



Geriatric Nutritional Risk Index and Prognostic Nutritional Index as Predictors of One-Year Mortality in Older Patients After Hip Fracture Surgery: A Retrospective Cohort Study

Wei Wu, MD^{1,2,3,4} , Huanyi Zhu, MD^{1,2,3,4}, Xiangxu Chen, PhD^{1,2,3,4}, Yucheng Gao, PhD^{1,2,3,4}, Chuwei Tian, MD^{1,2,3,4}, Chen Rui, MD^{1,2,3,4}, Tian Xie, MD^{1,2,3,4}, Liu Shi, PhD^{1,2,3,4}, Yingjuan Li, MD^{2,5}, and Yunfeng Rui, PhD^{1,2,3,4} 

Abstract

Background: Malnutrition is a prevalent issue among older patients with hip fracture and is significantly associated with poor outcomes. The Geriatric Nutritional Risk Index (GNRI) and Prognostic Nutritional Index (PNI) are nutritional screening tools that may assist in predicting outcomes in older patients undergoing hip fracture surgery. This study aimed to evaluate the effects of GNRI and PNI on 1-year mortality after hip fracture surgery in older patients.

Methods: This retrospective study included 577 patients aged 60 years and older with hip fractures treated surgically at a single center from January 2018 to December 2021. Nutritional status was evaluated using GNRI and PNI. The primary outcomes were 180-day and 1-year mortality, while secondary outcomes included short-term postoperative complications and length of stay. Univariate and multivariate analyses were performed to identify independent risk factors for 1-year mortality. Subgroup analysis was employed to identify potential population heterogeneity.

Results: Patients with low GNRI and low PNI had significantly higher 1-year mortality rates and short-term postoperative complication rates compared to those with higher scores. Low GNRI was an independent risk factor for one-year mortality (95% CI 1.09 - 3.25, $P = 0.022$). Subgroup analyses revealed significant heterogeneity, with males patients and patients with ASA III-IV showing higher hazard ratios for 1-year mortality associated with low GNRI. Pulmonary infections and older age were also identified as independent risk factors for one-year mortality.

Conclusion: This study demonstrated that low GNRI was the risk factor for 1-year mortality after hip fracture surgery in older patients.

Keywords

hip fracture, malnutrition, older patients, mortality, geriatric nutritional risk index, prognostic nutritional index

Received: 28 August 2024; revised: 9 April 2025; accepted: 22 April 2025

¹Department of Orthopaedics, Zhongda Hospital, School of Medicine, Southeast University, Nanjing, PR China

²School of Medicine, Southeast University, Nanjing, PR China

³Multidisciplinary Team (MDT) for Geriatric Hip Fracture Management, Zhongda Hospital, School of Medicine, Southeast University, Nanjing, PR China

⁴Orthopaedic Trauma Institute (OTI), Southeast University, Nanjing, PR China

⁵Department of Geriatrics, Zhongda Hospital, School of Medicine, Southeast University, Nanjing, People's Republic of China

Corresponding Author:

Yunfeng Rui, Department of Orthopaedics, Zhongda Hospital, School of Medicine, Southeast University, NO. 87 Ding Jia Qiao, Nanjing, Jiangsu 210009, PR China.

Email: ruiyunfeng@126.com



Creative Commons Non Commercial CC BY-NC: This article is distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 License (<https://creativecommons.org/licenses/by-nc/4.0/>) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed as specified on the

SAGE and Open Access pages (<https://us.sagepub.com/en-us/nam/open-access-at-sage>).

Introduction

Hip fracture is one of the most common orthopedic injuries.^{1,2} As the global population continues to age, the incidence of hip fractures is projected to nearly double over the next 20 to 30 years.³ Due to substantial morbidity and mortality risks, hip fracture represents a significant health challenge in the older population.³⁻⁵ It is of great clinical significance to comprehensively assess the patient's health status to screen out older patients with hip fracture who may have poor prognoses.

Malnutrition is prevalent among older patients with hip fractures.⁶ Insufficient nutritional intake in older patients with hip fractures has been demonstrated to exacerbate their already compromised nutritional status.⁷ Nutritional status is considered a critical factor of postoperative prognosis in older hip fracture patients.^{8,9} European Society of Parenteral and Enteral Nutrition (ESPEN) guidelines recommended early nutritional supplementation for all older patients after orthopedic surgery.¹⁰

The geriatric nutritional risk index (GNRI) is calculated using serum albumin levels, actual body weight and ideal body weight. It was designed to predict the risk of nutrition-related complications and mortality in older patients who are hospitalized.¹¹ The GNRI has been demonstrated to be a predictor of outcomes in many diseases, including cancer, hemodialysis, and heart failure.¹²⁻¹⁴ The prognostic nutritional index (PNI) is an index that evaluates nutritional status by calculating serum albumin levels and absolute lymphocyte counts. The PNI was initially employed to evaluate the nutritional status of patients undergoing gastrointestinal surgery.¹⁵ Furthermore, PNI has been demonstrated to be significantly related to the prognosis of various tumors.¹⁶⁻¹⁸

Nevertheless, few studies have examined the association between nutritional screening tools and postoperative mortality and complications in older patients after hip fracture surgery.^{19,20} The aim of this study was to evaluate the effects of GNRI and PNI on 1-year mortality after hip fracture in older patients and to investigate their relationship with short-term postoperative complications.

