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A clinical nomogram for predicting major adverse cardiovascular and cerebrovascular events in elderly Chinese patients with acute coronary syndrome undergoing percutaneous coronary intervention: development and validation in a real-world cohort

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ABSTRACT

BACKGROUND As the global population ages, the number of elderly patients with acute coronary syndrome (ACS) rises. However, prognostic assessment tools for elderly patients with ACS remain lacking, particularly in the Chinese population. This study aimed to develop and validate a nomogram to predict 2-year major adverse cardiovascular and cerebrovascular events (MACCE) in elderly Chinese patients with ACS.

METHODS A retrospective analysis was conducted using two independent cohorts of ACS patients aged ≥ 65 years who underwent percutaneous coronary intervention: the derivation cohort (n = 1674) and the validation cohort (n = 2333). Candidate predictors were selected using multivariable Cox proportional hazards regression and the Akaike information criterion. A final nomogram incorporating ten variables was constructed. Model performance was evaluated in terms of discrimination [concordance index (C-index) and area under the receiver operating characteristic curve (AUC)] and calibration (calibration plots).

RESULTS The 2-year incidence of MACCE was 12.5% (n = 210) in the derivation cohort and 15.6% (n = 364) in the validation cohort. The nomogram demonstrated good discrimination, with C-index values of 0.727 and 0.661 and AUCs of 0.723 and 0.699 in the derivation cohort and the validation cohort, respectively; significantly outperforming the GRACE risk score (P < 0.001). Calibration plots showed good agreement between the predicted and observed outcomes. Patients classified as the high-risk group by the nomogram had a significantly higher MACCE incidence compared to that of the low-risk group (log-rank P < 0.001).

CONCLUSIONS This newly developed nomogram provides a reliable tool for individualized prediction of the 2-year MACCE risk in elderly Chinese patients with ACS who underwent percutaneous coronary intervention. It outperformed the GRACE score in both discrimination and calibration and may help improve clinical decision-making and personalized risk stratification in this vulnerable population.

Acute coronary syndrome (ACS) is the most critical manifestation of coronary heart disease and accounts for a substantial proportion of mortality and morbidity in affected patients.[1] Advanced age is an independent predictor of adverse outcomes in a population with ACS. With the global acceleration in population aging, the incidence of ACS and its associated complications in elderly patients has been experiencing a progressive increase annually.[2,3] Despite the fact that two-thirds of the deaths due to myocardial infarction occur in elderly individuals, the proportion of elderly patients included in ACS-related studies is insufficient, and in some

cases, they are excluded directly.[4] Elderly individuals often present with various diseases and functional changes in multiple organs,[5] leading to an increased risk of ischemic events. Moreover, risk factors for ischemic events in the elderly may differ from those in the general population.[6] Therefore, for this high-risk and specific population of elderly patients with ACS, risk stratification, and precise treatment are crucial.

Currently, in clinical practice, the Global Registry of Acute Coronary Events (GRACE) and Thrombolysis in Myocardial Infarction (TIMI) scores are widely used to assess the risk of ischemic events during hospitalization and the short-term post-discharge period in patients with ACS.[7] In recent years, some researchers have used nomograms to predict long-term adverse outcomes in patients with ACS.[8-10] However, these tools do not adequately consider the unique risk features of elderly patients. Currently, there are limited tools available for assessing clinical prognostic risk, specifically in elderly patients with ACS, especially in the Chinese population. Therefore, the objective of this study was to develop and externally validate a clinical nomogram using two large Chinese cohorts to predict the two-year risk of major adverse cardiovascular and cerebrovascular events (MACCE) in elderly patients with ACS who underwent percutaneous coronary intervention (PCI). This study aimed to provide a better risk stratification tool for a continuously growing population of these patients.

METHODS

Study Design and Participants

This study was conducted on two cohorts. The derivation cohort consisted of 10,724 patients who underwent PCI at Fuwai Hospital between January 2013 and December 2013. The validation cohort comprised 18,701 patients with coronary artery disease who were recruited from January 2015 to May 2019 at nine medical centers in China. Inclusion criteria were: (1) age ≥ 65 years; and (2) meeting the diagnostic criteria for ACS,[7] including acute ST-segment elevation myocardial infarction, acute non-ST-segment elevation myocardial infarction, or unstable angina. The exclusion criteria included: (1) non-receipt of PCI; (2) loss to follow-up; and (3) incomplete or inaccurate recordings of demographic information, lifestyle data, or biochemical indicators. Following the standardized inclusion and exclusion criteria, 1674 elderly patients with ACS who underwent PCI were included in the derivation cohort and 2333 in the validation cohort, as illustrated in Figure 1. This study was approved by the Review Board of Fuwai Hospital and complied with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to their enrollment in the study.

