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RESEARCH ARTICLE

Geriatric Nutritional Risk Index as a Predictor of Delirium and Pressure Injuries in Critically Ill Older Patients With Ischaemic Stroke: An Observational Cohort Study

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ABSTRACT

Background: Malnutrition is a prevalent phenomenon among patients with ischaemic stroke, and it is associated with a multitude of adverse health outcomes.

Aim: To evaluate the Geriatric Nutritional Risk Index (GNRI) as a predictor of both delirium and pressure injuries in critically ill older adults with ischaemic stroke.

Study Design: An observational cohort study of 969 patients with ischaemic stroke conducted at a tertiary academic medical centre in the United States, divided into two groups based on GNRI scores: at risk of malnutrition (GNRI ≤ 98) and not at risk (GNRI > 98). Delirium was assessed via the Confusion Assessment Method for the Intensive Care Unit and nursing notes; pressure injuries were identified through direct clinical observation using the International Pressure Injury Staging System. Multivariable logistic regression, propensity score matching, and inverse probability of treatment weighting were used for analysis.

Results: Patients at risk for malnutrition had a significantly higher prevalence of delirium and pressure injuries compared with those not at risk (66.4% vs. 46.4% for delirium and 30.3% vs. 9.7% for pressure injuries, both $p < 0.001$). Multivariable analysis showed that lower GNRI scores were significantly associated with increased risks of both delirium (OR: 1.75, 95% CI: 1.28–2.40, $p < 0.001$) and pressure injuries (OR: 2.70, 95% CI: 1.79–4.09, $p < 0.001$). The results remained consistent even after propensity score matching and inverse probability of treatment weighting analyses.

Conclusions: The study shows that the GNRI is an effective predictor of the risk of pressure injury and delirium in older adults with ischaemic stroke.

Relevance to Clinical Practice: The assessment and management of nutritional status using GNRI in clinical practice has the potential to facilitate the early detection of high-risk patients and the implementation of targeted nutritional interventions.

Dong Wang and Ankang Liu these authors contributed equally.

Summary

- What is known about this topic
  - Malnutrition is common in patients with ischaemic stroke and is associated with poorer health outcomes, including increased rates of morbidity and mortality.
  - The Geriatric Nutritional Risk Index (GNRI) is an established tool for assessing the nutritional status of older adults and has proven predictive value for various adverse clinical outcomes.
- What this paper adds
  - This study establishes a significant association between GNRI-assessed malnutrition and an increased risk of delirium in critically ill older adults with ischaemic stroke, underscoring the need for early nutritional assessment.
  - The study supports integrating GNRI into routine clinical practice to identify at-risk patients early, facilitating timely nutritional interventions that can reduce complications and improve overall patient outcomes in critical care settings.

1 | Introduction

Stroke is a leading cause of death and disability worldwide, significantly impacting physical and psychological health. According to the World Health Organization, approximately 15 million individuals suffer from strokes annually. Clinically, strokes can result in permanent disabilities, creating substantial burdens on families and society. By 2020, the global disability-adjusted life years (DALYs) attributable to stroke were approximately 61 million [1, 2]. Two main types of stroke are distinguished: ischaemic stroke and haemorrhagic stroke. Ischaemic stroke, which accounts for 80%–90% of all stroke cases, occurs because of thrombotic or embolic events that interrupt blood flow to the brain [3]. This type of stroke can lead to a range of complications, including aphasia, stroke-associated pneumonia, post-stroke depression and post-stroke delirium [4–6]. These complications not only threaten patients' lives and health but also significantly increase the economic burden associated with stroke care globally [7]. Post-stroke delirium is a prevalent and significant complication, affecting up to 25% of patients with stroke, with an even higher prevalence observed among older patients [8]. It is associated with numerous adverse outcomes, including prolonged hospital stays, increased medical costs, higher mortality rates and long-term cognitive and functional impairments. Moreover, post-stroke delirium is a key predictor of poor recovery outcomes [9]. Given the significant impact of post-stroke delirium, early detection and prevention are critical for improving patient prognosis. The development and implementation of novel clinical assessment tools can streamline the evaluation process, facilitating the early identification and effective management of patients at high risk for delirium. This proactive approach is essential for enhancing the overall recovery and quality of life for stroke patients.

Malnutrition is widely recognized for its detrimental impact on the prognosis of cardiovascular diseases [10–13] and vascular dementia [14]. Patients with ischaemic stroke are particularly vulnerable to malnutrition because of factors such as dysphagia, motor impairments and cognitive dysfunction [15]. Malnutrition can exacerbate disease symptoms, impede the recovery process, increase the risk of complications and reduce survival rates [16]. Therefore, early detection of malnutrition and the implementation of proactive interventions are essential in the comprehensive treatment of patients with ischaemic stroke. These measures are of paramount importance for improving recovery outcomes and enhancing survival rates. By promptly addressing nutritional deficiencies, health care providers can mitigate the adverse effects of malnutrition, thereby supporting better clinical outcomes for persons with stroke.

The Geriatric Nutritional Risk Index (GNRI) is a novel, easily accessible and effective nutritional assessment tool that has been widely used to evaluate nutritional risk [17]. Moreover, the GNRI has been demonstrated to forecast a multitude of complications associated with malnutrition, including postoperative survival rates in oesophageal cancer [18], postoperative complications in gastric cancer [19], postoperative bleeding in pancreatic surgery [20], mortality in heart failure [21], prognosis in coronavirus disease [22, 23], and cognitive impairment after stroke [24]. The growing body of research indicates that GNRI has the potential to be a valuable tool for evaluating complex conditions in intensive care settings, extending beyond its original scope. This has prompted our interest in exploring the potential link between GNRI and delirium. However, studies investigating the relationship between GNRI and delirium in patients with ischaemic stroke are relatively scarce, necessitating further exploration. The determination of whether GNRI can serve as an effective predictor of delirium in patients with ischaemic stroke could assist in the identification of those at high risk for delirium, thereby facilitating closer monitoring and potential early intervention measures.

2 | Background

The global health burden of ischaemic stroke continues to escalate, underscoring the urgent need for effective strategies to manage its consequences. Among the myriad complications associated with ischaemic stroke, delirium is a critical challenge that significantly impacts patient outcomes and health care costs. Despite advances in stroke management, the prediction and prevention of post-stroke delirium remain elusive. Malnutrition, a common condition in patients with stroke, has been implicated in exacerbating disease severity and impeding recovery, thereby increasing the risk of delirium and other adverse outcomes.

