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Original article

Geriatric Nutrition Risk Index is comparable to the mini nutritional assessment for assessing nutritional status in elderly hospitalized patients

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SUMMARY

Background & aims: Malnutrition is common among hospitalized elderly patients, and the prevalence is increasing not only in Malaysia but also in the rest of the world. The Geriatric Nutrition Risk Index (GNRI) and the Mini Nutritional Assessment (MNA) were developed to identify malnourished individuals among this group. The MNA was validated as a nutritional assessment tool for the elderly. The GNRI is simpler and more efficient than the MNA, but studies on the use of the GNRI and its validity among the Malaysian population are absent. This study aimed to determine the prevalence of malnourished hospitalized elderly patients and assess the criterion validity of the GNRI and MNA among the geriatric Malaysian population against the reference standard for malnutrition, the Subjective Global Assessment (SGA), and determine whether the optimal cutoff value of the GNRI is suitable for the Malaysian population and determine the optimal tool for use in this population.

Methods: A cross-sectional study was conducted among 134 geriatric patients with a mean age of 68.9 ± 8.4 who stayed at acute care wards in Hospital Tuanku Ampuan Rahimah, Klang from July 2017 to August 2017. The SGA, MNA, and GNRI were administered through face-to-face interviews with all the participants who gave their consent. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the GNRI and MNA were analyzed against the SGA. Receiver-operating characteristic (ROC) curve analysis was used to obtain the area under the curve (AUC) and suitable optimal cutoff values for both the GNRI and MNA.

Results: According to the SGA, MNA, and GNRI, 26.9%, 42.5%, and 44.0% of the participants were malnourished, respectively. The sensitivity, specificity, PPV, and NPV for the GNRI were 0.622, 0.977, 0.982, and 0.558, respectively, while those for the MNA were 0.611, 0.909, 0.932, and 0.533, respectively. The AUC of the GNRI was comparable to that of the MNA (0.831 and 0.898, respectively). Moreover, the optimal malnutrition cutoff value for the GNRI was 94.95.

Conclusions: The prevalence of malnutrition remains high among hospitalized elderly patients. Validity of the GNRI is comparable to that of the MNA, and use of the GNRI to assess the nutritional status of this group is proposed with the new suggested cutoff value (GNRI $\leq$ 94.95), as it is simpler and more efficient. Underdiagnosis of malnutrition can be prevented, possibly reducing the prevalence of malnourished hospitalized elderly patients and improving the quality of the nutritional care process practiced in Malaysia.

Abbreviations: GNRI, Geriatric Nutrition Risk Index; MNA, Mini Nutritional Assessment; ROC, Receiver-Operating Characteristic; AUC, Area Under the Curve; SGA, Subjective Global Assessment; BMI, Body Mass Index; Alb, Albumin; Hb, Hemoglobin; TLC, Total Lymphocyte Count; PPV, Positive Predictive Value; NPV, Negative Predictive Value.

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1. Introduction

Malnutrition refers to undernutrition and is generally defined as "*a state resulting from lack of intake or uptake of nutrition that leads to altered body composition (decreased fat free mass) and body cell mass leading to diminished physical and mental function and impaired clinical outcome from disease*" [1–3]. Sick and vulnerable individuals, specifically the elderly, often face the issue of underdiagnosis of undernutrition in hospital settings [4]. Indeed, the prevalence of malnutrition among the elderly in hospital settings is common, ranging from 11% to 45% internationally, while in Malaysia, the prevalence ranges from 16% to 61.3% [5–14].

Healthcare facilities in Malaysia practice the standardized nutritional care pathways as recommended by European Society for Clinical Nutrition and Metabolism (ESPEN) [1,3]. Every patient needs to be nutritionally screened by a healthcare professional within 24 h after admission to the hospital using a nutritional screening tool. Patients at high risk of malnutrition will then be referred to a dietitian for further in-depth nutritional assessment. The use of nutritional assessment tools is recommended to aid dietitians in assessing patients' conditions. However, a gold standard for the diagnosis of malnutrition is still lacking, and the use of different indicators might explain the wide range of malnutrition prevalence rates stated in the literature [15]. Nevertheless, it is important to note that all nutritional tools should be well validated whereby they should be sensitive for screening and specific for diagnostic purposes [16]. The Mini Nutritional Assessment (MNA) is a validated nutritional assessment tool for use with elderly patients [17]. However, studies have found that the MNA has a higher risk of overdiagnosing malnutrition because it has a very low specificity [17,18]. In addition, an inability to complete the full MNA among elderly patients with dementia or communication problems and the length of time needed to complete the assessment are some of the disadvantages of using the full MNA [12]. The Geriatric Nutrition Risk Index (GNRI) is a nutritional formula developed specifically for the elderly to identify and predict nutrition-related complications rather than diagnose malnutrition [19]. It is practical and provides reliable assessment in most healthcare settings, particularly among elderly patients with dementia, aphasia, or apraxia [20]. However, further studies are still needed to support current findings on the validity of the GNRI [21].

