The Geriatric Nutrition Risk Index versus the Mini-Nutritional Assessment Short Form in predicting postoperative delirium and hospital length of stay among older non-cardiac surgical patients: a prospective cohort study

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Abstract

Backgrounds: Malnutrition has been shown to be associated with a poor prognosis in older surgical patients. Several tools are available for detecting malnutrition. But little is known about their ability to assess risks of postoperative adverse outcomes. The study aimed to compare the ability of the Geriatric Nutritional Risk Index (GNRI) and the Mini-Nutritional Assessment Short Form (MNA-SF) in predicting postoperative delirium (POD) and length of stay (LOS) among older non-cardiac surgical patients.

Methods: Prospective study of 288 older non-cardiac surgical patients from the West China Hospital of Sichuan University. Preoperative nutritional status was assessed using the GNRI and MNA-SF, and patients were followed for the occurrence of POD and LOS. Multivariate logistic regression and linear regression analyses were used to identify predictors of these outcomes. The relative performance of the GNRI and MNA-SF as predictors of these outcomes were determined by Receive Operator Characteristic curves (ROC) analyses and the area under the curve (AUC).

Results: Multivariate analysis revealed that high nutritional risk (GNRI < 92) and malnutrition/risk of malnutrition (MNA-SF < 8 and MNA-SF=8-11) were significantly associated with POD. Linear regression analysis showed that low/high nutritional risk (GNRI=92-98 and GNRI < 92) and malnutrition (MNA-SF < 8) were independent predictors of prolonged LOS. Moreover, the area under the curve (AUC) of MNA-SF scores (AUC=0.718, \( P<0.001 \), 95%CI: 0.64-0.80) for POD was better than GNRI scores (AUC=0.606, \( P=0.019 \), 95%CI: 0.52-0.69), whereas, GNRI scores (AUC=0.611, \( P=0.006 \), 95%CI: 0.54-0.69) had larger AUC when predicting prolonged LOS as
compared to MNA-SF scores (AUC=0.533, \( P=0.421 \), 95%CI: 0.45-0.62).

**Conclusion:** The GNRI was more effective than the MNA-SF at predicting prolonged LOS, but the MNA-SF was a superior predictor of POD in older non-cardiac surgical patients.

**Keywords:** Geriatric Nutritional Risk Index, Mini-Nutritional Assessment Short Form, Older people, Postoperative delirium, Length of stay, Non-cardiac surgery
Background

The rapid aging of the general population is resulting in a greater number of older patients in need of surgery. Malnutrition is a common comorbidity in surgical patients. Advanced age, chronic disease, reliance upon a large number of drugs, low nutrient intake, reduced appetite, and psychological conditions are risk factors for the development of nutritional deficiencies (1, 2). The prevalence of malnutrition in geriatric hospitalized patients has been estimated to range from 30% to 60% depending on the population studied and the applied assessment tools (3, 4). Despite these high rates of malnutrition, this issue has not received sufficient clinical attention (5). The presence of malnutrition is associated with adverse clinical outcomes, including a higher rate of delirium, prolonged length of stay, morbidity, mortality and increase of healthcare costs (6-8). Furthermore, several studies have found that nutritional intervention can mitigate the risk of delirium and prolonged hospitalization (9, 10). Therefore, early nutritional screening in hospitalized patients is important for estimating the risk of nutrition-related complications, especially delirium and length of hospital stay.

There are currently multiple different screening tools available for assessing nutritional status in the older people. Of these tools, the Mini Nutritional Assessment-Short Form (MNA-SF) is recommended by the European Society for Clinical Nutrition and Metabolism (ESPSN), as it has been validated for the diagnosis of malnutrition and for prediction of clinical outcomes (11, 12). Recently, a novel screening tool, the Geriatric Nutritional Risk Index (GNRI), has been proposed (13). As this screening
method is dependent upon objective measurements that do not require patient cooperation, it can be applied in all clinical settings (14, 15). The validity of the GNRI for the prediction of short and long-term outcomes has been clearly demonstrated in previous studies (16, 17). To date, some studies have compared the ability of different nutritional screening tools to assess malnutrition status, hospital length of stay, mortality, and infection-associated complications in hospitalized patients (17-19). However, studies comparing the ability of the GNRI and MNA-SF in predicting postoperative delirium (POD) and length of hospital stay (LOS) are still poor.