Methods

Study design and populations

This study included 577 patients aged 60 and above who had undergone emergency or elective surgery for hip fractures at a teaching hospital in a China's eastern province between 1 January 2018 and 31 December 2021. The inclusion criteria were: (1) confirmed hip fracture and surgical treatment; (2) over 60 years old at the time of injury; (3) the time of admission was 2018.01 - 2021.12. Exclusion criteria were: (1) pathological and periprosthetic fractures; (2) conservative treatment; (3) loss of follow-up; (4) miss data. The flow diagram of patients enrolled

in this study is shown in [Figure 1](#). The sample size should be at least 10 times the number of variables, and there were 20 variables in the current study, thus the sample size in this study should be at least 200.²¹ This work has been reported in line with the "Strengthening the Reporting of Observational Studies in Epidemiology" (STROBE) checklist.

Data Collection

The demographic characteristics, clinical characteristics, and laboratory test results of 577 patients were obtained from electronic medical records. The demographic data included age, gender (male and female), body mass index (BMI), and general health status according to the American Society of Anaesthesiologists (ASA) classification and comorbidities (consisting of hypertension, diabetes, and heart disease). Injury-related data included fracture type (femoral neck fracture or intertrochanteric fracture). The surgery-related data included type of anesthesia, duration of surgery, and type of surgery (THA, HHA, and internal fixation). Hospitalization data included laboratory tests on admission, time from admission to surgery, perioperative blood transfusion requirements, short-term postoperative complications (consisting of pulmonary infections, urinary tract infections, neurological complications, and cardiovascular or cerebrovascular complications) and length of stay (LOS). Investigators routinely followed up at 30 days, 90 days, 180 days, and 1 year after surgery by telephone interview or outpatient review. The follow-up data included patient survival status and date of death. The endpoint event was defined as either all-cause mortality or the conclusion of the study, whichever occurred first.

Definitions

The GNRI was calculated using the following formula: $GNRI = [14.89 \times \text{serum albumin level (g/dL)}] + [41.7 \times \text{actual body weight/ideal body weight}]$. The GNRI nutritional assessment level determination: high nutritional risk ($GNRI \leq 98$) and low nutritional risk ($GNRI > 98$).¹¹ The population was divided into the following two groups based on GNRI nutritional assessment level: the high GNRI group ($GNRI \leq 98$) and the low GNRI group ($GNRI > 98$). And the PNI was calculated using the following formula: $PNI = \text{serum albumin level (g/L)} + 5 \times \text{absolute lymphocyte count (} 10^9/\text{L)}$.¹⁵ The PNI nutritional assessment level determination: high nutritional risk ($PNI \leq 38$) and low nutritional risk ($PNI > 38$). The population was divided into the following two groups based on PNI nutritional assessment levels: the high PNI group ($PNI \leq 38$) and the low PNI group ($PNI > 38$). Patients were divided into older (60 - 85) and super-older (≥ 85) groups based on age. Delayed surgery was defined as surgery performed more than 48 hours after the patient's admission to the hospital. The American Society of

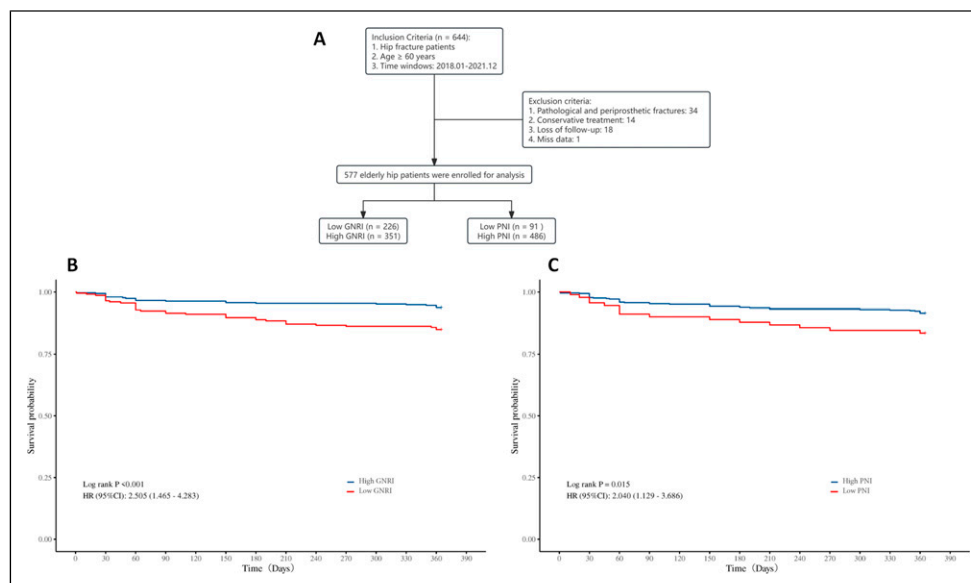


Figure 1. (A) Flow Diagram of Patients Enrolled in this Study. (B) Survival Curves of Patients with High and Low GNRI. (C) Survival Curves of Patients with High and Low PNI.

Anesthesiologists (ASA) classification is divided into classes I-II and III-IV. Short-term postoperative complications were defined as complications that occurred during the hospitalization period and within 30 days of follow-up.

Outcome Measures

The primary outcomes of this study were 180-day mortality and 1-year mortality. The secondary outcomes included short-term postoperative complications (consisting of pulmonary infections, urinary tract infections, neurological complications and cardiovascular or cerebrovascular complications) and length of stay (LOS).

Statistical Analysis

The distributions of all continuous variables were evaluated for normality using the Shapiro–Wilk test. For variables that were normally distributed, the mean and standard deviation were used to represent the baseline characteristics of the patients. Median and interquartile range were used to represent variables with skewed distributions. Comparisons of characteristics between groups were conducted using appropriate statistical tests. The Student's t-test was employed for continuous variables with normal distributions, the Mann-Whitney U test for continuous variables with skewed distributions, and the chi-square test for categorical variables. Survival curves were calculated using the Kaplan-Meier method. Subsequently, univariate and multivariate analyses were used to further examine the independent influencing factors of 1-

year mortality. Potential population heterogeneity was identified by examining interactions between low GNRI/low PNI and various subgroups. All statistical analyses were completed using R version 4.3.0 (2023-04-21). All descriptive studies were tested for significance using two-sided tests, and the significance level was $P < 0.05$.