Although the MNA is widely used in assessing the nutritional status of the elderly, only a few validity studies are available, and the tool did not consistently perform well [6]. This study aims to evaluate the criterion validity of the GNRI against the SGA, which is considered the reference standard in the hospital setting, because this tool has been shown to be a valid reference method to assess the criterion validity of other tools in previous studies [7,22]. This study also aims to compare the applicability of the GNRI and MNA in assessing the nutritional status of hospitalized elderly patients in Malaysia.

2. Materials and methods

2.1. Study design and population

This cross-sectional study involved 134 hospitalized elderly patients admitted between July 2017 and August 2017 at a general hospital in Selangor, Malaysia. The participants were recruited from both medical and surgical wards using a purposive sampling method. All Malaysian elderly inpatients aged 60 years and above were eligible to participate in this study. Patients who were under intensive care, palliative care treatment, dietitian supervision and/or nutritional support (such as patients on Ryle's tube feeding or oral nutritional supplementation) were excluded. They were also excluded if they had undergone surgery the same day, had fluid retention, were not fit to complete the study protocols, or had communication barriers or difficulties even with the help of a caregiver. Eligible participants were screened according to the selection criteria by referring to the patient's medical record.

Written informed consent forms were signed by and obtained from the participants who agreed to participate in the study in the presence of an impartial witness (such as a caregiver or family member). Participants' sociodemographic data, including age, gender, education level, marital status, and medical history, were obtained and recorded. The study protocol was approved by the Medical Research Ethics Committee (MREC) of the Ministry of Health, Malaysia [(5)KKM/NIHSEC/P197-997] and Research Ethics Committee of Universiti Teknologi MARA, Malaysia [600-IRMI(5/1/6)].

2.2. Assessment of nutritional status

Nutritional assessment was performed using SGA, GNRI and MNA. SGA is a validated tool that includes a medical history and physical examination. It is widely used with surgical and clinical patients, and most studies have shown that its performance is similar or superior to commonly used traditional methods such as anthropometric and laboratory data [23,24]. The items included in this assessment tool are changes in weight, dietary intake, gastrointestinal symptoms that persist for more than 2 weeks and functional capacity. The physical examination includes an evaluation of subcutaneous fat, muscle wasting, ankle and sacral edema, and ascites. In terms of scoring, the participants are assigned a nutritional rating as follows:

SGA A = well-nourished/not malnourished
SGA B = mildly moderately malnourished/at risk of malnutrition
SGA C = severely malnourished/malnourished

These three nutritional status categories are used to report the prevalence rate of malnutrition among the participants. SGA is differed from GNRI in terms of identification of patient's nutritional status. SGA provides nutritional diagnosis of the patients from well-nourished to severely malnourished throughout subjective measurements [23,24]. In contrast, GNRI provides a prognostic nutritional index based on the quantitative determination of the risk of nutrition-related morbidity and mortality in elderly from no risk to major risk [19]. GNRI was developed by modifying the Nutritional Risk Index (NRI) for elderly patients. This index is calculated by using the following equation:

$$GNRI = [1.489 \times \text{albumin (g/L)}] + [41.7 \times (\text{weight/WLo})]$$

where WLo = the ideal weight calculated from the Lorentz formula as follows:

For men: height (cm) − 100 − [(height in cm − 150)/4]

For women: height (cm) − 100 − [(height in cm − 150)/2.5]

When the "weight/WLo" is equal to or greater than 1, the ratio is set to 1. The original nutritional status categories were based on the following cutoff values [19]:

GNRI < 82 = major risk of nutrition-related complications
GNRI 82 to <92 = moderate risk of nutrition-related complications
GNRI 92 to ≤98 = low risk of nutrition-related complications
GNRI >98 = no risk of nutrition-related complications

Cereda et al. proposed three-categories of GNRI cutoff values in their study to compare the GNRI with the MNA [25]. The purpose was to obtain a three-category tool similar to the MNA, and this modified cutoff value has been shown to be associated with an increased risk of overall health complications [25]. Thus, the following cutoff value categories were used to report the prevalence of malnutrition in this study:

GNRI <92 = severe risk of nutrition-related complications/malnourished
GNRI 92–98 = moderate risk of nutrition-related complications/at risk of malnutrition
GNRI >98 = no risk of nutrition-related complications/not malnourished

Meanwhile, the full MNA is a questionnaire consisting of 18 questions and is divided into four parts: anthropometric measurements (including weight, height, MUAC, CC, and weight loss during the past 3 months), global assessments (six questions related to lifestyle, medication, and mobility), dietary questionnaires (eight questions related to number of meals, food and fluid intake, and autonomy of feeding), and subjective assessments (self-perception of health and nutrition). There are two parts to the MNA: the first part of the questionnaire (items A to F), also known as the Mini Nutritional Assessment-Short Form (MNA-SF), is used as a screening tool, and the second part of the questionnaire (items G to R) requires more in-depth nutritional assessment of the subjects. The total score represents the nutritional status of the participants based on the following categories [26]:

MNA < 17 = Malnourished
MNA 17–23.5 = At risk of malnutrition
MNA 24–30 = Normal nutritional status

