1998;91:247–58.
23. Patient Registration Committee, Japanese Society for Dialysis Therapy. An overview of dialysis treatment in Japan (as of Dec. 31, 1995). Nagoya, Japan: Japanese Society for Dialysis Therapy, 1996 (in Japanese).
24. Patient Registration Committee, Japanese Society for Dialysis Therapy. An overview of dialysis treatment in Japan (as of Dec. 31, 2005). Nagoya, Japan: Japanese Society for Dialysis Therapy, 2006 (in Japanese).
25. Sullivan C, Leon JB, Sehgal AR. Job satisfaction among renal dietitians. J Ren Nutr 2006;16:337–40.
26. Blank L, Peters J, Lumsdon A, et al. Regional differences in the provision of adult renal dialysis services in the UK. QJM 2005;98:183–90.
27. Kalantar-Zadeh K, McAllister CJ, Lehn RS, Lee GH, Nissenson AR, Kopple JD. Effect of malnutrition-inflammation complex syndrome on EPO hyporesponsiveness in maintenance hemodialysis patients. Am J Kidney Dis 2003;42:761–73.
28. Buzby GP, Knox LS, Crosby LO, et al. Study protocol: a randomized clinical trial of total parenteral nutrition in malnourished surgical patients. Am J Clin Nutr 1988;47(suppl):366–81.
29. Buzby GP, Williford WO, Peterson OL, et al. A randomized clinical trial of total parenteral nutrition in malnourished surgical patients: the rationale and impact of previous clinical trials and pilot study on protocol design. Am J Clin Nutr 1988;47(suppl):357–65.