Results

Characteristics and Outcomes of Patients in the Low and High GNRI Groups

A total of 577 patients were included in this study. Patients were divided into two groups according to their GNRI levels: the low GNRI group (n = 226) and the high GNRI group (n = 351). Regarding baseline characteristics, there were statistically significant differences between the two groups in terms of age, gender, BMI, ASA classification, hypertension, fracture type, type of surgery, duration of surgery, and transfusion (Table 1). For the primary outcome, there were statistically significant differences in 180-day mortality and 1-year mortality between the two groups. For secondary outcomes, there were statistically significant differences between the two groups in the incidence of pulmonary infections and neurological complications (Table 2).

Characteristics and Outcomes of Patients in the Low and High PNI Groups

Patients were divided into two groups according to their PNI level: the low PNI group (n = 91) and the

Table 1. Characteristics of Patients in the High and Low GNRI Groups.

Variables	High GNRI	Low GNRI	Statistic	P
No. of patients	n = 351	n = 226		
Age, median (IQR), years	81.00 (73.50, 86.00)	84.00 (78.00, 87.00)	Z = -3.38	<0.001
Gender, n (%)			$\chi^2 = 23.519$	<0.001
Male	86 (24.50)	99 (43.81)		
Female	265 (75.50)	127 (56.19)		
BMI, Mean \pm SD, kg/m ²	24.50 \pm 3.13	19.91 \pm 2.79	t = 17.950	<0.001
ASA Classification, n (%)			$\chi^2 = 4.152$	0.042
I~II	178 (50.71)	95 (42.04)		
III~IV	173 (49.29)	131 (57.96)		
Number of comorbidities, median (IQR)	4 (2 - 5)	4 (2 - 5)	Z = -0.883	0.377
Hypertension, n (%)	224 (63.82)	113 (50.00)	$\chi^2 = 10.805$	0.001
Diabetes, n (%)	91 (25.93)	56 (24.78)	$\chi^2 = 0.095$	0.758
Heart Disease, n (%)	54 (15.38)	40 (17.70)	$\chi^2 = 0.540$	0.462
Fracture type, n (%)			$\chi^2 = 5.009$	0.025
Femoral neck fracture	195 (55.56)	104 (46.02)		
Intertrochanteric fracture	156 (44.44)	122 (53.98)		
Type of anesthesia, n (%)			$\chi^2 = 0.075$	0.783
General	337 (96.01)	218 (96.46)		
Regional	14 (3.99)	8 (3.54)		
Delayed surgery, n (%)			$\chi^2 = 0.929$	0.335
<48	158 (45.01)	111 (49.12)		
≥ 48	193 (54.99)	115 (50.88)		
Type of surgery, n (%)			$\chi^2 = 6.249$	0.044
THA	81 (23.08)	35 (15.49)		
HHA	103 (29.34)	63 (27.88)		
Internal fixation	167 (47.58)	128 (56.64)		
Duration of surgery, median (IQR), min	100.00 (85.00 - 120.00)	90.00 (79.80 - 110.00)	Z = -2.306	0.021
Transfusion, n (%)	97 (27.64)	91 (40.27)	$\chi^2 = 9.984$	0.002

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; GNRI, geriatric nutritional risk index; HHA, hip hemiarthroplasty; IQR, interquartile range; n, number; PNI, prognostic nutritional index; SD, standard deviation; THA, total hip arthroplasty.

high PNI group (n = 486). Regarding baseline characteristics, there were statistically significant differences between the two groups in terms of age, gender, BMI, number of comorbidities, heart

disease, and transfusion (Table 3). For the primary outcome, there were statistically significant differences in 1-year mortality between the two groups. For secondary outcomes, there were statistically significant

Table 2. Outcomes of Patients in the High and Low GNRI Groups.

Variables	GNRI>98	GNRI \leq 98	Statistic	P
No. of patients	n = 351	n = 226		
Primary outcomes				
180-day mortality, n (%)	15 (4.27)	25 (11.06)	$\chi^2 = 9.82$	0.002
1-year mortality, n (%)	22 (6.27)	34 (15.04)	$\chi^2 = 12.08$	<0.001
Secondary outcomes				
Pulmonary infections, n (%)	31 (8.83)	39 (17.26)	$\chi^2 = 9.154$	0.002
Urinary tract infections, n (%)	3 (0.85)	3 (1.33)	$\chi^2 = 0.016$	0.9
Neurological complications, n (%)	23 (6.55)	30 (13.27)	$\chi^2 = 7.446$	0.006
Cardiovascular or cerebrovascular complications, n (%)	24 (6.84)	24 (10.62)	$\chi^2 = 2.578$	0.108
LOS, median (IQR)	9.87 (8.42 - 12.62)	9.98 (7.96 - 12.88)	Z = -0.808	0.419

Abbreviations: GNRI, geriatric nutritional risk index; IQR, interquartile range; LOS, length of stay; n, number.

Table 3. Characteristics of Patients in the High and Low PNI Groups.