2.3. Criterion validation of GNRI and MNA against SGA

As there is no universally accepted definition or reference gold standard for malnutrition, a comparison of the results between the GNRI and MNA was made based on the criterion validity of each nutritional assessment tool against the reference standard, the SGA. The validity was evaluated in terms of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), determined by using a contingency table. For this purpose, the nutritional status for each tool falls into either 'not malnourished' or 'malnourished' (binary variable). For the reference standard, the SGA, participants with SGA-A were categorized as well-nourished, while participants with SGA-B and C were categorized as malnourished. These binary nutritional status categories have also been used in previous validity studies of nutritional screening and assessment tools [7,27]. Meanwhile, GNRI score less than 92 were categorized as malnourished and used in the validity and comparison examination:

GNRI <92 = Moderate to severe risk of nutrition-related complications/Malnourished
GNRI ≥92 = No risk or at risk of nutrition-related complications/Not malnourished

A GNRI score less than 92 was suggested as a clinical trigger for routine nutritional support [28]. Moreover, another study suggested referring to a GNRI score less than 87 as a threshold to initiate nutritional support in acute care settings [29]. Thus, to prevent from underdiagnosis of malnutrition, GNRI score less than 92 were categorized as malnourished in this study. In a comparison study between the Patient-Generated Subjective Global Assessment (PG-SGA) and MNA, the authors categorized nutritional status from each of these tools as binary variables whereby for the MNA, malnourished participants were rated as those who had MNA scores less than 17 [27]. This method was used to examine criterion validity and report prevalence in the study. Thus, the current study also used an MNA score of less than 17 to represent malnourished participants in validity and comparison examinations as follow:

MNA < 17 = Malnourished
MNA 18–30 = Not malnourished

The validity result of the GNRI was then compared with the validity result of the MNA to choose which nutritional tool was suitable to be used among hospitalized elderly Malaysian patients.

2.4. Anthropometric measurements

Weight, height, body mass index (BMI), mid-upper arm circumference (MUAC), and calf circumference (CC), were obtained to complete the SGA, GNRI, and MNA. Body weight was measured in light clothes without shoes with a SECA 813 electronic flat scale to the nearest 0.1 kg, and height was measured without shoes as well with a SECA 217 stable stadiometer to the nearest 0.1 cm. For subjects who could not stand upright or who had kyphosis, half arm span was measured using a nonelastic SECA 201 ergonomic circumference measuring tape to the nearest 0.1 cm to obtain an estimated standing height measurement using a predictive equation [30,31]. Weight and height were used to calculate BMI (weight [kg]/height $[m]^2$). Additionally, CC and MUAC (of the nondominant arm) were also measured to the nearest 0.1 cm with a nonelastic SECA 201 ergonomic circumference measuring tape, as these measurements are required to complete the full MNA.

2.5. Statistical analysis

The minimum sample size required for this study was 131 participants and was calculated using the 'Sample size calculator for Sensitivity and Specificity Studies' program [32]. The expected sensitivity (0.95) and specificity (0.67) of the GNRI were obtained from a previous validity study of the GNRI, as there was no local study on the validity of the GNRI available [20]. The expected prevalence (0.35) of the GNRI was obtained from the latest local study on the prevalence of malnutrition conducted among 8 general hospitals in peninsular Malaysia [7]. These values were entered into the program with the desired precision level of 0.10 and confidence level of 95%. This method of sample size calculation was also used in a previous local study to validate the MRST-H screening tool [7].

All statistical analyses were performed using Statistical Package for Social Sciences (SPSS) (version 17.0). Means and standard deviations were calculated for continuous variables, while frequencies and percentages (%) were calculated for categorical data. An unpaired t-test was used to differentiate between the sex and age groups for numerical data. The chi-squared test was used to assess the differences between sex and demographic and psychosocial factors that were categorical data.

To determine the validity of GNRI and MNA, both nutritional tools were validated against the reference standard, the SGA to obtain their sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). The sensitivity of a tool depends on its probability of accurately identifying participants with malnutrition (true positive rate) and was calculated as true positive/(true positive + false negative). The specificity of a tool depends on its probability of identifying the participants who were

not malnourished (true negative rate) and was calculated as true negative/(true negative + false positive) [33]. On the other hand, PPV refers to the probability of identifying the participants diagnosed as malnourished by the tool (either GNRI < 92 or MNA < 17) who were also categorized as malnourished by the SGA [33,34]. PPV was calculated as true positive/(true positive + false positive). Similarly, NPV indicates the probability of identifying the participants categorized as not malnourished by the tool who were also categorized as not malnourished by SGA [33]. NPV was calculated as true negative/(true negative + false negative). Higher values of PPV or NPV (close to 1) suggest that the ability of the tool to accurately identify patients' nutritional status is comparable to that of the reference standard, the SGA. The receiver-operating characteristic (ROC) curves of the GNRI and MNA were obtained by plotting its sensitivity against the corresponding false positive rate (1-specificity) at every possible cutoff score. The ROC area under the curve (AUC) represents the overall indication of the GNRI and MNA diagnostic accuracy [35]. An AUC of 0.9–1.0 is considered an excellent test, 0.8 to 0.9 is a very good test, 0.7 to 0.8 is a good test, 0.6 to 0.7 is a sufficient test, 0.5 to 0.6 is a bad test, and lastly, less than 0.5 indicates that the test has no use [36]. The cutoff values that had sensitivity and specificity were considered equally important in determining the new suggested cutoff value [27]. Thus, sensitivity and specificity above 0.8 for each cutoff value from the ROC analysis were determined to calculate the Youden Index. The Youden Index determined the optimized cutoff value with optimized sensitivity and specificity using the formula Youden Index = sensitivity + specificity − 1. The cutoff value with the maximum Youden Index was chosen as the new suggested cutoff value of the GNRI to diagnose malnourished elderly patients [7,36]. All statistical analyses were conducted at the 95% confidence level and at a significant level of 0.05.