Given the importance of early intervention, there is an urgent need for reliable tools to identify patients at risk for delirium. GNRI, a validated nutritional assessment tool, has demonstrated its utility in predicting several clinical outcomes in diverse patient populations, including those with cardiovascular disease and postoperative complications. However, the application of GNRI in the context of ischaemic stroke and its potential role in the prediction of delirium remain underexplored.

This background underscores the rationale for the current work, which aims to explore the relationship between GNRI

and delirium in patients with ischaemic stroke. By elucidating this relationship, we hope to contribute to the development of evidence-based strategies for the early identification and management of delirium in this high-risk population, ultimately improving patient outcomes and reducing the associated health care burden.

3 | Aims and Objectives of Study

This study aims to investigate the relationship between the GNRI and the risk of delirium in patients with ischaemic stroke. A deeper understanding of this association will help to identify high-risk groups for delirium in patients with stroke, thereby facilitating more personalized attention and care, and potentially enabling the implementation of early intervention measures. The hypothesis of this study was that lower GNRI might be associated with an increased risk of delirium or other adverse outcomes, including pressure injury.

4 | Design and Methods

4.1 | Setting and Sample

This study is an observational cohort study based on the Medical Information Mart for Intensive Care IV (MIMIC-IV), which was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [25]. MIMIC-IV is a large, open-access medical dataset providing anonymized data from tens of thousands of intensive care unit (ICU) patients collected between 2008 and 2019 [26]. The dataset encompasses a comprehensive range of information, including clinical details, physiological parameters, laboratory results, medication treatments and disease diagnoses. The data was collected by the Beth Israel Deaconess Medical Center in Boston and processed with rigorous privacy measures to ensure patient confidentiality. One of the authors of this study completed the requisite training and obtained certification to access the database. The inclusion criteria for this study are as follows: (1) patients aged 65 or older who have been diagnosed with ischaemic stroke; (2) patients who have been admitted to the ICU for the first time; and (3) patients with complete GNRI records. The diagnosis of ischaemic stroke was based on the International Classification of Diseases; Ninth Edition (ICD-9) codes 433, 434, 436, 437.0 and 437.1; or Tenth Edition (ICD-10) codes I63, I65 and I66 [27]. Patients were excluded if their ICU stay was less than 1 day, if they lacked delirium assessment, or if delirium occurred before ICU admission. Additionally, patients with abnormal or extreme values for the main study variables (height, weight, albumin and GNRI) were excluded. The interquartile range (IQR) method was used to detect and handle outliers [28]. After screening, 969 participants were included in the study. The screening process is depicted in Figure 1.

4.2 | Data Collection Tools and Methods

The Navicat Premium software (version 16.0.11) was employed to extract data utilizing structured query language. All data and information were preprocessed by health care professionals to ensure data quality and integrity before analysis [26]. The following information was extracted: (1) Demographics: sex, age, race, height, weight, BMI, total hospital stay, ICU stay and

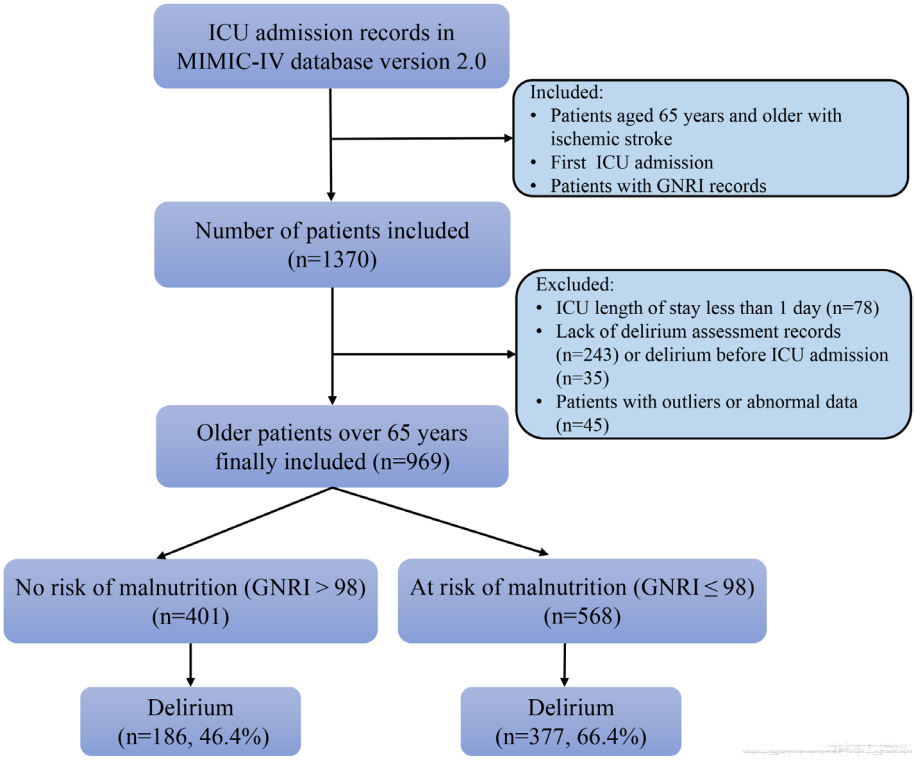

FIGURE 1 | Inclusion and exclusion flowchart of the study. GNRI, Geriatric Nutritional Risk Index; ICU, Intensive Care Unit; MIMIC-IV, Medical Information Mart for Intensive Care IV.

in-hospital mortality; (2) Comorbidities: hypertension, myocardial infarction, congestive heart failure, peripheral vascular disease, diabetes, chronic lung disease, liver disease, kidney disease, dementia, paraplegia and malignancy; (3) Laboratory parameters: white blood cells, red blood cells, platelets, serum albumin, haemoglobin, sodium, potassium, calcium and magnesium; (4) Vital signs: temperature, heart rate, respiratory rate and mean blood pressure; (5) Disease severity scores: Glasgow Coma Scale (GCS), Sequential Organ Failure Assessment (SOFA) score, Charlson Comorbidity Index, Braden score and Simplified Acute Physiology Score II (SAPS II); (6) Therapeutic interventions: sedatives, vasopressors, renal replacement therapy, mechanical ventilation, enteral nutrition and indwelling urinary catheter; (7) Outcomes: delirium and pressure injuries. For variables measured multiple times, we extracted the first measurement taken upon ICU admission. All extracted variables had less than 20% missing data, and multiple imputation was employed to address missing values. Survival time was calculated by subtracting the ICU admission time from the time of death. Each patient in the MIMIC-IV database was followed for at least 1 year.