Variables	High PNI	Low PNI	Statistic	P
No. of patients	n = 486	n = 91		
Age, median (IQR), years	82.00 (75.00, 87.00)	84.00 (78.50, 87.00)	Z = -2.14	0.032
Gender, n (%)			$\chi^2 = 14.996$	<0.001
Male	140 (28.81)	45 (49.45)		
Female	346 (71.19)	46 (50.55)		
BMI, Mean \pm SD, kg/m ²	22.86 \pm 3.75	21.84 \pm 3.61	t = 2.410	0.016
ASA Classification, n (%)			$\chi^2 = 2.605$	0.107
I~II	237 (48.77)	36 (39.56)		
III~IV	249 (51.23)	55 (60.44)		
Number of comorbidities, median (IQR)	4(2-5)	4 (3-6)	Z = -2.191	0.028
Hypertension, n (%)	286 (58.85)	51 (56.04)	$\chi^2 = 0.248$	0.618
Diabetes, n (%)	123 (25.31)	24 (26.37)	$\chi^2 = 0.046$	0.831
Heart Disease, n (%)	72 (14.81)	22 (24.18)	$\chi^2 = 4.925$	0.026
Fracture type, n (%)			$\chi^2 = 0.903$	0.342
Femoral neck fracture	256 (52.67)	43 (47.25)		
Intertrochanteric fracture	230 (47.33)	48 (52.75)		
Type of anesthesia, n (%)			$\chi^2 = 1.380$	0.24
General	465 (95.68)	90 (98.90)		
Regional	21 (4.32)	1 (1.10)		
Delayed surgery, n (%)			$\chi^2 = 0.017$	0.895
<48	226 (46.50)	43 (47.25)		
≥ 48	260 (53.50)	48 (52.75)		
Type of surgery, n (%)			$\chi^2 = 1.503$	0.472
THA	102 (20.99)	14 (15.38)		
HHA	138 (28.40)	28 (30.77)		
Internal fixation	246 (50.62)	49 (53.85)		
Duration of surgery, median (IQR), min	95.00 (79.80 - 115.00)	90.00 (80.00 - 120.00)	Z = -0.665	0.506
Transfusion, n (%)	147 (30.25)	41 (45.05)	$\chi^2 = 7.651$	0.006

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; GNRI, geriatric nutritional risk index; HHA, hip hemiarthroplasty; IQR, interquartile range; n, number; PNI, prognostic nutritional index; SD, standard deviation; THA, total hip arthroplasty.

differences between the two groups in the incidence of pulmonary infections (Table 4).

Univariate Analysis of One-Year Mortality

A total of 577 patients were divided into two groups (n = 56 vs n = 521) based on whether they died within one year. The results of the univariate analysis showed that 7 variables, including age, intertrochanteric fracture, THA or HHA, pulmonary infections, cardiovascular or cerebrovascular complications, low GNRI and low PNI, met the inclusion criteria for the Cox regression model ($P < 0.05$) (Table 5).

Multivariate analysis of one-year mortality

When low GNRI was included in the multivariate analysis, older patients (vs younger patients, 95% CI 1.04 - 1.13, $P < 0.001$), pulmonary infections (vs no pulmonary infections,

95% CI 1.47 - 4.73, $P = 0.001$) and low GNRI (vs high GNRI, 95% CI 1.09 - 3.25, $P = 0.022$) were found to be independent risk factors for 1-year mortality (Table 6). When low PNI was included in the multivariate analysis, older patients (vs younger patients, 95% CI 1.04 - 1.13, $P < 0.001$) and pulmonary infections (vs no pulmonary infections, 95% CI 1.55 - 4.95, $P = < 0.001$) were found to be independent risk factors for 1-year death (Table 7).

Subgroup Analysis

The forest graphs showed the correlation between low GNRI and the risk of one-year mortality in different subgroups of age, sex, ASA classification, fracture type and delayed surgery. The results showed that in the subgroup analysis of low GNRI and one-year mortality risk, the HRs of the subgroups aged 60-85 years, male, ASA III-IV, femoral neck fracture, non-delayed surgery and delayed surgery remained significant with values of 2.71

Table 4. Outcomes of Patients in the High and Low PNI Groups.

Variables	High PNI	Low PNI	Statistic	P
No. of patients	n = 486	n = 91		
Primary outcomes				
180-day mortality, n (%)	30 (6.17)	10 (10.99)	$\chi^2 = 2.76$	0.097
1-year mortality, n (%)	41 (8.44)	15 (16.48)	$\chi^2 = 5.66$	0.017
Secondary outcomes				
Pulmonary infections, n (%)	52 (10.70)	18 (19.78)	$\chi^2 = 5.929$	0.015
Urinary tract infections, n (%)	6 (1.23)	0 (0.00)	-	0.597
Neurological complications, n (%)	43 (8.85)	10 (10.99)	$\chi^2 = 0.421$	0.516
Cardiovascular or cerebrovascular complications, n (%)	39 (8.02)	9 (9.89)	$\chi^2 = 0.350$	0.554
LOS, M (Q ₁ , Q ₃)	9.82 (8.14 - 12.64)	11.39 (8.19 - 13.46)	Z = -1.533	0.125

Abbreviations: IQR, interquartile range; LOS, length of stay; n, number; PNI, prognostic nutritional index.

(95% CI, 1.14 - 6.42), 10.23 (95% CI, 2.40 - 43.63), 4.25 (95% CI, 2.00 - 9.04), 3.61 (95% CI, 1.44 - 9.06), 2.40 (95% CI, 1.14 - 5.09), and 2.56 (95% CI, 1.19 - 5.53), respectively (Figure 2). Of these, significant interactions and increased risk estimates of one-year mortality associated with low GNRI risk were observed in the subgroups of male and ASA III-IV (P for interaction <0.05).

Discussion

Our current retrospective study found that patients with low GNRI and low PNI had significantly higher 1-year mortality rates and short-term postoperative complication

rates compared to those with higher scores. Low GNRI was identified as the independent risk factor for 1-year mortality following hip fracture surgery in older patients. Additionally, subgroup analyses showed statistically significant heterogeneity were present in the subgroups of gender and ASA classification. These findings of this study indicated that enhancing nutritional status could serve as an effective preventive measure against mortality following hip fractures in the older population.