Data Collection and Definitions

Patient information, including demographic data, clinical characteristics, medication treatments, and echocardiography and coronary angiography details, was collected from electronic medical records. All the statistical data were verified and managed by independent statisticians. The GRACE risk score for each patient was calculated before discharge using the GRACE risk score calculator (http://www.outcomes-umassmed.org/grace). Age was dichotomized at ≥ 85 years (versus < 85 years), as this threshold identifies "ultra-elderly" patients who typically present with higher comorbidities, polypharmacy, and a corresponding higher risk of adverse cardiovascular events. Cardiac insufficiency was defined as the left ventricular ejection fraction (LVEF) < 40%, indicating significant systolic dysfunction. Current smoking status was defined as "yes" if the patient had a history of smoking and had not quit smoking at the time of admission. Dual antiplatelet therapy (DAPT) use was defined as "yes" if the patient was prescribed both aspirin and a $P2Y_{12}$ inhibitor at discharge. History of PCI or coronary artery bypass grafting (CABG) was defined as "yes" if the patient had a history of either procedure prior to the current admission. Intra-aortic balloon pump (IABP) usage was defined as "yes" if an IABP was used during hospitalization. The number of target lesions was dichotomized at ≥ 4 lesions (versus < 4 lesions), as a count of ≥ 4 lesions is considered indicative of potential diffuse, multi-vessel disease. The residual SYNTAX score was categorized as 0 (representing complete revascularization) or > 0 (representing incomplete revascularization). Based on World Health Organization and Chinese guidelines for anemia, and considering that our study population consists of elderly patients with ACS, and a high proportion of males, preoperative hemoglobin was dichotomized using a uniform cutoff value of 120 g/L (< 120 g/L *vs.* ≥ 120 g/L). Preoperative platelet (PLT) was dichotomized at < 100×10^9/L (versus ≥ 100×10^9/L), based on the standard clinical definition of thrombocytopenia.

