Developing a Scoring Model to Predict the Risk of Injurious Falls in Elderly Patients: A Retrospective Case-control Study in Multi-center Acute Hospitals

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Research article

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Abstract

Background Injurious falls seriously threaten the safety of elderly patients. The identification of risk factors to predict the probability of injurious falls is an important issue still needed to be solved urgently. We aimed to identify predictors and develop a nomogram as an appropriate assessment tool for distinguishing high-risk populations of injurious falls from older adults in acute settings.

Methods A retrospective case-control study was conducted in three acute care hospitals in Shanghai, China. We included elderly patients with injurious falls from 2014 to 2018, and the control patients without falls randomly identified from the electronic medical records. A new nomogram was established based on risk factors and its discrimination and calibration were verified to confirm the accuracy of the prediction. And the cut-off value of risk stratification was determined to help medical staff identify the high-risk groups.

Results 115 elderly patients with injurious falls and 230 controls were identified in our study. The history of fractures, orthostatic hypotension, function status, sedative-hypnotics and the level of serum albumin were independent risk factors for injurious falls in elderly patients. And the scoring nomogram showed an acceptable predicting performance of injurious falls (C-index: 0.865, 95%CI: 0.789-0.941; corrected C-index: 0.868, 95%CI: 0.852-0.884). The threshold was 153 points to distinguish the high-risk groups from the aging patients, with acceptable sensitivity (72.2%) and specificity (86.1%).

Conclusions The established nomogram will allow for identifying the high-risk populations among elderly patients, providing a new assessment tool to forecast the individual risk of injurious falls.

Background

Accidental falls are a serious threat to public health, especially among the elderly, and have become a major problem that needs to be addressed urgently [1]. Approximately one-third of older elders reported one or more falls in the past 12 months, with 37.5% of falls resulting in injuries and requiring medical treatment [2]. And in acute care settings, falls are also the common adverse events in the elderly due to complex disease conditions, reduced adaptability and other causes, resulting in a significant increase in the length of days and medical expenses because of the additional treatment of fall-related injuries [3–7].

The guidelines released to provide instructions for prevention falls recommend to screen and assess risk factors for older persons and consider the identifying factors to be a meaningful risk-averse approach to reduce the incidence of falls [8, 9]. In recent years, several studies pointed out that falls are the result of a combination of internal and external factors of the elderly and had developed relevant assessment tools for screening the high-risk population, which would be important and essential for implementing effective interventions and reducing the incidence of falls [10–12]. But more importantly, regarding the negative outcomes such as limited function, disability and loss of independence, identifying the factors associated with injurious falls deserve more great attention in the prevention program, which has not been further exploration completely. It remains unknown that the predicting performance of tools designed for assessing the risk of falls was suitable for the effective prediction of injuries.

Concerning injurious falls, some studies had shown that predictors such as gender, history of falls, medications, etc. were significantly related to the adverse events, which could be the accessible reference for medical staff [13–16].Aryee [13] pointed out that a history of falls, male, psychotropic agents, joint replacement and recent surgery were associated with the event of injurious falls. Lorraine [15] collected the data of whose patients sustained an injury after falls and argued that race and medicines were independent risk factors of injurious falls. However, the above studies only focused on the exploration of risk factors rather than risk prediction. How to translate the results into the appropriate form and make it easier for medical staff to apply to clinical practice is a priority issue that needs to be dealt with urgently.

A nomogram, based on the predictive indicators of a clinical event, can calculate the individual probability by presenting a simple and visible graphical representation [17, 18]. Due to the user-friendly interfaces, rapid and accurate predictive capabilities, it has been extensively used in oncology [17, 19].And in the inpatient settings, the risk of falls is usually expressed in a graded manner, which may cause some elderly patients and their primary caregivers to misunderstand the risk of falls that may be caused by educational or regional differences. Using a nomogram to represent the numerical risk, for older adults and their primary caregivers, may improve the awareness of the prevention falls actively. And for medical staff, the way of direct numerical risk and corresponding stratification, which can be applied to smart devices, is easy to use and facilitate clinical decision-making.

In light of these considerations, the purpose of this investigation was to determine the risk factors and developed a scoring nomogram to predict the risk of injurious falls for elderly patients in acute hospitals. Meanwhile, the construction of a new method of risk stratification to identify the high risk of populations can give the advantage to implement targeted interventions to reduce severe consequences and improve the quality of care.