Malnutrition is a prevalent issue among older patients with hip fractures, and early detection of malnutrition is crucial to improving prognosis.²² A variety of nutritional screening and assessment tools have been employed in an

Table 5. Univariate Analysis of 1-Year Mortality.

Variables	HR (95%CI)	P
Age	1.11 (1.06 ~ 1.16)	<0.001
Gender	0.67 (0.39 ~ 1.14)	0.141
ASA III~IV	1.67 (0.97 ~ 2.88)	0.067
Intertrochanteric fracture	2.00 (1.16 ~ 3.46)	0.013
Hypertension	1.04 (0.61 ~ 1.77)	0.886
Diabetes	1.54 (0.89 ~ 2.68)	0.126
Heart Disease	1.61 (0.87 ~ 3.00)	0.130
General anesthesia	0.49 (0.18 ~ 1.36)	0.172
Delayed surgery	0.81 (0.48 ~ 1.36)	0.418
THA or HHA	0.61 (0.36 ~ 1.05)	0.041
Duration of surgery	1.01 (1.01 ~ 1.01)	0.076
Transfusion	1.38 (0.81 ~ 2.36)	0.240
Pulmonary infections	3.87 (2.21 ~ 6.79)	<0.001
Urinary infections	1.75 (0.24 ~ 12.64)	0.579
Neurological complications	1.96 (0.96 ~ 4.00)	0.065
Cardiovascular or cerebrovascular complications	2.95 (1.53 ~ 5.71)	0.001
LOS	0.99 (0.94 ~ 1.04)	0.573
Low GNRI	2.51 (1.47 ~ 4.28)	<0.001
Low PNI	2.04 (1.13 ~ 3.69)	0.018

Abbreviations: ASA, American Society of Anesthesiologists; CI, confidence interval; GNRI, geriatric nutritional risk index; HHA, hip hemiarthroplasty; LOS, length of stay; HR, hazard ratio; PNI, prognostic nutritional index; THA, total hip arthroplasty.

Table 6. Multivariate Analysis of 1-Year Mortality (including Low GNRI).

Variables	HR (95%CI)	P
Age	1.08 (1.04 ~ 1.13)	<0.001
Intertrochanteric fracture	1.49 (0.85 ~ 2.60)	0.166
Pulmonary infections	2.64 (1.47 ~ 4.73)	0.001
Cardiovascular or cerebrovascular complications	1.62 (0.81 ~ 3.25)	0.175
Low GNRI	1.89 (1.09 ~ 3.25)	0.022

Abbreviations: CI, confidence interval; GNRI, geriatric nutritional risk index; HR, hazard ratio.

effort to achieve this objective among hospitalized patients.²³ This study demonstrated the advantages of utilizing GNRI and PNI to evaluate the nutritional status of older patients with hip fractures who are hospitalized. Firstly, the GNRI and PNI can be easily calculated using serum albumin level, weight, height and lymphocyte count. A meta-analysis demonstrated that serum albumin concentration and total lymphocyte count on admission were effective predictors of mortality in patients with hip fracture.²⁴ A study by Sheriff D. Akinleye et al. demonstrated that patients with hip fractures and low body weight exhibited a higher mortality rate.²⁵ Secondly, the simplicity and ease of use of GNRI and PNI enable medical teams to rapidly and accurately assess patients' nutritional status, thereby enabling the timely formulation of personalized nutritional intervention plans and improving patient recovery and survival rates. Several studies have demonstrated that early surgical intervention within 48 hours of admission is beneficial for older patients with hip fractures.²⁶⁻²⁸ The rapid and convenient assessment of GNRI and PNI is well aligned with this requirement. Thirdly, GNRI and PNI employ objective body measurements and laboratory outcomes, which effectively mitigate potential biases associated with interviews and self-reports, such as recall and judgment errors. In contrast, the Mini-Nutritional Assessment Short Form comprises six items, including food intake, recent weight loss, mobility impairment, acute disease/stress, neuropsychological problems, and body mass index.²⁹ It is challenging for older adults to provide accurate health information. A

review of 39 studies revealed a high prevalence of dementia and cognitive impairment among older adults with hip fractures.³⁰

The precise mechanisms underlying these findings remain to be fully elucidated. The GNRI and PNI are nutritional screening tools that typically indicate malnutrition when values are low. Numerous previous studies have consistently shown a clear association between malnutrition and poor outcomes after hip fracture, including an increased risk of complications and higher mortality rates.^{7,31} Reduced skeletal muscle mass and delayed bone healing may be the major causes. Malnutrition in the older adults is frequently associated with a reduction in protein intake, which is the fundamental component of muscle metabolism.³² In patients who have sustained trauma, elevated protein catabolism during the stress response accelerates the loss of skeletal muscle amino acids, resulting in severe skeletal muscle atrophy.³³ The implications of this are particularly profound in the context of hip fracture recovery, where muscular strength and mass are integral to the restoration of mobility and independence. In addition, malnutrition has been identified as a significant risk factor for impaired bone healing.³⁴ The balance between osteoblastic bone formation and osteoclastic bone resorption is crucial for the process of bone repair.³⁵ L. Henry Goodnough et al found that chronic inflammation associated with aging can disrupt this balance.³⁶ This imbalance can result in ineffective healing of the bones following a fracture. Therefore, adequate nutrition is crucial for supporting the body's natural healing processes

Table 7. Multivariate Analysis of 1-Year Mortality (including Low PNI).