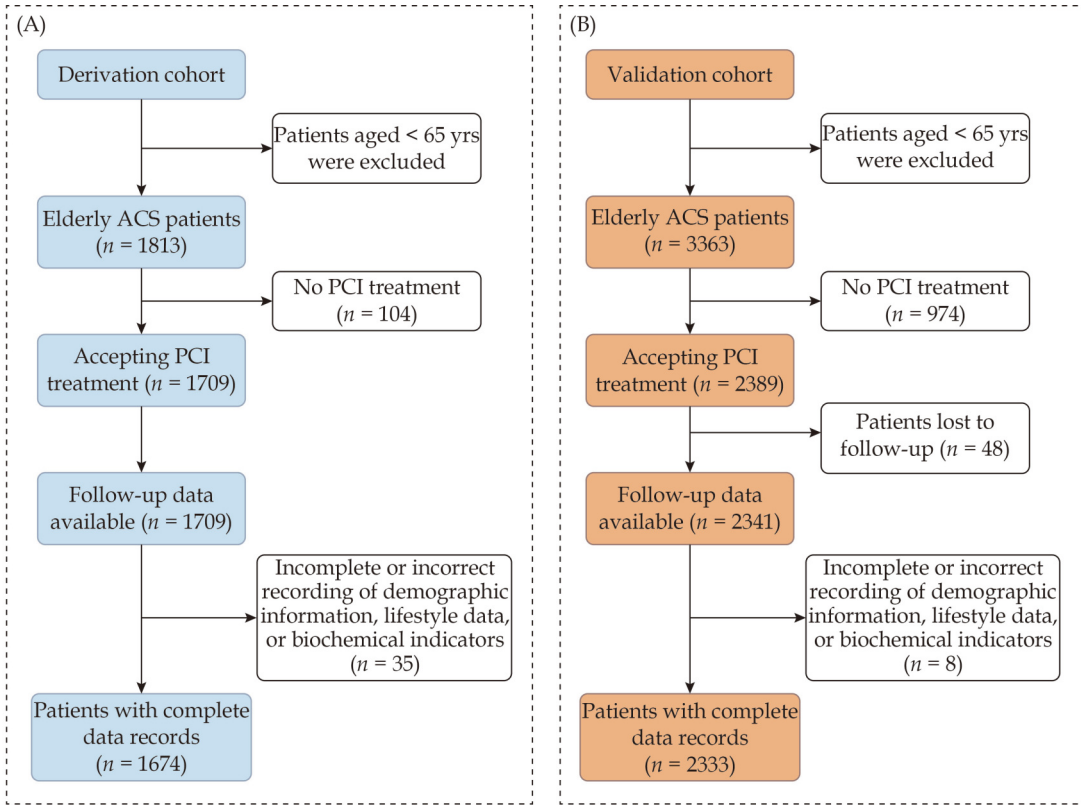

Figure 1 Flowchart of the study population selection. (A): Derivation cohort; and (B): validation cohort. ACS: acute coronary syndrome; PCI: percutaneous coronary intervention.

Follow-up and Endpoint Events

All patients in the derivation cohort underwent outpatient or telephone follow-up at 30 days, 6 months, 1 year, and 2 years post-discharge. In the validation cohort, all patients underwent outpatient clinic visits or telephone follow-ups 1-year and 2-year post-discharge. The study endpoints were defined as MACCE, including all-cause mortality, nonfatal myocardial infarction, nonfatal stroke, and revascularization. All clinical events were reviewed independently by two experienced clinical physicians who were blinded to the study protocol, with discrepancies resolved through consensus.

Statistical Analysis

Continuous variables were presented as mean ± SD, and the Student's *t*-test was used for comparisons between the two groups. Categorical variables were expressed as counts (percentages), and intergroup comparisons were performed using the Pearson's chi-squared test or the Fisher's exact probability test. Initially, variables with a univariate Cox analysis result of *P*-value < 0.2 were selected. Subsequently, variables for potential inclusion in the multivariate model were chosen based on expert consensus and clinical research results. These selected variables were then included in the multivariate Cox model, and model selection was performed using the Akaike information criterion (AIC). This approach is used in statistical model selection to strike a balance between model fit and complexity, aiding in the selection of the model that best suits the data, while avoiding overfitting or underfitting. Using the variable selection results from AIC, we constructed the final risk assessment model. Given the necessity of the Cox model to satisfy the fundamental proportional hazards assumption, we examined this assumption using the Finkelstein-Schoenfeld test. Subsequently, the model performance was evaluated internally within the derivation cohort and externally within the validation cohort. The model performance was assessed in terms of discrimination and calibration. For discrimination, we calculated the concordance index (C-index) based on the bootstrap resampling method, plotted receiver operating characteristic curves to assess the model's ability to differentiate patients, and compared the model with the GRACE risk score. Calibration curves were used to assess the deviation between the model's predicted

outcomes and actual observations. Furthermore, event prediction probabilities for the participants were calculated using the nomogram. Subsequently, Kaplan-Meier analysis was performed to stratify the participants into groups based on the median predicted probability.

All statistical tests were two-tailed, and a *P*-value < 0.05 was considered statistically significant. All statistical analyses were performed using the R statistical software 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Baseline Characteristics

The derivation cohort enrolled 1674 elderly patients with ACS (mean age: 70.97 ± 4.68 years, 23.24% female), whereas the validation cohort included 2333 such patients (mean age: 72.13 ± 5.82 years, 35.83% female). Over the 2-year follow-up period, the incidence of MACCE was 12.5% (*n* = 210) in the derivation cohort and 15.6% (*n* = 364) in the validation cohort.

The baseline characteristics of patients in both cohorts are summarized in Table 1. Significant variable differences between the derivation cohort and the validation cohort included gender, age, body mass index, smoking, hyperlipidemia, peripheral vascular disease, prior myocardial infarction, prior PCI, prior CABG, preoperative hemoglobin, preoperative PLT, preoperative white blood cell count, preoperative and residual SYNTAX score, LVEF, number of target lesions, IABP usage, stent placement count, in-hospital use of low-molecular-weight heparin, and discharge use of DAPT.