Methods

A retrospective case-control study was performed to identify predictors of injurious falls in three acute care hospitals in Shanghai. And the primary goal was to construct a user-friendly nomogram to forecast the risk of injurious falls and validate its predicting performance for confirming the feasibility of a clinical application.

Study Population

All elderly patients with injurious falls after admission in the three acutely public hospitals were included in our study between 2014 to 2018, which had already reported by the adverse events system designed for recording the information about the characteristic of the fall event. The definition and classification criteria for injuries were based on the insights of the National Quality Forum (NQF) [20]. A control group of patients during hospitalization were identified from the electronic medical record system, which was randomly matched according to the admitted ward and data in a 1:2 ratio to balance the difference of overall medical conditions and environment of hospitals for adjustment of selection bias. Inclusion criteria for both groups

included that age ≧65 years and the medical records were relatively complete for the data collected. Psychiatric patients were excluded from the study due to the characteristics of disease with a significant tendency to fall. The Ethics Committee of Hua Shan Hospital Affiliated Fudan University approved this study protocol and waived the informed consent due to the retrospective design.

Measures

Details on the demographic and medical data were tended to collect, including the age, gender, body mass index (BMI), number of comorbidities, history of falls or fractures, orthostatic hypotension (OH), altered or limited mobility gait problems, function status (independent vs. partially dependent vs. completely dependent), increased toileting needs, medication(sedative-hypnotics/antipsychotics/diuretics)and the laboratory tests [serum albumin/ hemoglobin/ international normalized ratio (INR)]. In the study, the laboratory tests collected was the first examination results, which were routinely monitored after admission. The related data of events were also gathered for summarizing the characteristics of injurious falls, including the time, location, activity, and so on.

Statistical analysis

All statistical analyses were calculated with IBM SPSS, Version 20.0 (SPSS Inc., Chicago, USA). A $P < 0.05$ was used to describe statistically significant differences. Characteristics of the study group and control group were described by mean ± standard deviation (SD) or frequency and percentage. Comparing the group difference, the Student's t-test or Mann-Whitney U-test was performed for continuous variables, and the Chi-square test or Fisher's exact test for categorical variables. Based on the results of univariate analysis, the variables ($P<0.05$) were included in a multivariate logistic regression model to screen out the independent predictors of injurious falls and generate odds ratio (OR) and 95% confidence intervals (95%CI) to draw the primary conclusion. A nomogram was established by R, Version 3.4.3 (https://www.r-project.org). The receiver operating characteristic (ROC) curve was illustrated and the area under curve (AUC) expressed by the C-index represented the predicting performance of the model, which reflected the ability of a model to discriminate between those who would suffer injurious falls from those who would not. The nomogram was then internally validated by the 1000 bootstrap resampling to reduce the bias and verify its accuracy of prediction. For the application in clinical practice, an optimal cut-off value with acceptable sensitivity and specificity was determined to risk stratification of high/low risk of injurious falls.

Results

A total of 115 elderly patients (49.1%) with different degree injuries among 234 patients (age≥18years) with falls after admitted hospitals, which were identified by the adverse events report system. 230 matched controls were included in our study, and no fall events occurred in the group. There is no subject was excluded because the psychiatric department was not set up in the three hospitals. Consequently, 345 patients were incorporated into our study for analysis.

1.1 Circumstances of injurious falls

As shown in Table 1, 31 (27.0%) had mild injuries, 12 (10.4%) had moderate damage, 69 (60.0%) had severe damage, and 3 (2.6) died among the study group. And a majority of cases occurred in internal departments (82.6%), and 0 (the day of admission)–3 days (32.2%) or 7–14 days (33.9%) after admission were the period of high incidence. The month and time were often from April to June (32.1%) and from 00:01 to 06:59 (34.8%). It was worth noting that 40.9% of the cases were not accompanied by anyone. And the primary activities associated with injurious fall were the change of position (33.9%) and excretion (30.5%), mainly due to weakness (44.3%), dizziness (23.4%) and slipping (21.7%).