Variables	HR (95%CI)	P
Age	1.08 (1.04 ~ 1.13)	<0.001
Intertrochanteric fracture	1.55 (0.89 ~ 2.71)	0.123
Pulmonary infections	2.77 (1.55 ~ 4.95)	<0.001
Cardiovascular or cerebrovascular complications	1.70 (0.85 ~ 3.41)	0.132
Low PNI	1.65 (0.91 ~ 2.99)	0.100

Abbreviations: CI, confidence interval; HR, hazard ratio; PNI, prognostic nutritional index.

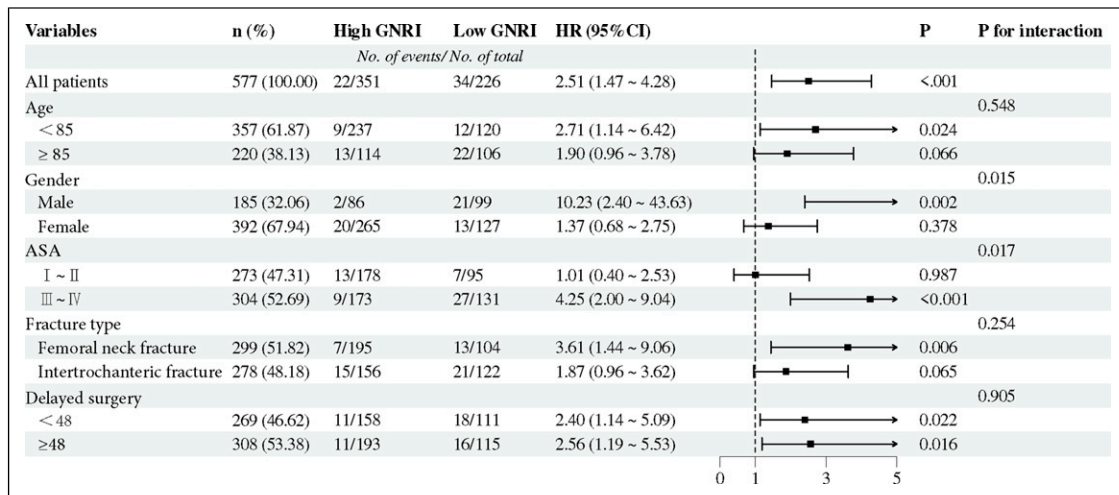


Figure 2. The Association of Low GNRI with the Risk of 1-Year Mortality in Various Subgroups. ASA, American Society of Anesthesiologists; CI, Confidence Interval; GNRI, Geriatric Nutritional Risk Index; n, Number; HR, Hazard Ratio.

and for improving the overall clinical outcomes for these patients.

The subgroup analysis revealed that significant heterogeneity and higher HR of low GNRI for 1-year mortality were observed in the subgroups of male and ASA III-IV. This indicated that focusing on and optimizing the nutritional status within these subpopulations might be especially critical in reducing the risk of mortality after hip fractures. With regard to the relationship between gender and mortality after hip fracture, a population-based prospective paired cohort study found that male hip fracture patients exhibited higher mortality than female patients in the first year after injury.³⁷ In the non-randomized intervention study by F. Reguant et al, patients with poorer health status, specifically those with ASA III-IV, showed that a multidisciplinary pre-surgical optimization could potentially reduce postoperative complications, hospital stay, and mortality.³⁸ These findings highlighted the necessity of targeted interventions focused on optimizing nutritional status in high-risk subpopulations to enhance outcomes and decrease mortality rates. Our study also found that older age and pulmonary infections were independent risk factors for mortality in multivariate analysis. This finding was consistent with the results of multiple previous studies.³⁹⁻⁴¹

This study had several limitations. Firstly, this was a retrospective study, with all data sourced from a single centre. Consequently, the possibility of selection bias was higher than in multicentre studies. As the hospital participating in this study is university-affiliated and has a Level I trauma centre, it is possible that the included cases may have experienced severe fractures or had complex comorbidities. Secondly, this study did not consider the potential influence of dietary intake, psychological factors,

physical activity, and medication use on patient outcomes. Thirdly, the sample size of this study was relatively small, and further prospective cohort studies are required to determine the effects of GNRI and PNI in older patients with hip fracture.

Conclusion

In conclusion, this study demonstrated that low geriatric nutritional risk index was the risk factor for 1-year mortality in older patients undergoing hip fracture surgery. Furthermore, increased risk estimates were observed in the subgroups of male and ASA III-IV, which underscored the importance of nutritional interventions for these populations. These findings suggest that timely nutritional assessment and intervention are essential for geriatric patients with hip fractures.

Acknowledgement

We thank all the participants included in this study.

ORCID iDs

Wei Wu <https://orcid.org/0009-0002-5888-3718>

Yunfeng Rui <https://orcid.org/0000-0001-9019-5531>

Ethical Statement

This study was approved by the Ethics Committee of Zhongda Hospital Affiliated to Southeast University (2022zdsyl183-p01). Consistent with national laws and institutional protocols, written informed consent was not required from study participants.

Author contributions

Wei Wu, Huanyi Zhu, Yucheng Gao, Chuwei Tian and Chen Rui contributed to the data acquisition. Wei Wu and Huanyi Zhu

conducted the analysis and interpretation of the data. Wei Wu and Xiangxu Chen drafted the initial manuscript. Wei Wu, Tian Xie, Liu Shi, Yingjuan Li and Yunfeng Rui provided substantial revisions to the manuscript. All authors read and approved the final manuscript.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by Winfast Charity Foundation (YL20220525).

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data Availability Statement

Due to data use agreements with the participating hospital, we are unable to provide the data used in this study.