A Pearson chi-square test was also performed to examine the relationship between nutritional status subcategorization with both nutritional tools, the MNA and GNRI, with the subclassification of nutritional status by the SGA.

3. Results

3.1. General characteristics of the subjects

A total of 134 geriatric patients 48 (35.8%) men and 86 (64.2%) women, with a mean age of 68.9 ± 8.4 (range, 60–90 years old), met the inclusion criteria, gave consent to participate in the study, and completed the study procedure through face-to-face interviews. Majority of the participants were Malay, married, had formal education up to primary school level, stayed with spouse or family members, unemployed, and financially dependent on their spouse or children (Table 1). The two most common primary diagnosis of the participants were circulatory-related diseases (include hypertensive diseases, ischemic heart diseases, and cerebrovascular disease), followed by endocrine, nutritional, and metabolic-related diseases (mostly diagnose with diabetes) as shown in Table 1.

3.2. Criterion validity of GNRI and MNA

The results of the criterion validity and the AUC from the ROC analysis for both the GNRI and MNA against the SGA are presented in Table 2. The GNRI had slightly lower sensitivity, specificity, PPV, and NPV compared to the MNA, but the values were still comparable to each other. Additionally, the AUC values shown by both the MNA (AUC = 0.898; CI = 0.762 to 0.899) and GNRI (AUC = 0.831; CI = 0.847 to 0.948) indicated that both nutritional assessment tools have a good test value in determining malnourished groups. This finding indicates that both tools have good diagnostic discriminative power to detect individuals with malnutrition compared with the SGA. Figs. 1 and 2 show the ROC plots of the GNRI and MNA against the reference standard, the SGA, respectively.

On the other hand, the high AUC results and low sensitivity of the GNRI at the original cutoff value of 92 prompted a revision of the cutoff value for diagnosing malnutrition among the Malaysian geriatric population. Thus, the optimal cutoff value for the GNRI in identifying elderly patients with malnutrition was established at 94.95, with a maximum Youden Index value of 0.542 (Table 3). However, when using the new optimal cutoff value, the sensitivity value increased only slightly from 0.611 to 0.678, while specificity decreased from 0.909 (at the original cutoff value of 92) to 0.864.

3.3. Malnutrition prevalence

Malnutrition prevalence varied according to different nutritional assessment tools. The prevalence of malnutrition according to the SGA, MNA, and GNRI were 26.9%, 42.5%, and 44.0%, respectively. Moreover, the SGA and MNA identified almost similar percentages of elderly patients at risk of malnutrition (40.3% and 41.8%, respectively) but not the GNRI (11.9%) (Table 4). Most malnourished elderly patients were men (ranging from 31.3% to 47.9%), and women made up a significantly higher proportion of the group identified by the MNA to be at risk of malnutrition than men ($p < 0.05$). When nutritional status was classified as a binary variable for all of the nutritional tools (Table 5), both the GNRI and MNA clearly identified fewer malnourished subjects than the reference standard, the SGA.

3.4. Anthropometric and biochemical characteristics of the subjects

As shown in Table 6, elderly subjects without malnutrition, as identified by the GNRI, have a higher BMI, CC, MUAC, albumin level, hemoglobin level and total lymphocyte count, with mean values of 25.6 kg/m^2, 34.6 cm, 30.3 cm, 38.7 g/L, 11.7 g/dL, and 2.2 × 10^9/L, respectively, compared with the malnourished group. Both the MNA and GNRI identified subjects with malnutrition with poor anthropometric and biochemical measurements.

4. Discussion

Nutritional tools may aid healthcare professionals in assessing the nutritional status of patients. However, validation of these tools is needed to evaluate the suitability and applicability of the tools for specific populations [7,16]. This study evaluated the criterion validity of the GNRI and is the first validity study of the GNRI among Malaysian geriatric patients. Criterion validity includes the comparison of nutritional assessment tools with the gold standard procedure [37]. Since a gold standard for assessing malnutrition is still lacking, the SGA was used as the reference standard since this tool has been established and is commonly used as a nutritional assessment tool in clinical settings [6,38].

According to the SGA, 67.1% of the geriatric patients were malnourished. This prevalence rate is consistent with the prevalence reported in a previous local study that applied the SGA among similar population groups that reported a prevalence of 61.3% malnourished geriatric patients [9]. However, the prevalence in our study was higher than identified in a recent local multicenter study, which reported that 34.7% of geriatric patients were malnourished [7]. Nevertheless, the study was based on the elderly admitted to hospital in between the year of 2011–2013. Thus, the prevalence may not represent the current situation.