4.3 | Exposure (GNRI)

The GNRI score, which is used to assess malnutrition, was calculated using the following formula: 1.489 × serum albumin (g/L) + 41.7 × actual weight (kg)/ideal weight [29]. The ideal weight was calculated using the Lorenz formula: for males, height (cm) − 100 − ([height (cm) − 150]/4); for females, height (cm) − 100 − ([height (cm) − 150]/2.5). In instances where the actual weight exceeded the ideal weight, the ratio of actual weight to ideal weight was considered to be 1. The older adults with ischaemic stroke in this study were divided into two groups: those with a GNRI score greater than 98 were considered not to be at risk of malnutrition, whereas those with a GNRI score of 98 or lower were considered to be at risk of malnutrition [30, 31].

4.4 | Outcomes and Definitions

The primary outcome of this study was the risk of delirium in patients. The Confusion Assessment Method for the Intensive Care Unit (CAM-ICU), which has been demonstrated to have high sensitivity (84%) and specificity (95%), was employed to assess the occurrence of delirium [32]. The CAM-ICU evaluation includes four aspects: (1) Acute onset or fluctuating course of mental status; (2) Inattention; (3) Altered level of consciousness; and (4) Disorganized thinking. A positive diagnosis of delirium is made when a patient has feature 1 and 2 and either feature 3 or feature 4. Detailed steps and procedures for assessing CAM-ICU can be found in Figure S1. The CAM-ICU is well-suited for the setting of critical care as it offers a rapid assessment that can be performed by non-specialists, including for non-verbal patients, yielding a dichotomous (present/absent) result for delirium [27, 33]. The tool has been validated in stroke populations, demonstrating high efficacy with a sensitivity of 76% (95% CI: 55% to 91%), a specificity of 98% (95% CI: 93% to 100%) and an overall accuracy of 94% (95% CI: 88% to 97%) [34]. Furthermore, the study identified delirium patients by reviewing nursing notes, using keywords such as delirium, confusion, agitation and altered mental status [35]. A combined approach that combines CAM-based and chart-based methods effectively identifies the greatest number and range of delirium cases [36].

The secondary outcome was the prevalence of pressure injuries. Critical care nurses assessed patients' skin conditions according to the international pressure injury classification system, which categorizes injuries into stages I through IV, unstageable and suspected deep tissue injury [37].

4.5 | Data Analysis

Statistical descriptions and comparisons were made between groups, with participants divided into two groups based on their nutritional risk: those at risk of malnutrition (GNRI ≤ 98) and those not at risk (GNRI > 98). The Shapiro–Wilk test was used to assess the normality of continuous variables, indicating that most variables did not follow a normal distribution. Non-normally distributed continuous variables were presented as medians and interquartile ranges (IQRs) and compared between groups using the Wilcoxon rank-sum test. Categorical variables were presented as frequencies and percentages, and group differences were compared using the chi-squared test.

To examine the association between GNRI and outcomes, logistic regression analysis was used to calculate odds ratios (OR) and 95% confidence intervals (CI). Our analysis included multivariable adjustments at four levels to ensure the accuracy and robustness of the results. Model 1 adjusted for age, sex and race to account for basic demographic characteristics. Model 2 further adjusted for clinical characteristics, including GCS, SAPS II, SOFA and Braden scores. Model 3 added adjustments for CCI, congestive heart failure, dementia, renal disease, atrial fibrillation, sepsis, malnutrition, liver disease, heart rate and mean blood pressure to control for additional potential confounders. Finally, Model 4 included adjustments for treatment-related factors such as alteplase, invasive mechanical ventilation, sedatives and vasopressors. Notably, albumin and BMI were excluded from these models to avoid multicollinearity. The variance inflation factor (VIF) was used to assess multicollinearity, and all variables had VIFs less than 4, indicating no significant multicollinearity. These multivariable adjustments ensured the reliability and accuracy of the results.

We then evaluated the survival of patients in different nutritional status groups at 30, 90 and 360 days using Kaplan–Meier (KM) survival curves and analysed the differences in survival distributions between the two groups using the log-rank test. Additionally, a subgroup analysis was conducted to further explore the association between GNRI and the primary outcome, delirium, within specific subpopulations. This analysis included subgroups based on age, sex, race, congestive heart failure, atrial fibrillation, diabetes and hypertension.

Statistical analyses were performed using R software (version 4.3.0, https://www.r-project.org/) with a *p*-value of less than 0.05 considered statistically significant in this study.

To ensure the reliability of our findings, we conducted a series of sensitivity analyses. The propensity score matching

(PSM) method was employed in order to reduce estimation bias and balance confounding variables. A logistic regression model was constructed to estimate propensity scores, which included covariates such as age, sex, race, the SOFA score, the SAPS II score, the GCS score, the Braden score, the CCI, invasive mechanical ventilation and sepsis. The optimal matching method, in the form of a 1:1 matching algorithm, was employed in the PSM. Furthermore, an inverse probability of treatment weighting (IPTW) logistic regression model was employed to estimate the association between the exposure factor and outcome measure. The IPTW method adjusts for potential confounding factors in observational studies by utilizing the same covariates as the PSM method. After performing PSM and IPTW, standardized mean differences (SMD) were calculated to assess the balance of baseline characteristics between the matched groups, with an SMD <0.1 indicating good balance. Subsequently, building on model 4, we further incorporated adjustments for electrolyte levels (sodium, potassium, calcium and magnesium), enteral nutrition and the presence of urinary catheters to test the robustness of the association between GNRI and outcomes.

Given that patients with a history of stroke may be more susceptible to malnutrition and delirium, the sensitivity analysis was limited to patients experiencing their first stroke. By focusing on first-time stroke cases, the potential confounding effects of previous strokes on the relationship between malnutrition and delirium were minimized. In addition, the influence of systemic inflammation and sepsis on albumin values was considered, with the sepsis population analysed separately. Finally, in recognition of the fact that in-hospital death often indicates severe illness, the study population was restricted to in-hospital survivors for further analysis. This approach was designed to eliminate the influence of severe disease states on the study outcomes.