References

- Bhandari M, Swiontkowski M. Management of acute hip fracture. *N Engl J Med*. 2017;377(21):2053-2062. doi:10.1056/NEJMcp1611090
- Veronese N, Maggi S. Epidemiology and social costs of hip fracture. *Injury*. 2018;49(8):1458-1460. doi:10.1016/j.injury.2018.04.015
- Sing CW, Lin TC, Bartholomew S, et al. Global Epidemiology of hip fractures: secular trends in incidence rate, post-fracture treatment, and all-cause mortality. *J Bone Miner Res*. 2023;38(8):1064-1075. doi:10.1002/jbmr.4821
- Abrahamsen B, van Staa T, Ariely R, Olson M, Cooper C. Excess mortality following hip fracture: a systematic epidemiological review. *Osteoporos Int*. 2009;20(10):1633-1650. doi:10.1007/s00198-009-0920-3
- Haentjens P, Magaziner J, Colón-Emeric CS, et al. Meta-analysis: excess mortality after hip fracture among older women and men. *Ann Intern Med*. 2010;152(6):380-390. doi:10.7326/0003-4819-152-6-201003160-00008
- Li Y, Liu F, Xie H, Zhu Y. Investigation and analysis of frailty and nutrition status in older adult patients with hip fracture. *Nutr Clin Pract*. 2023;38(5):1063-1072. doi:10.1002/ncp.10993
- Malafarina V, Reginster JY, Cabrerizo S, et al. Nutritional status and nutritional treatment are related to outcomes and mortality in older adults with hip fracture. *Nutrients*. 2018;10(5):555. doi:10.3390/nu10050555
- Kramer IF, Blokhuis TJ, Verdijk LB, van Loon LJC, Poeze M. Perioperative nutritional supplementation and skeletal muscle mass in older hip-fracture patients. *Nutr Rev*. 2019;77(4):254-266. doi:10.1093/nutrit/nuy055
- Li S, Zhang J, Zheng H, Wang X, Liu Z, Sun T. Prognostic role of serum albumin, total lymphocyte count, and mini nutritional assessment on outcomes after geriatric hip fracture surgery: a meta-analysis and systematic review. *J Arthroplast*. 2019;34(6):1287-1296. doi:10.1016/j.arth.2019.02.003
- Volkert D, Berner YN, Berry E, et al. ESPEN guidelines on enteral nutrition: geriatrics. *Clin Nutr*. 2006;25(2):330-360. doi:10.1016/j.clnu.2006.01.012
- Bouillanne O, Morineau G, Dupont C, et al. Geriatric Nutritional Risk Index: a new index for evaluating at-risk elderly medical patients. *Am J Clin Nutr*. 2005;82(4):777-783. doi:10.1093/ajcn/82.4.777
- Lidoriki I, Schizas D, Frountzas M, et al. GNRI as a prognostic factor for outcomes in cancer patients: a systematic review of the literature. *Nutr Cancer*. 2021;73(3):391-403. doi:10.1080/01635581.2020.1756350
- Xiong J, Wang M, Zhang Y, et al. Association of geriatric nutritional risk index with mortality in hemodialysis patients: a meta-analysis of cohort studies. *Kidney Blood Press Res*. 2018;43(6):1878-1889. doi:10.1159/000495999
- Li H, Cen K, Sun W, Feng B. Prognostic value of geriatric nutritional risk index in elderly patients with heart failure: a meta-analysis. *Aging Clin Exp Res*. 2021;33(6):1477-1486. doi:10.1007/s40520-020-01656-3
- Buzby GP, Mullen JL, Matthews DC, Hobbs CL, Rosato EF. Prognostic nutritional index in gastrointestinal surgery. *Am J Surg*. 1980;139(1):160-167. doi:10.1016/0002-9610(80)90246-9
- Sun K, Chen S, Xu J, Li G, He Y. The prognostic significance of the prognostic nutritional index in cancer: a systematic review and meta-analysis. *J Cancer Res Clin Oncol*. 2014;140(9):1537-1549. doi:10.1007/s00432-014-1714-3
- Park S, Ahn HJ, Yang M, Kim JA, Kim JK, Park SJ. The prognostic nutritional index and postoperative complications after curative lung cancer resection: a retrospective cohort study. *J Thorac Cardiovasc Surg*. 2020;160(1):276-285.e1. doi:10.1016/j.jtcvs.2019.10.105
- Nogueiro J, Santos-Sousa H, Pereira A, et al. The impact of the prognostic nutritional index (PNI) in gastric cancer. *Langenbecks Arch Surg*. 2022;407(7):2703-2714. doi:10.1007/s00423-022-02627-0
- Kotera A. Geriatric nutritional risk index and controlling nutritional status score can predict postoperative 180-day mortality in hip fracture surgeries. *JA Clin Rep*. 2019;5(1):62. doi:10.1186/s40981-019-0282-6
- Ren H, Wu L, Hu W, Ye X, Yu B. Prognostic value of the c-reactive protein/prognostic nutritional index ratio after hip fracture surgery in the elderly population. *Oncotarget*. 2017;8(37):61365-61372. doi:10.18632/oncotarget.18135
- Riley RD, Ensor J, Snell KIE, et al. Calculating the sample size required for developing a clinical prediction model. *Bmj*. 2020;368:m441. doi:10.1136/bmj.m441
- Han TS, Yeong K, Lisk R, Fluck D, Fry CH. Prevalence and consequences of malnutrition and malnourishment in older individuals admitted to hospital with a hip fracture. *Eur J Clin Nutr*. 2021;75(4):645-652. doi:10.1038/s41430-020-00774-5