According to the present findings, the GNRI and MNA perform differently because the group at risk of malnutrition was larger when identified by the MNA than when identified by the GNRI. This

Table 1
Sociodemographic characteristics of participants according to sex [expressed as number (%)].

Characteristic	Men (n = 46)	Women (n = 86)	Total (n = 134)
Marital status			
Married	37 (77.1)	48 (55.8)	85 (63.4)
Single	4 (8.3)	0 (0.0)	4 (3.0)
Divorced	0 (0.0)	1 (1.2)	1 (0.7)
Widowed	7 (14.6)	37 (43.0)[a]	44 (32.8)
Race			
Malay	25 (52.1)	40 (48.5)	65 (48.5)
Indian	11 (22.9)	27 (31.4)	38 (28.4)
Chinese	12 (25.0)	19 (22.1)	31 (23.1)
Education			
None	8 (16.7)	31 (36.0)	39 (29.1)
Primary	19 (39.6)	33 (38.4)	52 (38.8)
Secondary	18 (37.5)	20 (23.3)	38 (28.4)
College	3 (6.3)	2 (2.3)	5 (3.7)
Living status			
Alone	3 (6.3)	2 (2.3)	5 (3.7)
With others	45 (93.8)	84 (97.7)	129 (96.3)
Job status			
Not working	38 (79.2)	82 (95.3)[a]	120 (89.6)
Working	10 (20.8)	4 (4.7)	14 (10.4)
Source of income			
Nondependent	25 (52.1)	7 (8.1)	32 (23.9)
Dependent	23 (47.9)	79 (91.9)[b]	102 (76.1)
Primary diagnosis			
Diseases of circulatory system	26 (54.2)	54 (62.8)	80 (59.7)
Endocrine, nutritional, and metabolic diseases	3 (6.3)	25 (29.1)	28 (20.9)
Diseases of the digestive system	3 (6.3)	1 (1.2)	4 (3.0)
Diseases of the respiratory system	2 (4.2)	0 (0.0)	2 (1.5)
Diseases of the genitourinary system	1 (2.1)	0 (0.0)	1 (0.7)
Certain infectious and parasitic diseases	0 (0.0)	1 (1.2)	1 (0.7)
Diseases of the blood and blood-forming organs and certain disorders involving the immune system	1 (2.1)	0 (0.0)	1 (0.7)
Diseases of the musculoskeletal system and connective tissue	0 (0.0)	1 (1.2)	1 (0.7)
Others	12 (25.0)	4 (4.7)	16 (11.9)

[a] $p < 0.05$.
[b] $p < 0.001$, significant difference between sex (Pearson chi-squared test).

finding is not new, as other studies have also found that the MNA has a tendency to overdiagnose the group at risk of malnutrition [20,25,39]. Although the MNA is able to identify patients at risk of malnutrition similarly to the SGA, careful consideration is recommended when using the MNA to determine the risk of developing malnutrition in relation to adverse health outcomes, because the implications of positive screening results are uncertain [40]. The observed differences in the prevalence of malnutrition reported in this study may be the result of the application of different tools.

Recently, the European Society for Clinical Nutrition and Metabolism, ESPEN, has recommended the use of an etiology-based diagnosis of malnutrition [3]; thus, Table 7 shows the subclassification of nutritional status of the subjects based on the assessment using the SGA. Among 26.9% of malnourished subjects, most clearly had disease-related malnutrition (DRM) without inflammation (17.2%), which was mainly related to the diseases of the circulatory system, such as stroke and hypertension. Moreover, 6.0% of the malnourished subjects had chronic DRM with inflammation mainly related to cancer and congestive heart failure. Approximately 3.7% of malnourished subjects were categorized as having acute DRM with inflammation, and most of these patients had undergone major surgical procedures due to certain diseases, such as diseases of the digestive system, diseases of the genitourinary system, and certain infectious and parasitic diseases. Based on Table 7 as well, the results revealed that there was a significant relationship between the MNA and GNRI with the subclassification of nutritional status by the SGA (chi-square value = 87.3, df = 8, p = 0.000), particularly for the subclassification of malnutrition diagnosis. This result demonstrates that the MNA and GNRI also have the ability to correctly classify malnourished subjects according to different types of malnutrition. Appropriate subclassification of the type of malnutrition is particularly important for understanding the related complications and planning appropriate treatment [3]. Moreover, the malnourished group identified by the MNA and GNRI showed poor anthropometric and biochemical characteristics, as shown in Table 6. Most of the malnourished group identified by both the GNRI and MNA had low MUAC and low CC measurements. These nutritional indicators are useful in representing the measurement of muscle mass and subcutaneous adipose tissue [41,42], which can be associated with mortality risk. Although the Academy of Nutrition and Dietetics (AND) and ASPEN no longer recommend the use of blood biomarkers for identifying malnutrition, the biochemical parameters such as albumin could still be used to detect the presence of a systemic inflammatory response, and thus contribute to the identification of the etiologic basis for the diagnosis of malnutrition [3,43,44].