Development of the Nomogram

The initial selection of 25 variables was based on the univariate Cox regression results and their clinical significance, as detailed in Table 1. These variables were then incorporated into a multivariable Cox proportional hazards model with model selection guided by the AIC. This process led to the final inclusion of ten variables: age, cardiac insufficiency, current smoking status, DAPT use, history of PCI or CABG, IABP usage, number of lesions, residual SYNTAX score, preoperative hemoglobin level, and preoperative PLT (supplemental material, Figure 1S). All the variables included in the final prognostic model were analyzed as categorical variables. The Finkelstein-Schoenfeld test indicated that the final Cox regression model satisfied the proportional hazards assumption, with hazard ratios remaining constant over time, as shown in supplemental material, Figure 2S. Finally, the model containing these predictive variables was represented as a nomogram (Figure 2). Each of these predictive variables is projected upwards to a 'points' value at the top of the forest plot, resulting in a score within the range of 0 to 10. The cumulative score was recorded to accurately predict the risk of 2-year MACCE in elderly patients with ACS who underwent PCI, with a higher total score indicating a higher risk of MACCE.

Validation of the Nomogram

The receiver operating characteristic curves demonstrated that the area under the curve (AUC) for the nomogram in the derivation cohort and the validation cohort was 0.723 and 0.699, respectively (Figure 3), indicating a relatively good discriminative ability (with C-index values of 0.727 and 0.661, respectively). The discriminative

Table 1 Baseline characteristics of the derivation cohort and the validation cohort.

Variables	Derivation cohort (*n* = 1674)	Validation cohort (*n* = 2333)	*P*-value
Patients with MACCE	210 (12.54%)	364 (15.60%)	0.01
Patients with all-cause mortality	47 (2.81%)	84 (3.60%)	0.16
Patients with non-fatal myocardial infarction	44 (2.63%)	53 (2.27%)	0.47
Patients with non-fatal stroke	41 (2.45%)	75 (3.21%)	0.15
Patients with revascularization	78 (4.66%)	152 (6.52%)	0.01
Demographics			
Age, yrs	70.97 ± 4.68	72.13 ± 5.82	< 0.01
Age ≥ 85 yrs	11 (0.66%)	64 (2.74%)	< 0.01
Female	389 (23.24%)	836 (35.83%)	< 0.01
Body mass index, kg/m^2	25.91 ± 3.17	24.76 ± 3.44	< 0.01

Continued

Variables	Derivation cohort (n = 1674)	Validation cohort (n = 2333)	P-value
ACS type			
ST-segment elevation myocardial infarction	300 (17.92%)	1304 (55.89%)	< 0.01
Non-ST-segment elevation myocardial infarction	134 (8.00%)	467 (20.02%)	< 0.01
Unstable angina	1240 (74.07%)	562 (24.09%)	< 0.01
Cardiovascular disease risk factors			
Current smoker	956 (57.11%)	474 (20.32%)	< 0.01
Diabetes mellitus	494 (29.51%)	738 (31.63%)	0.15
Hypertension	1087 (64.93%)	1557 (66.74%)	0.24
Hyperlipidemia	1111 (66.37%)	1475 (63.22%)	0.04
Medication history			
Stroke history	285 (17.03%)	406 (17.40%)	0.77
Chronic obstructive pulmonary disease history	37 (2.21%)	58 (2.49%)	0.60
Peripheral vascular disease history	47 (2.81%)	115 (4.93%)	< 0.01
Myocardial infarction history	312 (18.64%)	282 (12.09%)	< 0.01
History of PCI or CABG	440 (26.28%)	404 (17.32%)	< 0.01
History of PCI	364 (21.74%)	379 (16.25%)	< 0.01
History of CABG	78 (4.66%)	32 (1.37%)	< 0.01
Preoperative status			
Hemoglobin, g/L	141.29 ± 15.64	136.46 ± 17.22	< 0.01
Hemoglobin < 120 g/L	147 (8.78%)	361 (15.47%)	< 0.01
PLT, × 10^9/L	204.08 ± 53.82	214.66 ± 62.23	< 0.01
PLT < 100 × 10^9/L	12 (0.72%)	26 (1.11%)	0.25
White blood cell, × 10^9/L	6.99 ± 1.99	8.56 ± 3.07	< 0.01
Preoperative SYNTAX score	12.84 ± 7.97	17.11 ± 9.93	< 0.01
LVEF, %	62.02 ± 7.77	56.89 ± 8.95	< 0.01
Cardiac insufficiency	112 (6.69%)	447 (19.16%)	< 0.01
Number of lesions	1.00 (1.00–2.00)*	1.00 (1.00–2.00)*	< 0.01
Number of lesions > 4	21 (1.25%)	25 (1.07%)	0.65
Intraoperative status			
IABP use	40 (2.39%)	156 (6.69%)	< 0.01
Number of implanted stents	2.00 (1.00–2.00)*	1.00 (1.00–2.00)*	< 0.01
Postoperative status			
Residual SYNTAX score	3.93 ± 5.97	7.73 ± 7.62	< 0.01
Residual SYNTAX score > 0	906 (54.12%)	1908 (81.78%)	< 0.01
Medication			
Low-molecular-weight heparin use during hospitalization	1013 (60.51%)	1240 (53.15%)	< 0.01
Glycoprotein IIb/IIIa inhibitors use during hospitalization	256 (15.29%)	397 (17.02%)	0.15
Statin use at discharge	1605 (95.88%)	2217 (95.03%)	0.22
DAPT use at discharge	1644 (98.21%)	1688 (72.35%)	< 0.01