5 | Ethical and Research Approvals

This study, which involved only the analysis of de-identified data, had no direct impact on clinical care and complied with all privacy regulations by anonymizing all protected health information. The study was reviewed and approved by the Ethics Committee of Nan'ao People's Hospital, Dapeng New District, Shenzhen on March 25, 2025. As noted in the review, the data used in this study were obtained from the MIMIC database, which is a public database and does not require additional ethical review. The study adhered to the relevant provisions of the Declaration of Helsinki, ensuring that ethical standards were maintained throughout the research process.

6 | Results

6.1 | Baseline Characteristics of Patients

This study included 969 older critically ill adults diagnosed with ischaemic stroke, of whom 568 (58.6%) were at risk of malnutrition. The baseline characteristics of the patients are shown in Table 1, divided into two groups based on GNRI scores with a cutoff of 98, and the differences between the groups were compared using statistical tests. The median age of the cohort was 77.17 years (IQR: 71.73, 83.02 years), with 448 (46.2%) being female and 637 (65.7%) being white. Compared with patients not at risk of malnutrition, those at risk had longer total hospital stays, longer ICU stays, more severe disease severity scores, and were more likely to have multiple comorbidities or underlying conditions. At-risk patients were also more likely to receive enteral nutrition (44.0% vs. 24.7%, $\chi^2=38.10$, $p<0.001$). In terms of outcomes, at-risk patients had higher incidences of delirium (66.4% vs. 46.4%, $\chi^2=38.58$, $p<0.001$) and pressure injuries (30.3% vs. 9.7%, $\chi^2=58.31$, $p<0.001$).

6.2 | GNRI and Outcomes

The association between GNRI scores (as a continuous variable) and primary and secondary outcomes in older adults with ischaemic stroke is presented in Table S1. After adjusting for confounding factors in models 1, 2, 3 and 4, multivariable logistic regression results indicated a significant negative correlation between GNRI scores and the risks of delirium and pressure injuries (all $p<0.05$). This indicates that lower GNRI scores are associated with an increased risk of delirium and pressure injuries in older adults with ischaemic stroke.

Patients were divided into two groups based on their GNRI scores (at risk of malnutrition and not at risk of malnutrition) in order to further investigate these associations. In the final model (Model 4), the results demonstrated that patients at risk of malnutrition exhibited a significantly higher incidence of delirium compared with those not at risk (OR: 1.75, 95% CI: 1.28–2.40, $p<0.001$). Furthermore, the study indicated that malnutrition may be associated with an increased risk of pressure injuries (OR: 2.70, 95% CI: 1.79–4.09, $p<0.001$) (Table 2).

6.3 | Delirium and Death

KM survival curves (Figure S2) showed significant differences in survival probabilities between older critically ill adults with ischaemic stroke with and without delirium (log-rank test: $p<0.001$). Specifically, at 30 days (Figure S2a), 90 days (Figure S2b) and 360 days (Figure S2c), patients with delirium had significantly lower survival probabilities than those without delirium. In comparison with patients without delirium, delirium may be a significant risk factor for older adults with ischaemic stroke during critical illness. This indicates that prompt identification and management of delirium in clinical settings may lead to improved patient outcomes.

6.4 | Subgroup Analysis

In this study, subgroup analysis was performed to further explore the association between malnutrition and delirium in patients with ischaemic stroke within specific populations (Figure 2). Significant statistical associations were found in subgroups defined by age, sex, race, congestive heart failure, atrial fibrillation, diabetes and hypertension (all $p<0.05$). Malnutrition, as assessed by the GNRI, appears to be an important risk factor for delirium in patients with ischaemic stroke, with consistent results across subgroups.

TABLE 1 | Baseline clinical characteristics of older patients with ischaemic stroke.

Variables	Overall ($n=969$)	No risk of malnutrition (GNRI > 98) ($n=401$)	At risk of malnutrition (GNRI ≤ 98) ($n=568$)	Statistic	p
Personal characteristics					
Age (years old)	77.17 (71.73, 83.02)	76.80 (71.65, 82.56)	77.51 (71.89, 83.28)	$Z=-0.72$	0.471
Sex (%)				$\chi^2=2.22$	0.136
Male	521 (53.8)	227 (56.6)	294 (51.8)		
Female	448 (46.2)	174 (43.4)	274 (48.2)		
Race (%)				$\chi^2=0.05$	0.825
White	637 (65.7)	262 (65.3)	375 (66.0)		
Other	332 (34.3)	139 (34.7)	193 (34.0)		
Hospital death (%)				$\chi^2=27.09$	< 0.001
Yes	170 (17.5)	40 (10.0)	130 (22.9)		
No	799 (82.5)	361 (90.0)	438 (77.1)		
Hospital LOS (days)	9.97 (6.13, 16.82)	7.87 (5.27, 12.05)	12.54 (7.03, 19.87)	$Z=-7.91$	< 0.001
ICU LOS (days)	4.14 (2.19, 7.91)	3.19 (1.96, 5.72)	5.05 (2.50, 9.72)	$Z=-6.44$	< 0.001
Weight (kg)	76.70 (65.75, 88.60)	79.55 (68.90, 90.35)	74.95 (64.11, 87.50)	$Z=-3.52$	< 0.001
Height (cm)	168.00 (160.00, 175.00)	168.00 (160.00, 175.00)	168.00 (160.00, 175.00)	$Z=-1.11$	0.267
BMI (kg/m^2)	27.20 (24.00, 30.80)	27.90 (24.90, 31.20)	26.80 (23.20, 30.63)	$Z=-3.48$	0.001
Scores					
GNRI	95.30 (87.86, 101.26)	102.75 (99.77, 105.73)	89.35 (83.39, 93.82)	$Z=-26.56$	< 0.001
SAPSII	39 (32, 47)	36 (30, 43)	41 (34, 50)	$Z=-6.86$	< 0.001
GCS	12 (7, 14)	13 (8, 14)	11 (7, 14)	$Z=-5.42$	< 0.001
SOFA	6 (4, 8)	5 (3, 7)	6 (4, 9)	$Z=-6.04$	< 0.001
Braden score	14 (12, 16)	14 (13, 16)	14 (12, 15)	$Z=-3.01$	0.003
Charlson comorbidity index	8 (6, 9)	7 (6, 9)	8 (7, 10)	$Z=-4.97$	< 0.001
Laboratory parameters or vital signs					
WBC ($\times 10^9$/L)	10.50 (7.60, 14.30)	10.30 (7.60, 13.50)	10.70 (7.77, 15.10)	$Z=-2.47$	0.014
RBC ($\times 10^{12}$/L)	3.49 (2.92, 4.09)	3.52 (2.90, 4.22)	3.45 (2.94, 4.02)	$Z=-1.43$	0.152