1.2 Predictors for injurious falls

The characteristics of the overall patients were presented in Table 2. The study group comprised 60 males (52.2%) and 55 females (47.8%), and the median age was 81.16±8.81 years. In the control group, the median age was significantly lower than the study group (76.73±8.76 years vs. 81.16±8.81 years, P<0.05), and the percent of the male was 55.7% (n = 128). Univariate analysis showed that age, history of falls, history of fractures, orthostatic hypotension, function status, increased needs of toileting, sedative-hypnotics, diuretics, the level of laboratory testing (hemoglobin, serum albumin, and INR) were statistically significant differences between groups (all P<0.05). The multivariate analysis revealed that history of fractures (OR = 4.378,95CI:2.227–8.609,P = 0.000), orthostatic hypotension (OR = 3.992, 95CI%:1.800–8.856,P = 0.001), function status (OR = 2.490,95CI%:1.110–5.586,P = 0.027), sedative-hypnotics (OR = 8.664,95CI%:4.377–17.149,P = 0.000) and low level of serum albumin (OR = 10.886, 95CI: 5.313–22.222,P = 0.000) were the valuable predictors for injurious falls.

1.3 Development of the predicting nomogram

We constructed a nomogram as illustrated in Figure 1, incorporated the above-identified five variables, to identify the individual risk of injurious falls in the elderly patients in the acute care settings. From Figure 2A, the AUC was determined with a C-index of 0.865 (95%CI: 0.789–0.941), and 0.868 (95%CI: 0.852–0.884) after correction by 1000 bootstrap resampling. The calibration plot presented that the satisfactory concordance of the nomogram-predicted and observed probabilities of elderly injurious falls (Figure 2B).

1.4 Risk stratification of the scoring mode

To facilitate medical staff to use the predicting model for risk stratification of injurious falls to identify the population of high-risk, the cut-off value with the optimal combination of sensitivity and specificity was calculated from the ROC curve.

When the total point of injurious falls predicted by the nomogram was over 153 points, the nomogram had a sensitivity and specificity of 72.2% and 86.1%, respectively. And the comparison of the length of stay and medical expenses for high-risk and low-risk groups was illustrated from Figure 3.

Discussion

Injuries falls can cause high disability and mortality for the elderly leading to the prolonged days of hospitalization and the increasing medical expenses. The crucial and cost-effective solution needed to be further explored in the prevention program is to identify high-risk elders of injurious falls. To the best of our knowledge, this was the first study to develop a predictive model of injurious falls among the older adults admitted in the acute care hospital settings. Our study suggested that the risk factors including the history of fractures, orthostatic hypotension, function status, sedative-hypnotics and low level of serum albumin can influence the risk of injurious falls in elderly patients. Furthermore, the new scoring nomogram developed by predictors showed an acceptable predictive performance for clinical practice to predict the individual risk of injurious falls and to contribute to implementing the intervention that targeted to modify risk factors.

In line with previous research, we found that those patients with a history of fractures were significantly associated with the risk of re-fracture after falls, possibly with an explanation of a decrease in the strength and quality of muscles and bones due to the limited activity caused by previous fractures [21]. Function status was a predictor of injurious falls, representing the capability of self-care in activities of daily living (ADL). Samuel et al. hold the consistent view of the elderly needing assistance with ADL tended suffering an injurious fall [22]. Our study suggests that OH, a common disorder of elderly adults, can influence the risk of injurious falls, in accordance with Chang [23] study. The common discomforts of the disease are dizziness, light-headedness, visual impairment, weakness and fatigue, which may contribute to the occurrence of injurious falls [24]. Since it usually occurs during the transformation of body posture, this is also compatible with the circumstance of injurious falls occurred at the bedside in our study. The previous studies had pointed out that the risk of hip fracture was significantly increased in elderly patients with taking sedative-hypnotics, in line with our suggestions that sedative-hypnotics was associated with severe injuries such as fractures after falls [25]. The reason for that may be due to the side effects on the central nervous system, especially in the first few hours after taking the drugs easily leading to some adverse reactions such as drowsiness, fatigue, impaired balance and functions of cognitive and motor, especially in elderly patients [26, 27]. And this is the first study to directly determine the relationship between the level of serum ALB and injurious falls, and the elders with a low level of ALB at admission were more likely prone to experience injuries after falling and needed to be highly valued. The reasonable interpretation is the fact that albumin, a biomarker representing nutritional status, has been at a low level for a long time, which is not conducive to

maintaining normal skeletal muscle mass, strength and function and may cause sarcopenia eventually causing severe injuries after the fall [28].