Data are presented as means ± SD or n (%). *Presented as median (interquartile range). ACS: acute coronary syndrome; CABG: coronary artery bypass grafting; DAPT: dual antiplatelet therapy; IABP: intra-aortic balloon pump; LVEF: left ventricular ejection fraction; MACCE: major adverse cardiovascular and cerebrovascular events; PCI: percutaneous coronary intervention; PLT: platelet.

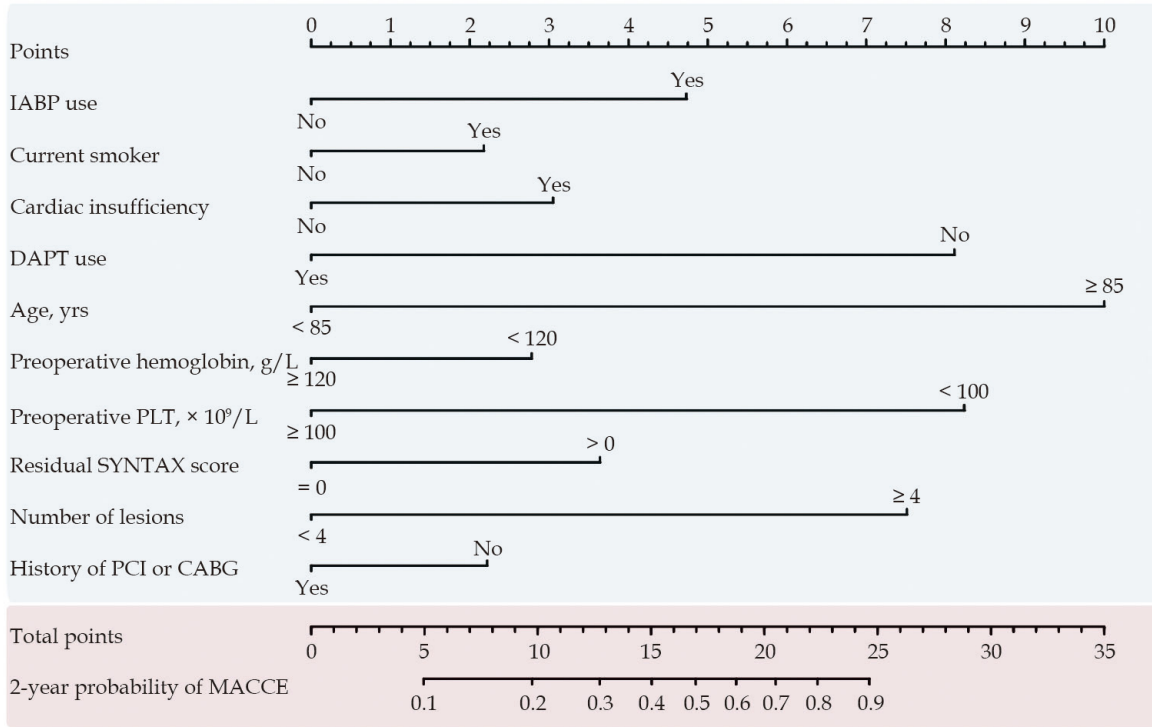

Figure 2 Nomogram predicting the risk of 2-year MACCE occurrence in elderly patients with ACS. ACS: acute coronary syndrome; CABG: coronary artery bypass grafting; DAPT: dual antiplatelet therapy; IABP: intra-aortic balloon pump; MACCE: major adverse cardiovascular and cerebrovascular events; PCI: percutaneous coronary intervention; PLT: platelet.