Table 2
Sensitivity, specificity, PPV, NPV, and AUC of the MNA and GNRI compared with the SGA.

Nutritional assessment tool	Sensitivity	Specificity	PPV	NPV	AUC (95% CI)
MNA	0.622	0.977	0.982	0.558	0.898
GNRI	0.611	0.909	0.932	0.533	0.831

PPV, positive predictive value; NPV, negative predictive value; AUC, area under the curve; MNA, Mini Nutritional Assessment; GNRI, Geriatric Nutritional Risk Index.

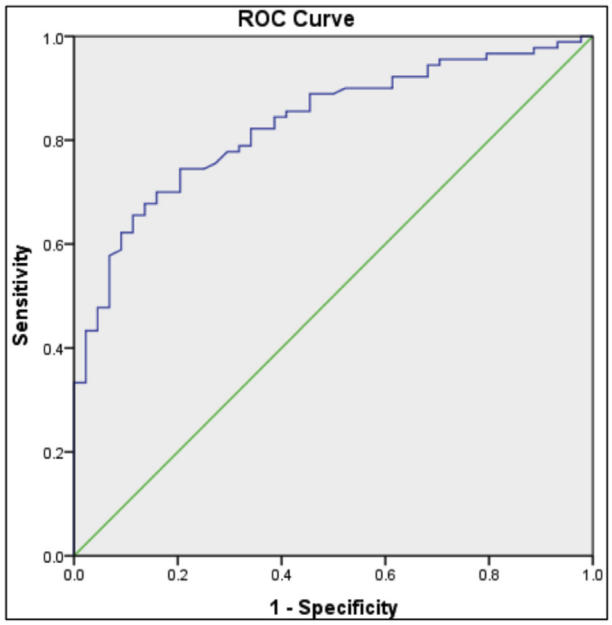

Fig. 1. Receiver-operating characteristic (ROC) curve plot of the true positive rate (sensitivity) rate against the false positive rate (1-specificity) at various Geriatric Nutrition Risk Index (GNRI) cut off values compared with Subjective Global Assessment (SGA).

The GNRI differs from any other nutritional assessment tools, in that it requires only three objective parameters of height, weight, and albumin parameters, making it a simpler method to assess the nutritional condition of the geriatric patients than the MNA. For diagnostic purposes, it is important for the tool to be specific, whereas for screening purposes, the tools should be sensitive [16]. This study found that both the GNRI and MNA had high specificity (>0.800), which is particularly important in nutritional assessment because accurate diagnosis of malnutrition will prevent unnecessary treatment in individuals who do not require it [5]. Individuals identified with malnutrition need proper treatment to prevent further nutritional status deterioration; thus, inaccurately diagnosed malnutrition will increase the unnecessary cost of hospitalization [16,17,45]. Nevertheless, the MNA and GNRI have low sensitivity, making them unsuitable for screening purposes. Another study also found that the GNRI tended to have low sensitivity (0.545) and high specificity (0.717) compared to the SGA, but that study involved patients on peritoneal dialysis [46]. Moreover, a study using a combined index to validate six nutritional screening tools, including the MNA-SF, SGA, and GNRI, found that the GNRI had the highest specificity (0.921) but the lowest sensitivity (0.66) among the other nutritional tools [47].

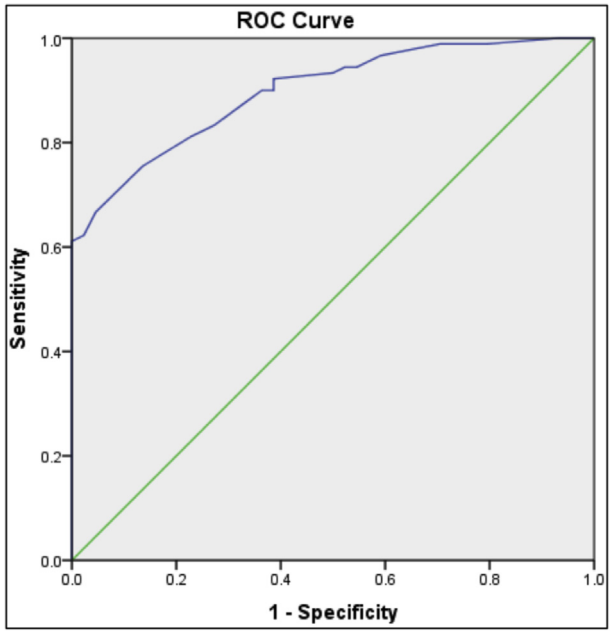

Fig. 2. Receiver-operating characteristic (ROC) curve plot of the true positive rate (sensitivity) rate against the false positive rate (1-specificity) at various Mini Nutritional Assessment (MNA) cut off values compared with Subjective Global Assessment (SGA).

Table 3
Sensitivity, specificity, and Youden Index of the GNRI at different cutoff values to identify SGA-determined malnourished elderly patients.