Thus, the aim of our study was to validate the use of GNRI in older non-cardiac surgical patients by assessing its ability to predict POD and prolonged LOS as compared with the MNA-SF.

Methods

Study design and population

This prospective cohort study was conducted in the West China Hospital of Sichuan University from April to June of 2015. Eligible patients were age 70 and older, scheduled to undergo non-cardiac surgery, and who had an anticipated length of stay of at least 3 days. Study exclusion criteria for patients were as follows: (1) severe hearing impairment and unable to communicate, (2) a history of dementia or psychiatric illness, (3) end-stage patients (not expected to survive longer than 6 months), (4) the presence of delirium before admission for surgery.

The study was approved by the Institutional Review Boards of West China Hospital, Sichuan University, and was carried out according to the principles of the Declaration
of Helsinki. All the participants provided written informed consent.

**Data collection**

All patients were preoperatively assessed by trained research nurses within 48 hours of admission, and the following data were collected: age, gender, and type of surgery (orthopedic, general, thoracic). Comorbidities were evaluated on admission using the CCI (20). Preoperative pain was measured using the Facial Scale (range 0–10) via patient interview (21). The presence of depressive symptoms was assessed using the 15-item version of the validated Geriatric Depression Scale (GDS-15) (22).

**Nutritional assessment**

The GNRI and MNA-SF were used to assess preoperative nutritional status. The GNRI, which was adapted from the Nutritional Risk Index (NRI) designed by Buzby et al. (23), is a simple nutritional screening tool to evaluate nutritional-related complications. The index was calculated as follows (14): GNRI = 1.489 × serum albumin (g/L) + 41.7 × present weight/ideal weight (kg). Ideal body weight was derived according to the following equations of Lorentz (14): ideal weight for men = 0.75 × height (cm) − 62.5, ideal weight for women = 0.60 × height (cm) − 40. The participants were stratified into the following three categories: no risk (GNRI > 98), low risk (92-98), severe/moderate risk (GNRI < 92) (14). The MNA-SF is a validated, sensitive, reliable screening tool which consists of six domains: appetite or eating problems in the past 3 months, weight loss in the past 3 months, mobility impairment, acute illness/stress, dementia or depression, and BMI. Total scores of MNA-SF range from 0 to 14, and patients were divided into the following three categories according to the following cut-offs: well-
nourished (12-14), risk of malnutrition (8-11), malnourished (0-7) (24).

133 Outcomes

134 All patients were followed for the occurrence of POD and LOS. Beginning on the first postoperative day, the Confusion Assessment Method (CAM) was used by the trained research assessors to screen patients for delirium (25). The CAM is based on four criteria found in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (DSM-IV-TR): (i) acute onset and fluctuating course; (ii) inattention; (iii) disorganized thinking; (iv) altered level of consciousness (26). A positive diagnosis of delirium required the presence of both items (i) and (ii), and either item (iii) or (iv). LOS was defined as the number of days in the hospital from the day of admission to the day of discharge. Prolonged LOS was defined as LOS beyond the 75th percentile of its distribution (computed to ≥22 days in our study) (27).

144 Statistical analysis

145 All statistical analyses were performed using IBM SPSS Statistics software v21.0. Continuous variables were expressed as means with the standard deviation (SD) for normally distributed data, and as medians with the interquartile range (IQR) for non-normally distributed data. ANOVAs and Kruskall-Wallis tests were used for between-group comparisons of continuous variables with normal and non-normal distributions, respectively. Categorical variables were expressed as the number of cases and percentages, and were compared using Chi-squared tests.

A multivariable logistic regression model was performed to investigate the association between two screening methods and POD, and a linear regression model
was used for LOS. Model 1 was adjusted for age and sex. Model 2 was adjusted for age, sex, depression, and CCI. A $P$ value $< 0.05$ was considered statistically significant.

To fulfill the purpose of the study, we utilized a ROC curve to test the discriminatory performance of each nutritional screening tool for the outcomes, and the AUC was computed for each score.

**Results**

**Baseline characteristic of patients**

A total of 348 patients were admitted to our hospital. 28 and 32 patients were excluded due to cancelling scheduled surgery and incomplete data, respectively. Finally, 288 subjects were included in the analyses. The median age of these patients was 74 years (IQR=6), and 148 patients (51.4%) were male. Of the overall population, 49 (17%) developed POD, and median LOS was 14 days (IQR=11). In the study, 65.6%, 24.7% and 9.7% of these patients underwent general, orthopedic, and thoracic surgery, respectively.