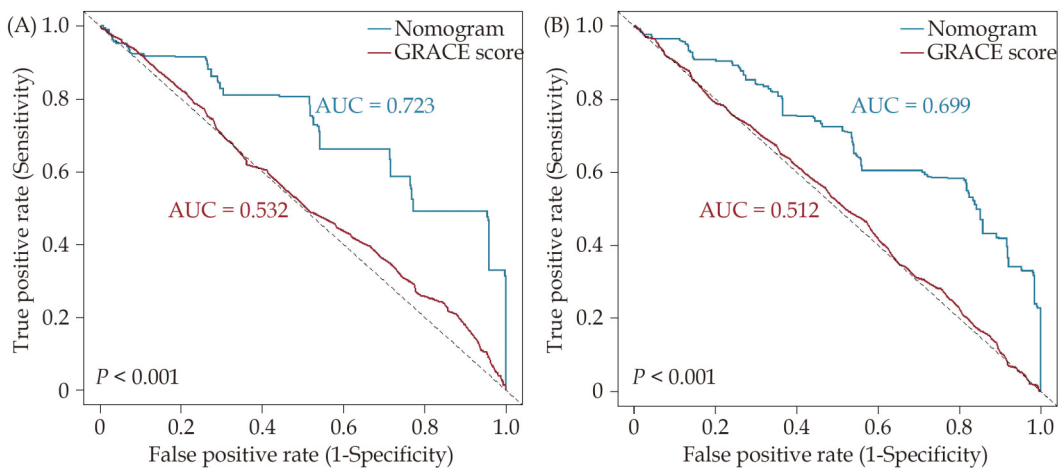

Figure 3 Receiver operating characteristic curves of the nomogram and GRACE risk score. (A): Derivation cohort; and (B): validation cohort. AUC: area under the curve; GRACE: Global Registry of Acute Coronary Events.

ability of the nomograms for 2-year MACCE was significantly higher than that of the GRACE risk score ($P < 0.001$) (Figure 3).

The calibration curves for the nomograms in both cohorts closely approximated the 45-degree diagonal line (Figure 4), suggesting good predictive accuracy.

The Kaplan-Meier analysis demonstrated that the high-risk group, stratified by the median predicted probability cutoff, had a significantly higher 2-year incidence of MACCE than the low-risk group (log-rank $P < 0.001$), as depicted in Figure 5.

DISCUSSION

Advanced age is an independent risk factor for coronary heart disease and remains one of the most robust pr-

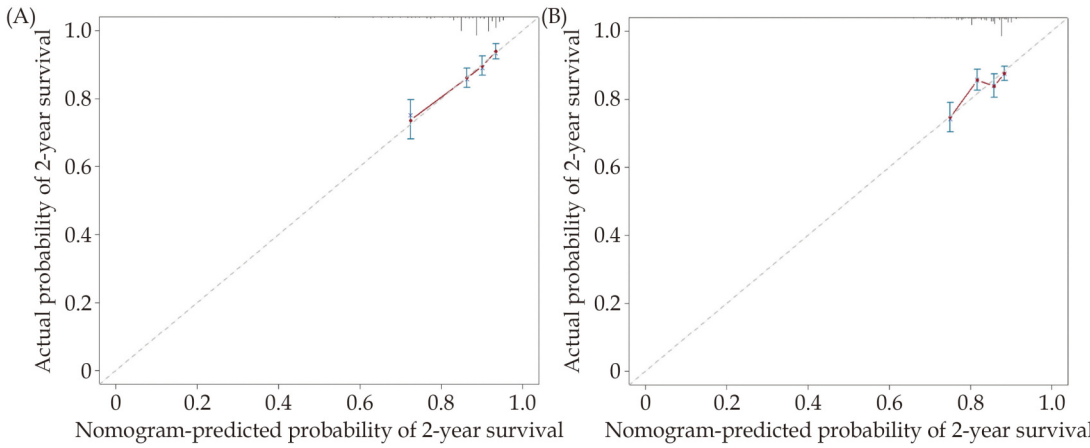

Figure 4 Calibration plots of the nomogram. (A): Derivation cohort; and (B): validation cohort.