The nomogram based on five independent risk factors was constructed to quantify the specific risk of injurious falls in older patients and showed the satisfactory performance of prediction. The risk assessment of injurious falls, using the nomogram constructed in our study, can be accomplished by reviewing past medical history, evaluating the results of laboratory tests, function status and medication at admission. The population with a total score of ≥ 153 points should be included in the high-risk groups and develop personalized and targeted interventions to early reduce the incidence of injurious falls, avoiding prolonged hospital stays and increased medical costs.

According to the results, older patients with risk factors revealed in our study should be identified and monitored timely to decrease the risk of injurious falls through targeted interventions. Elderly patients should be advised to exercise appropriately or to use assistive walking equipment for gait and posture problems. Meanwhile, personalized education should be also conducted, such as the placement of commonly used items, the methods of position changing and the correct responses after fall for improving the fall management ability of patients and caregivers [29, 30]. And the applicability of sedative-hypnotics should be strict to avoid improper use of drugs by medical staff, and the patients with OH should be paid great attention as well, and remind patients to avoid the following specific circumstances, such as changing position rapidly, overeating, standing for a long time, etc., which easily trigger the occurrence of OH. At the same time, raising the bedside properly and increasing blood volume by adding to the intake of water (2–3L) and salts (6–10g) could be considered as feasible strategies to prevent OH [31, 32]. Furthermore, elderly patients with chronic kidney disease, severe liver disease or other multi-comorbidities, nutritional assessment and supplementation should be carried out to timely avoid frailty, malnutrition and other conditions.

Through the application of the visual model, it was possible to calculate the individualized probability, and avoid the deviation of understanding caused by the degree of education, thereby improving the active prevention awareness of patients and primary caregivers to jointly participate in the program of falls. And medical staff can identify the high-risk population that should be included in the prior management monitoring to implement effective interventions to reduce serious adverse consequences of falls. Meanwhile, the model can be set in the electronic medical record system, automatically extracting the key data, to facilitate the labor-saving efficiently.

However, there were several limitations in our study: the types of sedative-hypnotics and fractures were not defined in detail, and the sample size of our study was limited. Additionally, laboratory tests were described using categorical variables due to the different research sites. Further study should provide a large sample and explore the mechanisms, specific types of sedative-hypnotics and fractures, behind the increased risk of injurious falls and investigate the association of injurious falls and specific values of laboratory indicators.

Conclusions

We identified significant predictors of injurious among the elderly patients in a retrospective case-control study, and elderly persons with five risk factors were more susceptible to suffer injuries falls than those without. Meanwhile, a nomogram was then constructed for predicting individualized risk and provided a new approach to risk stratification for identifying a high-risk population in acute care hospitals. Different from the traditional risk assessment tools, the nomogram can improve the perception of injurious falls for patients and primary caregivers through a numerical representation of risk. And medical staff can use this model to quickly screen and identify high-risk groups and implement targeted interventions to reduce the incidence of injuries falls and ensure patient safety.

Declarations

Ethics approval and consent to participate

The Ethics Committee of Huashan Hospital Affiliated to Fudan University approved this study protocol and waived the informed consent due to the retrospective data collected by Electronic medical record system.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors’ contributions

MZ: Data acquisition, analysis, and interpretation; writing the article; and final approval of the version to be published.

SL: Data analysis and interpretation, writing the article, and final approval of the version to be published.

YX: Conceptualization, data interpretation, critical revision of the article, and final approval of the version to be published.

XS: Data analysis and interpretation, critical revision of the article, and final approval of the version to be published.

HJ: Conceptualization, data interpretation, writing and critical revision the article, and final approval of the version to be published.