23. Serón-Arbeloa C, Labarta-Monzón L, Puzo-Foncillas J, et al. Malnutrition screening and assessment. *Nutrients*. 2022;14(12):2392. doi:[10.3390/nu14122392](https://doi.org/10.3390/nu14122392)
24. Laulund AS, Lauritzen JB, Duus BR, Mosfeldt M, Jørgensen HL. Routine blood tests as predictors of mortality in hip fracture patients. *Injury*. 2012;43(7):1014-1020. doi:[10.1016/j.injury.2011.12.008](https://doi.org/10.1016/j.injury.2011.12.008)
25. Akinleye SD, Garofolo G, Culbertson MD, Homel P, Erez O. The role of BMI in hip fracture surgery. *Geriatr Orthop Surg Rehabil*. 2018;9:2151458517747414. doi:[10.1177/2151458517747414](https://doi.org/10.1177/2151458517747414)
26. Khan SK, Kalra S, Khanna A, Thiruvengada MM, Parker MJ. Timing of surgery for hip fractures: a systematic review of 52 published studies involving 291,413 patients. *Injury*. 2009;40(7):692-697. doi:[10.1016/j.injury.2009.01.010](https://doi.org/10.1016/j.injury.2009.01.010)
27. Simunovic N, Devereaux PJ, Sprague S, et al. Effect of early surgery after hip fracture on mortality and complications: systematic review and meta-analysis. *Cmaj*. 2010;182(15):1609-1616. doi:[10.1503/cmaj.092220](https://doi.org/10.1503/cmaj.092220)
28. Anthony CA, Duchman KR, Bedard NA, et al. Hip fractures: appropriate timing to operative intervention. *J Arthroplast*. 2017;32(11):3314-3318. doi:[10.1016/j.arth.2017.07.023](https://doi.org/10.1016/j.arth.2017.07.023)
29. Rubenstein LZ, Harker JO, Salvà A, Guigoz Y, Vellas B. Screening for undernutrition in geriatric practice: developing the short-form mini-nutritional assessment (MNA-SF). *J Gerontol A Biol Sci Med Sci*. 2001;56(6):M366-M372. doi:[10.1093/gerona/56.6.m366](https://doi.org/10.1093/gerona/56.6.m366)
30. Seitz DP, Adunuri N, Gill SS, Rochon PA. Prevalence of dementia and cognitive impairment among older adults with hip fractures. *J Am Med Dir Assoc*. 2011;12(8):556-564. doi:[10.1016/j.jamda.2010.12.001](https://doi.org/10.1016/j.jamda.2010.12.001)
31. Foo MXE, Wong GJY, Lew CCH. A systematic review of the malnutrition prevalence in hospitalized hip fracture patients and its associated outcomes. *JPEN J Parenter Enteral Nutr*. 2021;45(6):1141-1152. doi:[10.1002/jpen.2211](https://doi.org/10.1002/jpen.2211)
32. Deutz NE, Bauer JM, Barazzoni R, et al. Protein intake and exercise for optimal muscle function with aging: recommendations from the ESPEN Expert Group. *Clin Nutr*. 2014;33(6):929-936. doi:[10.1016/j.clnu.2014.04.007](https://doi.org/10.1016/j.clnu.2014.04.007)
33. Bano G, Trevisan C, Carraro S, et al. Inflammation and sarcopenia: a systematic review and meta-analysis. *Maturitas*. 2017;96:10-15. doi:[10.1016/j.maturitas.2016.11.006](https://doi.org/10.1016/j.maturitas.2016.11.006)
34. Ernst A, Wilson JM, Ahn J, Shapiro M, Schenker ML. Malnutrition and the orthopaedic trauma patient: a systematic review of the literature. *J Orthop Trauma*. 2018;32(10):491-499. doi:[10.1097/bot.0000000000001254](https://doi.org/10.1097/bot.0000000000001254)
35. Lu W, Gao B, Fan J, et al. Mesenchymal progenitors derived from different locations in long bones display diverse characteristics. *Stem Cells Int*. 2019;2019:5037578. doi:[10.1155/2019/5037578](https://doi.org/10.1155/2019/5037578)
36. Goodnough LH, Goodman SB. Relationship of aging, inflammation, and skeletal stem cells and their effects on fracture repair. *Curr Osteoporos Rep*. 2022;20(5):320-325. doi:[10.1007/s11914-022-00742-x](https://doi.org/10.1007/s11914-022-00742-x)
37. Forsén L, Sogaard AJ, Meyer HE, Edna T, Kopjar B. Survival after hip fracture: short- and long-term excess mortality according to age and gender. *Osteoporos Int*. 1999;10(1):73-78. doi:[10.1007/s001980050197](https://doi.org/10.1007/s001980050197)
38. Reguant F, Arnaú A, Lorente JV, Maestro L, Bosch J. Efficacy of a multidisciplinary approach on postoperative morbidity and mortality of elderly patients with hip fracture. *J Clin Anesth*. 2019;53:11-19. doi:[10.1016/j.jclinane.2018.09.029](https://doi.org/10.1016/j.jclinane.2018.09.029)
39. von Friesendorff M, McGuigan FE, Wizert A, et al. Hip fracture, mortality risk, and cause of death over two decades. *Osteoporos Int*. 2016;27(10):2945-2953. doi:[10.1007/s00198-016-3616-5](https://doi.org/10.1007/s00198-016-3616-5)
40. Wang PW, Yao XD, Zhuang HF, et al. Mortality and related risk factors of fragile hip fracture. *Orthop Surg*. 2022;14(10):2462-2469. doi:[10.1111/os.13417](https://doi.org/10.1111/os.13417)
41. Kim SD, Park SJ, Lee DH, Jee DL. Risk factors of morbidity and mortality following hip fracture surgery. *Korean J Anesthesiol*. 2013;64(6):505-510. doi:[10.4097/kjae.2013.64.6.505](https://doi.org/10.4097/kjae.2013.64.6.505)