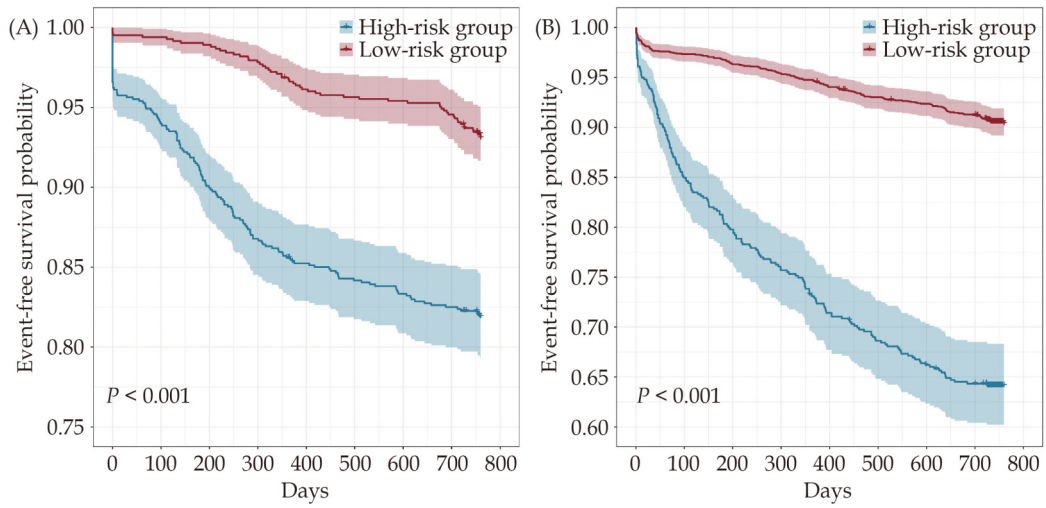

Figure 5 Kaplan-Meier analysis for MACCE events stratified by median predicted probability (0.1). (A): Derivation cohort; and (B): validation cohort. MACCE: major adverse cardiovascular and cerebrovascular events.

edictors of adverse outcomes in patients with ACS.[6] Compared with younger patients, elderly individuals with ACS tend to have a relatively poor prognosis. With global aging, the proportion of elderly patients with ACS is gradually increasing. However, elderly individuals are often affected by various diseases, changes in sensory abilities, and cognitive impairments, leading to atypical symptoms that subsequently reduce the specificity and sensitivity of diagnosis.[11,12] This may result in delayed disease assessment and treatment. Elderly patients with ACS face an elevated risk for both ischemia and bleeding.[13] Therefore, accurate assessment and precise treatment are crucial in this population.

The commonly used assessment tools have not been specifically developed for elderly patients with ACS, and it is unclear whether they are suitable for the prognostic assessment of these patients in China. In the present study, we developed and externally validated a clinical predictive nomogram for estimating the 2-year risk of MACCE after discharge in elderly patients with ACS who underwent PCI. The predictive factors investigated in this study were age, current smoking status, preoperative hemoglobin level, preoperative PLT count, history of PCI or CABG, cardiac insufficiency, IABP usage, number of lesions, residual SYNTAX score, and DAPT use. Smoking is a well-established risk factor for coronary artery disease,[14] and the results of our study also support this finding. Anemia is more prevalent in elderly patients with ACS and in individuals with various diseases. In certain situations, severe anemia may contribute to type 2 myocardial infarction. Persistent or worsening anemia in patients with ACS is associated with an increased risk of recurrent ischemic events, mortality, and major bleeding.[15-17] Our study found that elderly patients with ACS and thrombocytop-