**The characteristics of the population as determined by the MNA-SF and GNRI**

The characteristics of the patients screened by the MNA-SF and GNRI are shown in tables 1 and 2. According to the GNRI, 29.5% and 15.6% of patients were low risk and high risk, respectively. Based on the MNA-SF, 34% and 14.2% of patients were at risk of malnutrition and malnourished, respectively. There were significant differences in the BMI, serum albumin, POD incidence, and LOS among different GNRI and MNA-SF categories. Additionally, the depression and the Charlson Comorbidity Index (CCI) scores differed significantly among MNA-SF categories, whereas no differences were
detected among GNRI classes. By a post-hoc comparison, we observed that patients with high risk and low risk by the GNRI exhibited lower body mass index (BMI) and albumin levels than those with no risk. Similarly, BMI and albumin levels were also significantly lower in subjects who were malnourished and at risk of malnutrition compared to those who were well-nourished according to the MNA-SF.

**Table 1** Characteristics of the studied population according to the Geriatric Nutritional Risk Index (GNRI)

| Characteristic                  | High Risk <92 (n = 45) | Low Risk 92-98 (n = 85) | No Risk >98 (n = 158) | P-value<sup>a</sup> |
|--------------------------------|------------------------|--------------------------|-----------------------|---------------------|
| Age (years), median (IQR)      | 75 (7)                 | 75 (7)                   | 74 (6)                | 0.086               |
| Male gender, n (%)             | 24 (53.3)              | 36 (42.4)                | 88 (55.7)             | 0.134               |
| Preoperative pain, n (%)       | 26 (57.8)              | 56 (65.9)                | 87 (55.1)             | 0.261               |
| Depression, n (%)              | 4 (8.9)                | 5 (5.9)                  | 10 (6.3)              | 0.79                |
| BMI (kg/m²), mean ± SD         | 21.96±3.49<sup>b</sup> | 21.54±3.30<sup>b</sup>   | 23.40±2.72<sup>b</sup> | <0.001              |
| Albumin (g/L), mean ± SD       | 32.87±4.14<sup>b</sup> | 38.06±2.31<sup>b</sup>   | 43.29±2.86<sup>b</sup> | <0.001              |
| CCI, n (%)                     |                        |                          |                       |                     |
| Mild (≤2)                      | 34 (75.6)              | 58 (68.2)                | 122 (77.2)            |                     |
| Moderate (3-4)                 | 7 (15.6)               | 21 (24.7)                | 24 (15.2)             | 0.546               |
| Severe (≥5)                    | 4 (8.9)                | 6 (7.1)                  | 12 (7.6)              |                     |
| GNRI score, mean ± SD          | 85.09±5.45<sup>b</sup> | 95.12±2.17<sup>b</sup>   | 105.01±4.49<sup>b</sup> | <0.001              |
| MNA-SF score, med (IQR)        | 9 (5)                  | 10 (4)                   | 12 (3)                | <0.001              |
| Postoperative delirium, n (%)  | 14 (31.1)              | 11 (12.9)                | 24 (15.2)             | 0.021               |
| Length of stay (days), med (IQR)| 17 (10)               | 17 (11)                  | 13 (9)                | <0.001              |

BMI body mass index, CCI Charlson Comorbidity Index, MNA-SF Mini Nutritional Assessment-Short Form.
Notes: *<sup>a</sup>p values according to ANOVA, Kruskall-Wallis or Chi-square tests;
<sup>b</sup>Significantly different from the other groups by post-hoc comparison.