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Tables

Table 1. Circumstances of injurious falls events

Variables	n	%
Degree of injury		
Mild	31	27.0
Moderate	12	10.4
Severe	69	60.0
Died	3	2.6
Department		
Internal	95	82.6
Surgical	17	14.8
Others	3	2.6
Admission-Falls(days)		
0-3	37	32.2
4-6	19	16.5
7-14	39	33.9
15-21	14	12.2
>21	6	5.2
Month		
1-3	32	26.8
4-6	37	32.1
7-9	27	23.5
10-12	19	16.5
Date		
1-10	45	39.1
11-20	36	31.3
≥21	34	29.6
Time		
7:00-13:00	24	20.9
13:01-19:00	21	18.3
19:01-24:00	30	26.1
00:01-06:59	40	34.8
Type of Accompany		
Family	27	23.5
Care workers	41	35.7
None	47	40.9
Location		
Bedside	42	36.5
Bathroom	39	33.9
Ward	16	9.6
Others	18	15.7
Type of reporting		

Patient him(her)self	14	12.2
Family and Care workers	41	35.7
Other Patients in the same ward	35	30.4
Medical staff	20	17.4
Others	5	4.3
Activity related events		
Change position	39	33.9
Excretion	35	30.5
Bathing	7	6.1
Hanging around	16	13.9
Examination	5	4.3
Others	13	11.3
Cause of falling		
Weakness	51	44.3
Dizziness	27	23.4
Slipping	25	21.7
Stumbling	9	7.8
Others	3	2.6

Table 2. Comparison of the characteristics of the patients with/ without injurious falls

Variables	Study group(n=115)		Control group(n=230)		Univariate P[a]	Multivariate P[b]	OR	95%CI
	n	%	n	%				
Age					**0.000**			
[65,75)	22	19.1	101	43.9				
[75,85)	39	33.9	78	33.9				
≥85	54	47.0	51	22.2				
Gender					0.541			
Male	60	52.2	128	55.7				
Female	55	47.8	102	44.3				
BMI					0.358			
18.5	12	10.4	15	6.5				
[18.5,25)	81	70.4	156	67.8				
[25,30)	20	17.4	51	22.2				
≥30	2	1.7	8	3.5				
Number of Comorbidities					0.827			
0-2	46	40.0	100	43.5				
3-6	60	52.2	113	49.1				
≥7	9	7.8	17	7.4				
History of falls					**0.000**			
Yes	54	47.0	46	20.0				
NO	61	53.0	184	80.0				
History of fractures					**0.000**	**0.000**	**4.378**	**2.227-8.609**
Yes	44	38.3	38	16.5				
NO	71	61.7	192	83.5				
OH					**0.000**	**0.001**	**3.992**	**1.800-8.856**
Yes	30	26.1	26	11.3				
NO	85	73.9	204	88.7				
					0.109			
	68	59.1	115	50.0				
	47	40.9	115	50.0				

Altered or limited mobility gait problems								
Yes								
NO								
Function Status					**0.000**	**0.027**	**2.490**	**1.110-5.586**
Independent								
Partially dependent	6	5.2	49	21.3				
Completely dependent	97	84.3	177	77.0				
	12	10.4	4	1.7				
Increased Needs of Toileting					**0.000**			
Yes	45	39.1	47	20.4				
No	70	60.9	183	79.6				
Sedative-hypnotics					**0.000**	**0.000**	**8.664**	**4.377-17.149**
Yes								
NO	56	48.7	23	10.0				
	59	51.3	207	90.0				
Antipsychotics					0.285			
Yes	10	8.7	13	5.7				
NO	105	91.3	217	94.3				
Diuretics					**0.000**			
Yes	51	44.3	52	22.6				
NO	64	55.7	178	77.4				
Level of Hemoglobin					**0.000**			
Normal	30	26.1	121	52.6				
Low	85	73.9	108	47.0				
High	0	0	1	0.4				
Level of Serum Albumin					**0.000**	**0.000**	**10.866**	**5.313-22.222**
Normal	22	19.1	137	59.6				

Low	93	80.9	93	40.4	
High	0	0	0	0	
Level of INR					**0.008**
Normal	96	83.5	212	92.2	
Low	5	4.3	2	0.9	
High	14	12.2	16	7.0	

BMI=body mass index; OH= orthostatic hypotension; INR=international normalized ratio; OR=odds ratio; 95%CI=95% confidence intervals)

[a] The x^2 test and Fisher's exact test were used to compare the two groups.

[b] The logistic regression model (Forward:LR) was used to determine the predictors.