Cutoff value of GNRI	Sensitivity	Specificity	Youden index
91.30	0.600	0.909	0.509
92.00	0.611	0.909	0.520
92.70	0.622	0.909	0.531
92.95	0.622	0.886	0.508
93.20	0.633	0.886	0.519
93.55	0.644	0.886	0.530
94.15	0.656	0.886	0.542
94.55	0.656	0.864	0.520
94.65	0.667	0.864	0.531
94.95	**0.678**	**0.864**	**0.542**
95.30	0.678	0.841	0.519
95.60	0.689	0.841	0.530
95.90	0.700	0.841	0.541
96.35	0.700	0.795	0.495
96.85	0.711	0.795	0.506
97.15	0.722	0.795	0.517
97.60	0.733	0.795	0.528

GNRI, Geriatric Nutrition Risk Index; SGA, Subjective Global Assessment.
Bold: optimal cutoff value of the GNRI with maximum Youden Index.

The high AUC value of the GNRI (0.831), which was close to that of the MNA (0.898), indicates that the GNRI has a discriminative power comparable to that of the MNA in differentiating between malnourished and nonmalnourished groups. Although using the new GNRI cutoff value (94.95) will increase the sensitivity only slightly, the specificity value remains high (>0.800). Therefore, with the comparable validities of the GNRI and MNA, the GNRI is suggested for use as a nutritional assessment tool for geriatric populations with a new cutoff value of 94.95, as it is very simple and not time-consuming to complete. In addition, albumin is one of the commonly used biochemical parameters in routine clinical practice. Thus, in a hospitalized setting, the GNRI may be a simpler and more practical method to use. Moreover, GNRI was also found to be sensitive to acute disease stress in view it relies on measurements of albumin concentration [44]. The data for albumin are readily available within 24–48 h of admission in patients' medical records, thus making it cost-effective and efficient. Although the MNA has been well recognized as a suitable nutritional assessment tool, it requires 15 min to be completed, which may not be practical for nutritional assessment among elderly patients in a hospital setting. Notably, it was not easy to assess the nutritional status of elderly patients in a hospitalized setting, as many of them were bedridden and some were unconscious, had dementia or had other problems with communications barriers [48].

Malnutrition is still an issue of concern among hospitalized elderly patients in Malaysia, and our study had proven this point. Malnutrition is known to cause many adverse outcomes; hence, the present study suggested using the GNRI as an alternative nutritional tool to assist healthcare professionals, especially dietitians, to accurately assess the nutritional status of this group. The established cutoff value of 94.95 has been suggested when using the

Table 4
Percentage of malnourished hospitalized elderly patients [expressed as number (%; 95% CI)].

Nutritional assessment	Men (n = 48)	Women (n = 86)	Total (n = 134)
SGA			
Not malnourished	17 (35.4; 23.4–49.6)	27 (31.4; 22.6–41.8)	44 (32.8; 25.5–41.2)
At risk of malnutrition	16 (33.3; 21.7–47.5)	38 (44.2; 34.2–54.7)	54 (40.3; 32.4–48.8)
Malnourished	15 (31.3; 20.0–45.3)	21 (24.4; 16.6–34.5)	36 (26.9; 20.1–34.9)
MNA			
Not malnourished	12 (25.0; 14.9–38.8)	9 (10.5; 5.6–18.7)	21 (15.7; 10.5–22.8)
At risk of malnutrition	13 (27.1; 16.6–41.0)	43 (50.0; 39.7–60.3)[a]	56 (41.8; 33.8–50.3)
Malnourished	23 (47.9; 34.5–61.7)	34 (39.5; 29.9–50.1)	57 (42.5; 34.5–51.0)
GNRI			
Not malnourished	19 (39.6; 27.0–53.7)	40 (46.5; 36.3–57.0)	59 (44.0; 35.9–52.5)
At risk of malnutrition	7 (14.6; 7.3–27.2)	9 (10.5; 5.6–18.7)	16 (11.9; 7.5–18.5)
Malnourished	22 (45.8; 32.6–59.7)	37 (43.0; 33.1–53.6)	59 (44.0; 35.9–52.5)

SGA, Subjective Global Assessment; MNA, Mini Nutritional Assessment; GNRI, Geriatric Nutrition Risk Index; CI, Confidence Interval.
[a] $p < 0.05$, significant difference between sex (Pearson chi-squared test).

Table 5
Prevalence of malnourished hospitalized elderly patients according to nutritional status as a binary variable [expressed as number (%; 95% CI)].

Nutritional assessment	Men (n = 48)	Women (n = 86)	Total (n = 134)
SGA			
Not malnourished	17 (35.4; 23.4–49.6)	27 (31.4; 22.6–41.8)	44 (32.8; 25.5–41.2)
Malnourished	31 (64.6; 50.4–76.6)	59 (68.6; 58.2–77.4)	90 (67.2; 58.8–74.5)
MNA			
Not malnourished	25 (52.1; 38.3–65.5)	52 (60.5; 49.9–70.1)	77 (57.5; 49.0–65.5)
Malnourished	23 (47.9; 34.5–61.7)	34 (39.5; 29.9–50.1)	57 (42.5; 34.5–51.0)
GNRI			
Not malnourished	26 (54.2; 40.3–67.4)	49 (57.0; 46.4–66.9)	75 (56.0; 47.5–64.1)
Malnourished	22 (45.8; 32.6–59.7)	37 (43.0; 33.1–53.6)	59 (44.0; 35.9–52.5)

SGA, Subjective Global Assessment; MNA, Mini Nutritional Assessment; GNRI, Geriatric Nutrition Risk Index.