(Continues)

TABLE 1 | (Continued)

Variables	Overall ($n=969$)	No risk of malnutrition (GNRI > 98) ($n=401$)	At risk of malnutrition (GNRI ≤ 98) ($n=568$)	Statistic	p
Platelet ($\times 10^9$/L)	182.0 (134.0, 244.0)	173.0 (128.0, 217.0)	195.0 (136.0, 264.5)	$Z=-4.14$	< 0.001
Haemoglobin (g/L)	10.4 (8.8, 12.2)	10.8 (8.7, 12.7)	10.2 (8.8, 12.1)	$Z=-2.21$	0.027
Albumin (g/dL)	3.6 (3.2, 4.0)	4.1 (3.9, 4.3)	3.3 (2.9, 3.5)	$Z=-26.38$	< 0.001
Potassium (mEq/L)	4.2 (3.8, 4.6)	4.1 (3.8, 4.5)	4.2 (3.8, 4.6)	$Z=-0.79$	0.427
Sodium (mEq/L)	139 (137, 142)	139 (137, 142)	139 (136, 142)	$Z=-0.30$	0.764
Calcium (mg/dL)	8.5 (8.0, 9.0)	8.6 (8.1, 9.0)	8.4 (8.0, 8.9)	$Z=-3.33$	0.001
Magnesium (mg/dL)	2.0 (1.8, 2.3)	2.1 (1.8, 2.4)	2.0 (1.8, 2.2)	$Z=-3.31$	0.001
Temperature (°C)	36.67 (36.39, 37.00)	36.67 (36.39, 36.94)	36.72 (36.39, 37.00)	$Z=-1.73$	0.084
Heart rate (beats/min)	80.00 (71.00, 93.00)	79.00 (69.00, 88.00)	82.00 (72.00, 97.00)	$Z=-4.80$	< 0.001
MBP (mmHg)	82.00 (72.00, 96.00)	84.00 (72.00, 98.00)	82.00 (71.75, 95.00)	$Z=-0.89$	0.372
Respiratory rate (beats/min)	18.00 (15.00, 22.00)	16.00 (14.00, 20.00)	19.00 (16.00, 23.00)	$Z=-6.90$	< 0.001
Comorbidities or symptoms					
Myocardial infarct (%)				$\chi^2=1.54$	0.215
Yes	267 (27.6)	102 (25.4)	165 (29.0)		
No	702 (72.4)	299 (74.6)	403 (71.0)		
Congestive heart failure (%)				$\chi^2=14.46$	< 0.001
Yes	363 (37.5)	122 (30.4)	241 (42.4)		
No	606 (62.5)	279 (69.6)	327 (57.6)		
Peripheral vascular disease (%)				$\chi^2=3.79$	0.052
Yes	249 (25.7)	90 (22.4)	159 (28.0)		
No	720 (74.3)	311 (77.6)	409 (72.0)		
Dementia (%)				$\chi^2=7.31$	0.007
Yes	78 (8.0)	21 (5.2)	57 (10.0)		
No	891 (92.0)	380 (94.8)	511 (90.0)		

(Continues)

TABLE 1 | (Continued)

Variables	Overall ($n=969$)	No risk of malnutrition (GNRI > 98) ($n=401$)	At risk of malnutrition (GNRI ≤ 98) ($n=568$)	Statistic	p
Chronic pulmonary disease (%)				$\chi^2=0.00$	0.993
Yes	256 (26.4)	106 (26.4)	150 (26.4)		
No	713 (73.6)	295 (73.6)	418 (73.6)		
Diabetes (%)				$\chi^2=3.66$	0.056
Yes	358 (36.9)	134 (33.4)	224 (39.4)		
No	611 (63.1)	267 (66.6)	344 (60.6)		
Paraplegia (%)				$\chi^2=0.74$	0.391
Yes	259 (26.7)	113 (28.2)	146 (25.7)		
No	710 (73.3)	288 (71.8)	422 (74.3)		
Renal disease (%)				$\chi^2=8.61$	0.003
Yes	266 (27.5)	90 (22.4)	176 (31.0)		
No	703 (72.5)	311 (77.6)	392 (69.0)		
Malignant cancer (%)				$\chi^2=1.80$	0.180
Yes	63 (6.5)	21 (5.2)	42 (7.4)		
No	906 (93.5)	380 (94.8)	526 (92.6)		
Liver disease (%)				$\chi^2=9.36$	0.002
Yes	49 (5.1)	10 (2.5)	39 (6.9)		
No	920 (94.9)	391 (97.5)	529 (93.1)		
Atrial fibrillation (%)				$\chi^2=1.11$	0.291
Yes	498 (51.4)	198 (49.4)	300 (52.8)		
No	471 (48.6)	203 (50.6)	268 (47.2)		
Hypertension (%)				$\chi^2=19.09$	< 0.001
Yes	521 (53.8)	249 (62.1)	272 (47.9)		
No	448 (46.2)	152 (37.9)	296 (52.1)		
Sepsis (%)				$\chi^2=13.51$	< 0.001

(Continues)

TABLE 1 | (Continued)