**Table 2** Characteristics of the studied population according to the Mini-Nutritional Assessment Short Form (MNA-SF)

| Characteristic                  | Malnourished ≤7 (n = 41) | At risk 8-11 (n = 98) | Well nourished 12-14 (n = 149) | P-value<sup>a</sup> |
|--------------------------------|--------------------------|-----------------------|-------------------------------|---------------------|
| Age (years), median (IQR)      | 76 (6)                   | 75.5 (6)              | 73 (7)                        | 0.078               |
| Male gender, n (%)             | 22 (53.7)                | 49 (50.0)             | 77 (51.7)                     | 0.921               |
| Preoperative pain, n (%)       | 30 (24.1)                | 59 (60.2)             | 80 (53.7)                     | 0.075               |
| Depression, n (%)              | 7 (17.1)                 | 6 (6.1)               | 6 (4.0)                       | 0.011               |
| BMI (kg/m²), mean ± SD         | 19.45±2.55<sup>b</sup>  | 21.42±3.07<sup>b</sup> | 23.70±2.88<sup>b</sup>        | <0.001              |
| Albumin (g/L), mean ± SD       | 36.93±5.13<sup>b</sup>  | 39.79±4.73<sup>b</sup> | 41.21±4.48<sup>b</sup>        | <0.001              |
CCI, n (%)

| Category      | n   | (%  ) |
|---------------|-----|-------|
| Mild (≤2)     | 25  | (61.0)|
| Moderate (3-4)| 9   | (22.0)|
| Severe (≥5)  | 7   | (17.1)|
| MNA-SF score, med (IQR) | 6 (2) b | 10 (2) b | 13 (2) b | < 0.001 |
| Postoperative delirium, n (%) | 16 (39.0) | 20 (20.4) | 13 (8.7) | < 0.001 |
| Length of stay (days), med (IQR) | 19 (11) | 14 (9) | 14 (10) | 0.022 |

BMI body mass index, CCI Charlson Comorbidity Index, GNRI Geriatric Nutritional Risk Index.

Notes: *p values according to ANOVA, Kruskall-Wallis or Chi-square tests;

b Significantly different from the other groups by post-hoc comparison.

### Multivariate logistic regression and linear regression analysis

In the multivariable model, malnourished and at risk of the MNA-SF were independent risk factors for POD after adjustment for age and sex, while only high risk of the GNRI was significantly associated with POD (Table 3, model 1). Further adjustment of this model for depression and CCI did not change the association (Table 3, model 2). By using linear regression, prolonged LOS was significantly associated with low and high risk of the GNRI, but only with malnourished group by the MNA-SF (Table 4, model 1). Adjusting for depression and CCI made minor differences to the finding but the MNA-SF and GNRI still remained their predictive ability (Table 4, model 2).

| GNRI categories        | Model 1 Adjusted OR (95% CI) | P-value | Model 2 Adjusted OR (95% CI) | P-value |
|------------------------|------------------------------|---------|------------------------------|---------|
| No risk (> 98)         | Reference                    |         | Reference                    |         |
| Mild risk (92-98)      | 0.78 (0.36-1.70)             | 0.532   | 0.69 (0.30-1.60)             | 0.389   |
| High risk (< 92)       | 2.32 (1.07-5.06)             | 0.033   | 2.56 (1.09-6.01)             | 0.032   |
| MNA-SF categories      |                              |         |                              |         |
| Well nourished (12-14) | Reference                    |         | Reference                    |         |
| At risk (8-11)         | 2.59 (1.22-5.52)             | 0.014   | 2.07 (0.93-4.61)             | 0.074   |
| Malnourished (≤7)      | 6.56 (2.80-15.39)            | < 0.001 | 4.48 (1.81-11.10)            | 0.001   |

**Table 3** Multivariate logistic regression analyses for the occurrence of postoperative delirium

OR odds ratio, CI confidence interval, GNRI Geriatric Nutritional Risk Index, MNA-SF Mini-Nutritional Assessment Short Form.

Model 1: adjusted for age, gender;
Model 2: adjusted for age, gender, depression and Charlson Comorbidity Index.

**Table 4** Linear regression analyses for increased length of stay. Model 1: adjusted for age, gender

| GNRI categories | Model 1 | Model 2 |
|-----------------|---------|---------|
|                 | β (95% CI) | P-value | β (95% CI) | P-value |
| No risk (> 98)  | Reference |         | Reference |         |
| Mild risk (92-98) | 4.93 (2.47-7.38) | < 0.001 | 4.66 (2.20-7.13) | < 0.001 |
| High risk (< 92) | 3.91 (0.84-6.99) | 0.013 | 3.85 (0.78-6.92) | 0.014 |
| MNA-SF categories | | | | |
| Well nourished (12-14) | Reference |         | Reference |         |
| At risk (8-11) | 0.89 (-1.51 to 3.30) | 0.466 | 0.53 (-1.90 to 2.97) | 0.666 |
| Malnourished (≤7) | 4.32 (1.06-7.58) | 0.01 | 3.97 (0.61-7.33) | 0.021 |

ROCs curve analysis

To further compare the value of the GNRI and MNA-SF in predicting POD and prolonged LOS, receive operating characteristic (ROC) curve was carried out. Although the GNRI and MNA-SF scores were statically significant scores by ROC curve in the evaluation of POD, the area under the curve (AUC) of MNA-SF scores was better than GNRI scores (Table 5, Fig. 1). We also found that the GNRI score was a better predictor of prolonged LOS according to the ROC analysis (Table 5, Fig. 2).