Table 6
Characteristics of anthropometric and biochemical measurement according to nutritional status (mean ± SD).

Parameter (unit)	MNA		GNRI	
	Normal	Malnourished	Normal	Malnourished
Anthropometric				
BMI (kg/m^2)	24.9 ± 5.3	19.1 ± 4.4	25.6 ± 4.9	18.3 ± 3.5
CC (cm)	33.9 ± 5.3	29.9 ± 5.1	34.6 ± 5.6	29.3 ± 3.8
MUAC (cm)	29.5 ± 5.4	24.4 ± 5.4	30.3 ± 5.6	23.5 ± 3.9
Biochemical				
Alb (g/dL)	3.7 ± 0.6	3.1 ± 0.7	3.9 ± 0.5	2.9 ± 0.6
Hb (g/L)	11.4 ± 2.0	10.1 ± 1.6	11.7 ± 1.9	9.7 ± 1.4
TLC ($\times 10^9$/L)	2.1 ± 0.9	1.9 ± 0.9	2.2 ± 0.9	1.8 ± 0.9

BMI, body mass index; CC, calf circumference; MUAC, mid-upper arm circumference; Alb, albumin; Hb, hemoglobin; TLC, total lymphocyte count.

GNRI in the assessment of nutritional status among the Malaysian geriatric population, as it allows early and accurate identification of malnourished elderly patients, improving patient outcomes and the quality of the nutritional care process practiced in Malaysia.

However, there are limitations to this study. The absence of a universally accepted gold standard to diagnose malnutrition may cause discrepancies in the validation of nutritional tools, which has commonly been a point of discussion in most studies. As mentioned, a gold standard to diagnose malnutrition is important to accurately diagnose some patients who truly have malnutrition problems. A well-established and valid nutritional assessment tool can be used as the reference standard to fill this gap. The present study validated the GNRI based only on its criterion validity. Thus, more studies should conduct in-depth evaluations of the predictive validity of the GNRI for hospitalization (i.e., length of stay and number of rehospitalizations), functional disability, and morbidity and mortality outcomes. Although this study recommends using the GNRI for the assessment of nutritional status among hospitalized elderly patients in Malaysia, further studies are needed as the

Table 7
Subclassification of subject's nutritional status identified by standard reference, SGA, and its relationship with the MNA and GNRI classification [expressed as number (%)].

Nutritional status	SGA	MNA			GNRI		
		Not malnourished	At risk of malnutrition	Malnutrition	Not malnourished	At risk of malnutrition	Malnutrition
Not malnourished	44 (32.8)	18 (40.9)	25 (56.8)	1 (2.3)	35 (79.5)	5 (11.4)	4 (9.1)
At risk of malnutrition	54 (40.3)	3 (5.6)	30 (55.6)	21 (38.9)	24 (44.4)	10 (18.5)	20 (37.0)
Undernutrition/Malnutrition							
a) Disease-related malnutrition (DRM) with inflammation							
Acute DRM with inflammation	5 (3.7)	0 (0.0)	0 (0.0)	5 (100.0)	0 (0.0)	0 (0.0)	5 (100.0)
Chronic DRM with inflammation	8 (6.0)	0 (0.0)	0 (0.0)	8 (100.0)	0 (0.0)	0 (0.0)	8 (100.0)
b) DRM without inflammation	23 (17.2)	0 (0.0)	1 (4.3)[a]	22 (95.7)	0 (0.0)	1 (4.3)[a]	22 (95.7)

SGA, Subjective Global Assessment; MNA, Mini Nutritional Assessment; GNRI, Geriatric Nutrition Risk Index; DRM, Disease-related malnutrition.
[a] $p < 0.001$, significant difference between nutritional status (Pearson chi-squared test).

sample size of this study was relatively small to represent the whole geriatric population in Malaysia.

5. Conclusion

In summary, the prevalence of malnourished hospitalized elderly patients remains high. Thus, early and accurate identification of malnutrition is crucial. This study found that the GNRI had comparable validity to the MNA, with both showing low sensitivity and PPV but high specificity and NPV. However, the high AUC of the GNRI, similar to that of the MNA and the SGA, demonstrated that its overall diagnostic accuracy in discriminating malnourished patients was still very good. A new cutoff value of 94.95 with optimal sensitivity and higher specificity than the original cutoff value was recommended when using the GNRI in the assessment of nutritional status among Malaysian geriatric patients. This study can serve as a preliminary study to open a new research area in Malaysia to suggest a better quality approach in the nutritional care process practiced in Malaysia.

Statement of authorship

All of the authors participated in the study design. Nur Adilah Shuhada Abd Aziz collected the data, performed the data analyses, and drafted the manuscript. Nur Islami Mohd Fahmi Teng was responsible for critically revising the manuscript. All authors contributed to the writing and approval of the final version of the manuscript.

Conflict of interest

The authors report no conflicts of interest in the preparation of this manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnesp.2018.12.002.

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