Variables	Overall ($n=969$)	No risk of malnutrition (GNRI > 98) ($n=401$)	At risk of malnutrition (GNRI ≤ 98) ($n=568$)	Statistic	p
Yes	572 (59.0)	209 (52.1)	363 (63.9)		
No	397 (41.0)	192 (47.9)	205 (36.1)		
Medication or treatment					
Vasoactive agents (%)				$\chi^2=4.13$	0.042
Yes	540 (55.7)	208 (51.9)	332 (58.5)		
No	429 (44.3)	193 (48.1)	236 (41.5)		
Invasive mechanical ventilation (%)				$\chi^2=24.68$	< 0.001
Yes	555 (57.3)	192 (47.9)	363 (63.9)		
No	414 (42.7)	209 (52.1)	205 (36.1)		
Enteral nutrition (%)				$\chi^2=38.10$	< 0.001
Yes	349 (36.0)	99 (24.7)	250 (44.0)		
No	620 (64.0)	302 (75.3)	318 (56.0)		
Indwelling urinary catheter (%)				$\chi^2=0.00$	0.973
Yes	380 (39.2)	157 (39.2)	223 (39.3)		
No	589 (60.8)	244 (60.8)	345 (60.7)		
Alteplase (%)				$\chi^2=13.15$	< 0.001
Yes	119 (12.3)	31 (7.7)	88 (15.5)		
No	850 (87.7)	370 (92.3)	480 (84.5)		
Sedatives (%)				$\chi^2=0.01$	0.907
Yes	775 (80.0)	320 (79.8)	455 (80.1)		
No	194 (20.0)	81 (20.2)	113 (19.9)		
Depression (%)				$\chi^2=0.27$	0.605
Yes	117 (12.1)	51 (12.7)	66 (11.6)		
No	852 (87.9)	350 (87.3)	502 (88.4)		

(Continues)

TABLE 1 | (Continued)

Variables	Overall ($n=969$)	No risk of malnutrition (GNRI > 98) ($n=401$)	At risk of malnutrition (GNRI ≤ 98) ($n=568$)	Statistic	p
Mechanical thrombectomy (%)				$\chi^2=1.89$	0.169
Yes	58 (6.0)	19 (4.7)	39 (6.9)		
No	911 (94.0)	382 (95.3)	529 (93.1)		
Malnutrition (%)				$\chi^2=28.93$	< 0.001
Yes	75 (7.7)	9 (2.2)	66 (11.6)		
No	894 (92.3)	392 (97.8)	502 (88.4)		
History of stroke (%)				$\chi^2=2.08$	0.149
Yes	72 (7.4)	24 (6.0)	48 (8.5)		
No	897 (92.6)	377 (94.0)	520 (91.5)		
Aphasic (%)				$\chi^2=0.16$	0.689
Yes	143 (/14.8)	57 (14.2)	86 (15.1)		
No	826 (85.2)	344 (85.8)	482 (84.9)		
Outcomes					
Delirium (%)				$\chi^2=38.58$	< 0.001
Yes	563 (58.1)	186 (46.4)	377 (66.4)		
No	406 (41.9)	215 (53.6)	191 (33.6)		
Pressure injury (%)				$\chi^2=58.31$	< 0.001
Yes	211 (21.8)	39 (9.7)	172 (30.3)		
No	758 (78.2)	362 (90.3)	396 (69.7)		

Note: Medians and interquartile ranges (25th and 75th percentiles) were computed for continuous variables, and frequencies and percentages for categorical variables. The Wilcoxon rank-sum test was used to compare group differences for continuous variables, and Chi-square tests for categorical variables.
Abbreviations: GCS, Glasgow Coma Scale; GNRI, Geriatric Nutritional Risk Index; LOS, Length of Stay; MBP, Mean Blood Pressure; RBC, Red Blood Cell count; SAPSII, Simplified Acute Physiology Score II; SOFA, Sequential Organ Failure Assessment; WBC, White Blood Cell count.

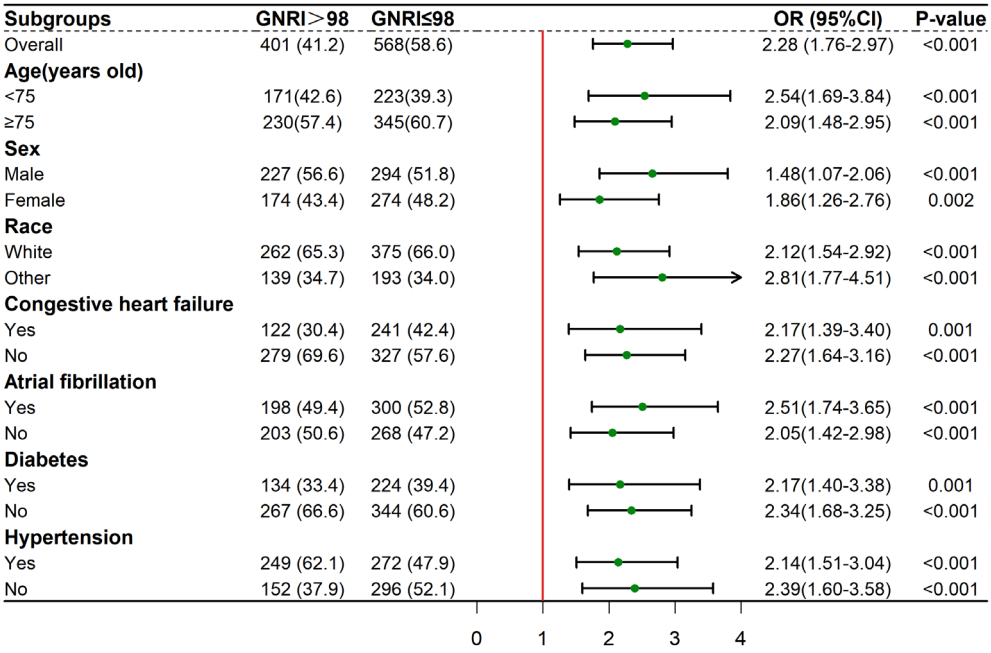

FIGURE 2 | Forest Plot of Odds Ratios for Delirium Associated with Low Geriatric Nutritional Risk Index (GNRI ≤ 98) across Patient Subgroups. Note: This forest plot illustrates the odds ratios (ORs) with corresponding 95% confidence intervals (CIs) for the association between a low Geriatric Nutritional Risk Index (GNRI ≤ 98) and the risk of delirium, compared to patients with a GNRI > 98 (reference group). Data are presented for the overall cohort and stratified by various patient subgroups. Each square represents the point estimate of the OR for a subgroup, with the horizontal line extending from the square indicating the 95% CI. The diamond at the top represents the summary OR and its 95% CI for the "Overall" group. The vertical line at an OR of 1.0 signifies the line of no effect (null effect). Points and confidence intervals located to the right of this line (OR > 1) indicate increased odds of delirium in patients with GNRI ≤ 98 compared to those with GNRI > 98. Conversely, points and confidence intervals to the left of this line (OR < 1) would indicate decreased odds. P-values are provided to assess the statistical significance of each OR. Abbreviations: GNRI, Geriatric Nutritional Risk Index; OR, Odds Ratio; CI, Confidence Interval.