**Table 5** Area under the curve (AUC) of nutritional screening tools

|                  | AUC (95% CI) | P (AUC) |
|------------------|-------------|---------|
| Postoperative delirium | | |
| GNRI             | 0.606 (0.52-0.69) | 0.019 |
| MNA-SF           | 0.718 (0.64-0.80) | < 0.001 |
| Prolonged length of stay | | |
| GNRI             | 0.611 (0.54-0.69) | 0.006 |
| MNA-SF           | 0.533 (0.45-0.62) | 0.421 |

CI confidence interval, GNRI Geriatric Nutritional Risk Index, MNA-SF Mini-Nutritional Assessment Short Form.

**Discussion**
Early and accurate identification of patients at risk of malnutrition-associated complications could effectively guide surgical practices. Although there are number of malnutrition assessment tools available designed to determine the risk of postoperative adverse outcomes, there are at present few studies evaluating the validity of the MNA-SF and the GNRI as predictors of nutrition-related morbidity in a surgical setting. To the best of our knowledge, this is the first prospective study to compare the ability of the GNRI and MNA-SF to predict POD and LOS in older patients undergoing non-cardiac surgery. Our results revealed that both of these tools were effective predictors of POD and LOS in older surgical patients. Specifically, we found that the GNRI seemed to be better at predicting prolonged LOS, whereas the MNA-SF was superior to the GNRI in the evaluation of the risk of POD among older non-cardiac surgical patients.

In this study, the prevalence of malnutrition varied depending on the screening methods used. The prevalence of both high and low risk of malnutrition by the GNRI was 45.1% (n=130), which was consistent with the prevalence found in the study by Cereda et al. (16). We further found that nearly half of study participants (139/288, 48.2%) were either malnourished or at risk of malnutrition according to the MNA-SF. Cohendy et al. used the MNA-SF in surgical patients aged ≥ 60 and investigated the prevalence of nutritional impairment (malnutrition and risk of malnutrition) was 35.3% (24), a figure markedly lower than that observed in our study. This difference may be attributable to the fact that the patients in our study were relatively older. Indeed, increased malnutrition prevalence has been shown to be associated with the aging
process (28).

Our data demonstrated that the relationships between nutritional status, as evaluated by the GNRI and MNA-SF, and both BMI and serum albumin were statistically significant. This may be because the GNRI measures albumin and body weight, and the MNA-SF contains nutritional parameters including BMI and weight loss. Similar to our results, Cereda et al. and Abd-El-Gawad et al. have found a significant association between both GNRI and MNA-SF scores and BMI (17, 19). Our results are consistent with previous studies indicating that lower albumin levels were independently correlated with lower GNRI and MNA-SF scores (17, 29). BMI and serum albumin are generally considered to be nutrition-related parameters. Nevertheless, these two markers are neither sensitive nor specific (30, 31). This may be partly due to the fact that BMI can be influenced by retention of fluids and electrolytes, causing true body weight to be overestimated (32). Furthermore, albumin as a marker of nutritional status remains uncertain given that it can be influenced by dehydration or inflammatory/infectious (33). Thus, the GNRI and MNA-SF tools are more reliable means of screening for malnutrition than are BMI or serum albumin alone.