Figures

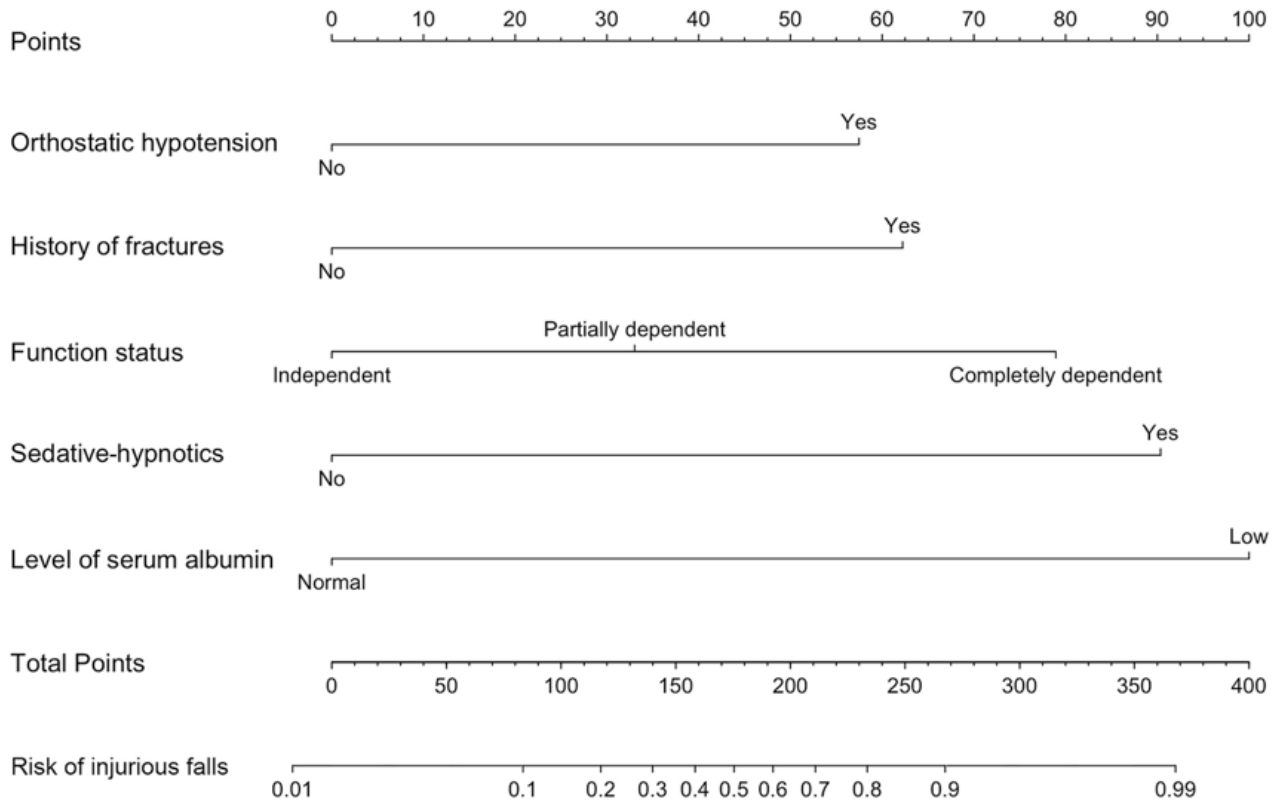

Figure 1. The novel nomogram to predict the probability of injurious falls in elderly patients in acute care hospitals.

Figure 1

The novel nomogram to predict the probability of injurious falls in elderly patients in acute care hospitals.