6.5 | Sensitivity Analysis

To test the robustness of our findings, sensitivity analyses were performed, including PSM, IPTW and further analysis in specific populations. Both PSM and IPTW methods achieved better balance between covariates, with corresponding changes in SMD shown in Figure S3. Consistent with the original cohort, results in the matched or weighted populations indicated that malnutrition, as assessed by GNRI, was associated with an increased risk of delirium and pressure injury in older adults with ischaemic stroke (Table S2). Additionally, robust results were also obtained after further adjustment for electrolyte levels (sodium, potassium, calcium and magnesium), enteral nutrition and the presence of a urinary catheter based on model 4 (Table S3).

In this study, the association between malnutrition as assessed by GNRI and outcomes was analysed using multiple models for older critically ill adults with ischaemic stroke. The results showed that patients at risk of malnutrition (GNRI ≤98) had a higher risk of delirium and pressure injury, with statistical significance observed among in-hospital survivors, first-time stroke patients and septic patients (all $p < 0.005$) (Table S4). This indicates that malnutrition is a robust independent risk factor for delirium and pressure injury in older adults with ischaemic stroke.

7 | Discussion

This study aimed to investigate the relationship between nutritional status and complications such as delirium and pressure injury in older adults with ischaemic stroke. By assessing patients' nutritional status and analysing its association with delirium and other complications, the study highlights the importance of nutrition in the recovery and prognosis of persons with stroke. The results indicate that patients at nutritional risk have a significantly higher risk of delirium after ischaemic stroke compared with those without nutritional risk, highlighting the direct impact of nutritional status on the occurrence of delirium. In addition, patients at nutritional risk also have an increased risk of developing pressure injuries. These findings underscore the importance of assessing nutritional status. Early identification and improvement of patients' nutritional status can significantly reduce the risk of complications such as delirium and pressure injuries, thereby improving prognosis and quality of life.

The increased risk of delirium in ischaemic stroke patients may be related to malnutrition through several mechanisms. First, malnutrition can lead to a compromised immune system, increasing the risk of infection [38]. Persons with stroke already have a weakened immune system, and malnutrition can further impair its function, making them more susceptible to bacterial and viral infections, thereby increasing the risk of delirium [39, 40]. Second, malnutrition can affect the function of the nervous system in patients with stroke. The nervous system requires

TABLE 2 | Association between GNRI-assessed nutritional risk and primary/secondary outcomes in patients with ischaemic stroke.

Outcome[a]	Model	Adjusted OR (95% CI)[b]	Wald statistic	*p*
Delirium	1	2.29 (1.76, 2.99)	$z=6.13$	<0.001
	2	1.97 (1.46, 2.65)	$z=4.47$	<0.001
	3	1.78 (1.30, 2.42)	$z=3.65$	<0.001
	4	1.75 (1.28, 2.40)	$z=3.51$	<0.001
PI	1	4.04 (2.77, 5.88)	$z=7.27$	<0.001
	2	3.09 (2.09, 4.59)	$z=5.63$	<0.001
	3	2.80 (1.86, 4.21)	$z=4.95$	<0.001
	4	2.70 (1.79, 4.09)	$z=4.71$	<0.001

Note: Model 1: Adjusted for GNRI, admission age, sex and race. Model 2: Model 1 plus adjustment for GCS, SAPS II, SOFA and Braden score. Model 3: Model 2 plus adjustment for CCI, congestive heart failure, dementia, renal disease, atrial fibrillation, sepsis, malnutrition, liver disease, heart rate and mean blood pressure. Model 4: Model 3 plus adjustment for alteplase, invasive mechanical ventilation, sedatives and vasoactive agents.
Abbreviations: CI = Confidence Interval; GNRI = Geriatric Nutritional Risk Index; OR = Odds Ratio.
[a]Multivariate logistic regression models were used to calculate odds ratios (OR) with 95% confidence intervals (CI).
[b]The older patients with ischemic stroke were categorized according to their nutritional risk using the Geriatric Nutritional Risk Index (GNRI). They were divided into two groups: those at risk of malnutrition (GNRI ≤98) and those with no risk of malnutrition (GNRI >98). The reference group is those who are not at risk of malnutrition.

high levels of several nutrients, and malnutrition can cause damage and dysfunction to nerve cells [41, 42]. This damage can affect normal brain functions, including perception, cognition and emotion regulation, increasing the likelihood of delirium [43, 44]. In addition, malnutrition can affect the psychological state of patients. It can lead to physical weakness, lethargy and even depression, all of which can contribute to an increased risk of delirium [45]. In addition, malnutrition can cause abnormalities in physiological parameters such as blood glucose and electrolytes, which can affect brain function. These abnormalities can disrupt normal neuronal activity, affecting cognitive and emotional states and thus increasing the occurrence of delirium [46, 47]. In summary, there are several potential links between the increased risk of delirium and malnutrition in patients with ischaemic stroke. These associations involve the immune system, nervous system, psychological state and physiological parameters and provide valuable insights into the mechanisms of delirium in persons with stroke. Therefore, early identification and improvement of patients' nutritional status are critical to reducing the incidence of delirium and promoting recovery.

A growing body of evidence indicates that malnutrition significantly impacts the health outcomes of patients with ischaemic stroke [15, 48, 49]. In addition to markedly increasing the risk of delirium, malnutrition is closely associated with the occurrence of pressure injuries. These complications not only heighten patient suffering but can also delay recovery and even threaten life. Pressure injuries, also known as pressure ulcers or bedsores, result from prolonged pressure on the skin and underlying tissues, leading to ischemia [50]. Given the limited mobility caused by ischaemic stroke, these patients are more prone to pressure injuries [51]. Malnutrition weakens the skin's elasticity and repair capacity, making it more susceptible to pressure and injury, thereby increasing the incidence of pressure injuries [52]. In clinical practice, nutritional intervention is critical in the treatment of patients with ischaemic stroke [53]. Adequate protein intake is essential for maintaining muscle mass and immune function, both of which are crucial for preventing infections and accelerating recovery. Antioxidants such as vitamins C and E aid in wound healing and reducing inflammation [54, 55]. Minerals such as zinc and iron also play a significant role in cellular repair and immune function [56, 57]. Patients with malnutrition should undergo a personalized nutritional assessment and intervention. Nutritional status can be improved through oral nutritional supplements, enteral nutrition or, if necessary, parenteral nutrition [58]. Nurses should play a pivotal role in coordinating nutritional care, collaborating closely with dietitians, physicians and other health care team members to develop, implement and monitor comprehensive nutritional therapy plans [59, 60]. Ensuring adequate nutritional intake is vital for preventing pressure injuries. Key nutrients such as proteins, vitamins and minerals play essential roles in maintaining skin integrity and promoting healing [61].