In this study, we found that although both the GNRI and MNA-SF were effective predictors of POD risk, the latter was better at estimating POD among elderly non-cardiac surgical patients. To date, only one study by Sugita, et al. compared different screening tools, including the GNRI, PNI and CONUT, for prediction of delirium in coronary intensive care unit patients. Unlike our study, they failed to find a significant association between GNRI and delirium (34). The difference may be related to the fact
that the incidence of delirium (17%) detected in our study is relatively higher than that observed in previous study (9%). In our study, the superiority of the MNA-SF as a predictor of POD may be explained by the fact that it incorporates neuropsychological, functional and psychological parameters, all of which are delirium-related factors. Recently, Chu et al. and Mazzola et al. used the MNA-SF as a screening tool among orthopedic surgical patients and detected a significant association between MNA-SF and POD (35, 36). In addition, previous studies have found that the nutritional intervention could reduce the incidence of postoperative delirium and shorten its duration in older surgical patients (10, 37, 38). Our results were consistent with these, and confirmed the value of the MNA-SF as a predictor of POD.

Our results revealed that GNRI was more reliable than MNA-SF for detecting prolonged LOS in older patients undergoing non-cardiac surgery. This might be explained by the fact that the GNRI is described as a nutrition-related risk index rather than an index of malnutrition (13). In agreement with our findings, Abd-EL-Gawad et al. found that the GNRI was more effective in the evaluation of prolonged hospitalization than was the MNA (19). In addition, Cereda et al. and Gartner et al. detected a significant relationship between nutritional status as screened by the GNRI, although not comparable to the MNA-SF, and length of hospital stay (39, 40). Furthermore, there is accumulating evidence that early nutritional screening in older patients who might benefit from nutritional treatment may result in a shorter LOS (6, 8, 9). These studies supported that the GNRI is useful for predicting LOS. Very few studies to date have evaluated the predictive performance of the GNRI in surgical patients and
as such our findings expand the existing knowledge. More studies using the GNRI in these patients are necessary to confirm our findings.

Indeed, the MNA-SF and GNRI are relatively simple screening tools that can be rapidly applied to clinical practice. Advantages of the MNA-SF are its high sensitivity in regard to nutritional assessment and the lack of requirement for biochemical tests. However, it cannot be used in patients receiving parenteral nutrition or who have poor cognitive function (3). Moreover, previous studies have suggested that the MNA-SF tends to overdiagnose elderly as being at risk, as the consequences of a positive screening result remain unclear (41). The GNRI was designed to overcome the subjective bias of the MNA and the difficulties in acquiring usual weight and standing height (13, 15). It may be useful in surgical patients with cognitive impairment because it is an objective index based only on weight, height, and serum albumin levels (13). Further studies comparing the GNRI and the MNA-SF as predictors of adverse outcomes are required to validate their utility.

This study has several strengths. First of all, it was a prospective study design. Moreover, the results may be representative of the general older surgical patients because we included multiple types of surgery in this study. Despite these strengths, there are still some limitations in our study. First, this was a single-center study with a small sample size. Larger studies are required to further investigate the association between malnutrition and poor prognosis among older surgical patients. Second, patients were screened for delirium from the first day to the seventh day after surgery, but there was no screening of delirium from the eighth day after surgery to the day of
discharge, leading to some cases of delirium have been missed. Finally, intraoperative data, which may affect prognosis, were not included in our study.

**Conclusion**

In conclusion, malnutrition as measured by both the GNRI and the MNA-SF can predict negative outcomes in older non-cardiac surgical patients. The GNRI is more reliable as a means of evaluating patients for prolonged LOS, whereas the MNA-SF is more effective at predicting the development of POD risk. However, it is important to note that these tests are not as sensitive and specific as expected. In the future, studies comparing nutritional screening tools with respect to their ability to assess risks of adverse outcomes among surgical patients are needed.

**Abbreviations**

GNRI, Geriatric Nutritional Risk Index; MNA-SF, Mini Nutritional Assessment Short Form; POD, postoperative delirium; LOS, length of stay; CCI, Charlson Comorbidity Index; CAM, Confusion Assessment Method.

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**Author Contributions**

JR Yue and YL Zhao conceptualized and designed the study; YL Liao and YY Wang coordinated data collection; YL Zhao, DM Xie, LL Gao and NG. analyzed data, prepared and reviewed figures. YL Zhao and JR Yue wrote the original draft; All authors
reviewed the manuscript.

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Availability of data and materials

The datasets used for the current study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

Ethics approval was obtained from the Institutional Review Boards of West China Hospital, Sichuan University. All the participants provided written informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figure Titles

**Figure 1.** Receiver operator curve (ROC) of the GNRI and MNA-SF scores for postoperative delirium

**Figure 2.** Receiver operator curve (ROC) of the GNRI and MNA-SF scores for prolonged length of stay