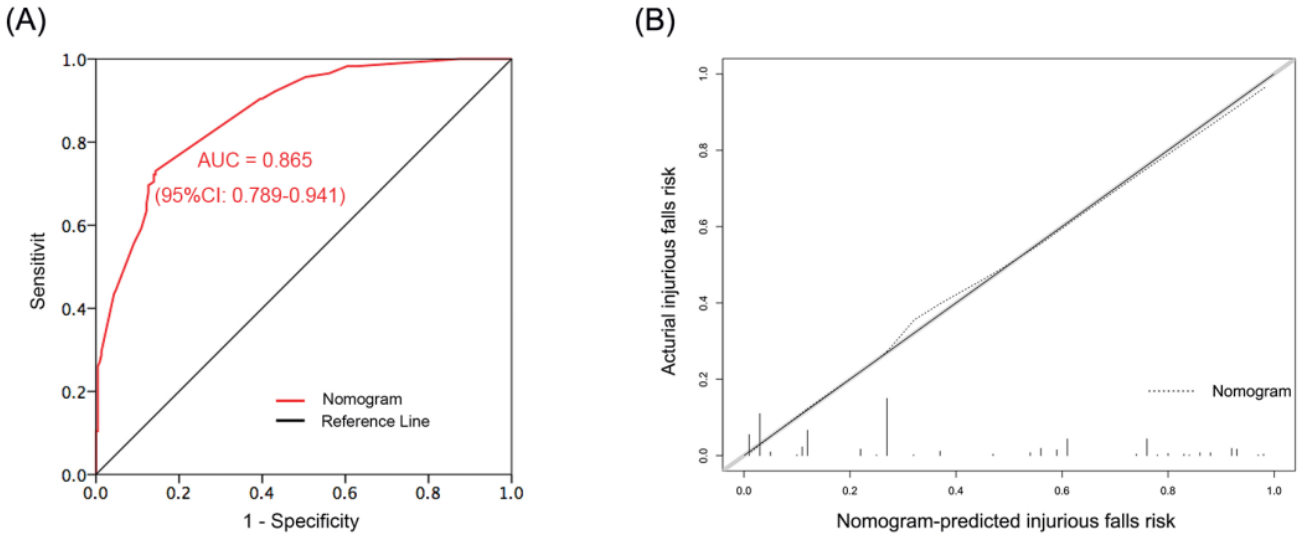

Figure 2. ROC(A) and calibration plot(B) of the nomogram for predicting the risk of injurious falls. The model-predicted probability of the clinical model is illustrated on the X-axis, and the observed probability of older adults with injury in a fall event is displayed on the Y-axis.

Figure 2

ROC (A) and calibration plot (B) of the nomogram for predicting the risk of injurious falls. The model-predicted probability of the clinical model is illustrated on the X-axis, and the observed probability of older adults with injury in a fall event is displayed on the Y-axis.

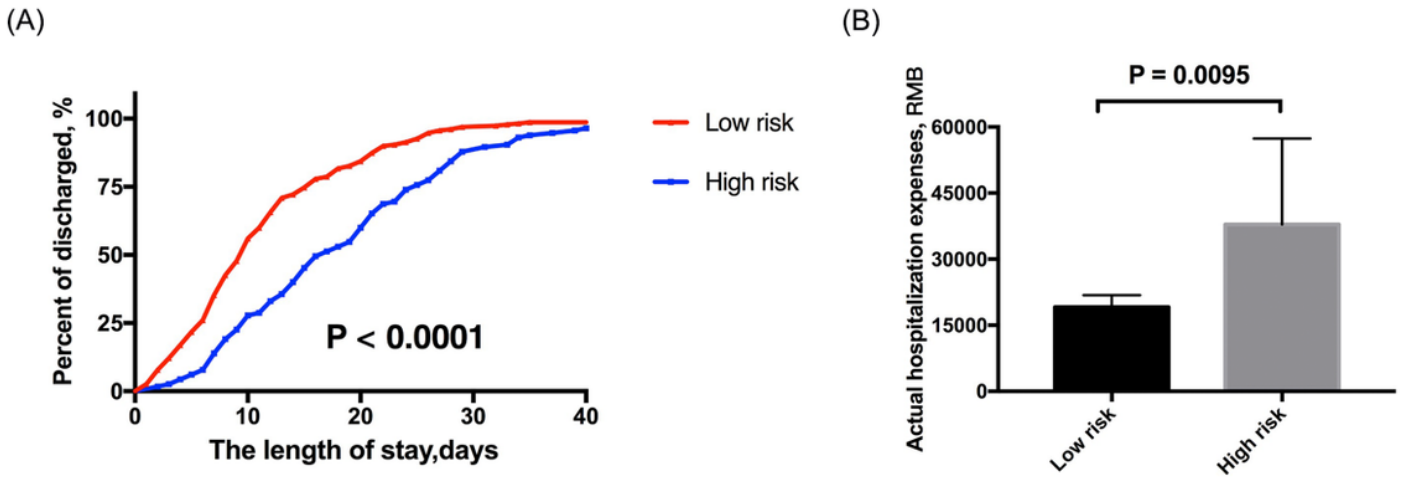

Figure 3. Comparison of the length of stay (A) and medical expenses (B) for high-risk and low-risk

Figure 3

Comparison of the length of stay and medical expenses for high-risk and low-risk groups.