A variety of tools are available for assessing nutritional risk, including the Nutritional Risk Screening Tool (NRS-2002), the Mini Nutritional Assessment (MNA) and the Subjective Global Assessment (SGA) [62, 63]. Among these, the GNRI has gained considerable attention because of its simplicity and ease of use. The results of this study indicate that the GNRI is an effective tool for predicting the risk of delirium and pressure injuries in older adults with ischaemic stroke during critical illness. This index, through simple calculations, provides a nutritional risk level for patients, enabling clinical health care professionals to quickly identify high-risk patients and implement appropriate interventions. In conclusion, optimal nutrition is a critical component of the recovery process for patients who have experienced an ischaemic stroke. Prompt identification and intervention to improve nutritional status can significantly reduce the risk of complications such as delirium and pressure injuries, thereby enhancing prognosis and facilitating a more comprehensive recovery.

8 | Limitations

It is important to consider several limitations when interpreting and applying the results of this study. Firstly, because of the retrospective design of our study, it is not possible to establish a causal relationship between malnutrition and delirium in patients with ischaemic stroke. Prospective studies are needed to better elucidate this relationship. Secondly, we only assessed the

initial nutritional status of patients with ischaemic stroke and did not account for dynamic changes during follow-up. Third, the study sample was primarily drawn from the United States and lacked external validation, which may limit the generalizability of our results. Therefore, caution is warranted when extrapolating these conclusions to persons with ischaemic stroke in other regions. Fourth, because of the availability of database information, some important covariates were inevitably omitted, such as relevant nutritional scores, blood transfusion, National Institutes of Health Stroke Scale and stroke subtypes. Finally, delirium is classified into three subtypes: hyperactive, hypoactive and mixed. Regrettably, our study did not conduct a comprehensive analysis of these subtypes, which may limit our understanding of delirium.

9 | Implications and Recommendations for Practice

The findings of this study have significant implications for critical care nursing, particularly in the domains of nutritional risk assessment, delirium prevention and pressure injury management among older adults with ischaemic stroke. A holistic approach to care should be prioritized, with vigilant assessment of patients' cognitive status, mobility and nutritional state. Given the substantial impact of malnutrition on health outcomes in this vulnerable population, proactive identification of early nutritional compromise indicators is imperative. The GNRI has emerged as an effective tool in this context, facilitating rapid identification of high nutritional risk patients. To illustrate, a 70-year-old female patient admitted to the ICU with an ischaemic stroke, standing 170 cm tall, weighing 73.6 kg and presenting a serum albumin level of 2.8 g/dL, would yield a GNRI score of 83.4. This score, falling below the threshold of 98, indicates significant nutritional risk and allows for prompt implementation of targeted care plans, including early nutritional interventions such as individualized enteral feeding protocols or appropriate oral nutritional supplements.

Based on this study result, older adults with ischaemic stroke at risk for malnutrition may be at increased risk for delirium and pressure injury, requiring a multifaceted preventive approach. Delirium prevention strategies should be intensified, with increased frequency of CAM-ICU assessments and implementation of evidence-based preventive measures. These measures may include minimizing nocturnal disturbances, promoting early mobilization and maintaining regular sleep–wake cycles [64]. At the same time, a pressure injury prevention approach is critical, especially in malnourished patients. This approach should include frequent repositioning of patients (ideally every 2 h), use of pressure redistributing surfaces and careful skin assessment to identify early signs of breakdown [65]. Critically, nurses must play a central role in coordinating multidisciplinary care by communicating GNRI results to the health care team and educating patients and families about the central role of nutrition in recovery and prevention of complications [66]. Periodic reassessment of the GNRI should guide ongoing nutritional support and inform adjustments to delirium and pressure injury prevention strategies. The integration of evidence-based practices enables critical care nurses to improve clinical outcomes for patients in this high-risk population.

10 | Conclusions

In conclusion, malnutrition, as assessed by the GNRI, significantly increases the risk of delirium in older adults with ischaemic stroke during critical illness. Additionally, malnutrition also elevates the risk of pressure injuries. These findings underscore the necessity of systematically assessing and managing malnutrition in clinical practice. Early identification and intervention for malnutrition by health care professionals can reduce the risks of delirium and pressure injuries, thereby improving overall prognosis and quality of life for patients. Nutritional support and personalized nutritional interventions may play a crucial role in reducing disease burden and promoting recovery. Future research should focus on exploring the potential mechanisms by which malnutrition impacts the prognosis of persons with ischaemic stroke and evaluating the effectiveness of targeted intervention strategies. This will provide stronger scientific evidence for clinical practice, promoting the development and implementation of higher-quality patient care and rehabilitation programmes.

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The authors have nothing to report.

Ethics Statement

The Medical Information Mart for Intensive Care IV (MIMIC-IV) database was supported by grants from the National Institute of Biomedical Imaging and Bioengineering (NIBIB) of the National Institutes of Health (NIH) under award numbers R01-EB001659 (2003–2013) and R01-EB017205 (2014–2018) and approved by the Institutional Review Boards of Beth Israel Deaconess Medical Center (Boston, MA) and the Massachusetts Institute of Technology (Cambridge, MA). The Ethics Committee of Nan'ao People's Hospital, Dapeng New District, Shenzhen reviewed this study on March 25, 2025, and determined that no additional review of the ethics application was required because the study used the public MIMIC-IV database.

Consent

Data extracted from the MIMIC-IV database do not require individual informed consent because the research data are publicly available, and all patient data are de-identified.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data were available on the MIMIC-IV website at https://mimic.physionet.org/. The data in this article can be reasonably applied to the corresponding author.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.