enia had worse prognoses. Previous studies have shown an association between baseline thrombocytopenia and increased all-cause mortality, ischemic events, and bleeding events in patients with ACS.[18,19] However, the impact of the thrombocytopenia etiology on prognosis and treatment has not yet been fully studied.[20] There is still controversy in previous studies regarding whether patients who have undergone CABG or PCI and revascularization have a worse prognosis.[21-23] However, the results of our study indicate that elderly patients with ACS and a history of PCI or CABG had a lower risk of MACCE, and LVEF is a crucial prognostic predictor in these patients. The incidence of cardiac insufficiency is higher in elderly patients with ACS,[5,24] and there is a correlation between reduced ejection fraction and heart failure, and adverse in-hospital and post-discharge outcomes.[25,26] The use of IABP during hospitalization in patients with ACS is indicative of the development of cardiogenic shock or severe mechanical complications,[7] and it is associated with adverse outcomes. Elderly patients with ACS exhibit an increased burden of atherosclerotic plaques, and their coronary lesions tend to be more complex. The severity of coronary artery disease increases with the number of target lesions, consequently increasing the risk of PCI treatment. An increased residual SYNTAX score is associated with poor long-term prognosis in patients with coronary artery disease who have undergone PCI.[27] A residual SYNTAX score of 0 indicates complete revascularization, while a residual SYNTAX score ≥ 1 indicates incomplete revascularization. Currently, research on whether elderly patients with ACS should undergo complete revascularization is limited. The recently published FIRE trial demonstrated that among patients aged ≥ 75 years with myocardial infarction and multi-vessel coronary artery disease, those undergoing functionally guided complete revascularization had a significantly lower 1-year incidence of major adverse cardiovascular events compared to those who received treatment only for the culprit lesion.[28] DAPT is crucial for patients with ACS as it reduces the probability of ischemic events.[6] For elderly patients, selecting the $P2Y_{12}$ inhibitor clopidogrel,[29,30] and shortening the duration of DAPT[31] can help mitigate the risk of bleeding.

Some researchers have established predictive models for long-term mortality and ischemic events in the general population with ACS,[8-10] including factors such as age, current smoking status, and cardiac insufficiency. However, there are currently limited risk prediction tools specifically tailored for the elderly population with ACS. Gao, *et al*.[32] developed a risk model for 1-year and 3-year mortality in elderly patients with acute myocardial infarction. The included factors were age, estimated glomerular filtration rate, body mass index, glycated hemoglobin, LVEF, left main or multi-vessel disease, and angiotensin-converting enzyme inhibitor or angiotensin II receptor blocker. This study shares similarities with our research, as it encompasses factors such as cardiac function, coronary artery lesions, and medication usage. Dodson, *et al*.[33] developed a risk model for the 6-month mortality rate in elderly patients with acute myocardial infarction after discharge, with the final model comprising 15 variables. Similar to our model, it included hemoglobin and ejection fraction. In addition, their model incorporated factors such as hearing impairment, mobility issues, weight loss, and patient-reported decline in health status. Due to the unavailability of these data in our study, we were unable to investigate frailty and cognitive impairment, which are common characteristics in the elderly. However, it is important to note that these two studies lacked external validation and focused exclusively on death outcomes without comparison to the currently recommended GRACE risk score. Zhu, *et al*.[34] developed a clinical prediction model for the incidence of major adverse cardiovascular events within one year after PCI in elderly patients with ACS. The model included eight variables: LVEF, prognostic nutritional index, brain natriuretic peptide, albumin, myoglobin, creatinine, hemoglobin, and age. The variables LVEF, hemoglobin level, and age in their study were also included in our study. However, their study primarily focused on laboratory indicators. In our study, in addition to laboratory indicators, we incorporated indicators related to coronary artery lesions (such as the number of target lesions and residual SYNTAX score) into the model. Furthermore, our study had a larger sample size, longer follow-up period, and included both internal and external validation sets, making the study results more reliable.

A key consideration when interpreting our findings was the observed difference in baseline characteristics between the derivation and validation cohorts. We believe that these differences are primarily attributable to the distinct hospital types and geographical coverage of patient populations. The derivation cohort was sourced exclusively from a single, highly specialized, top-tier cardiovascular center in Beijing. Such specialized single-center environments typically manage a more concentrated patient profile, often characterized by higher disease severity and uniform treatment protocols. This selection explains the

observed profile of the derivation cohort: they were younger, had a higher proportion of males, presented with more myocardial infarction, showed higher rates of several traditional risk factors (e.g., smoking and hyperlipidemia) and prior interventions (e.g., PCI/CABG). Furthermore, more aggressive medical management (e.g., higher low-molecular-weight heparin use during hospitalization and DAPT use at discharge) is consistent with practice patterns in highly specialized academic centers. An external validation cohort was drawn from a diverse network of nine tertiary hospitals across multiple Chinese provinces. This multi-center approach ensured geographical and institutional heterogeneity, capturing a wide spectrum of clinical practice variations and patient characteristics. Crucially, rather than being a limitation, this disparity underscores the strength of the study design. The strategy of using a single-center derivation followed by a multi-center, geographically dispersed external validation allows for a rigorous assessment of the robustness and portability of the model in a truly independent and varied clinical environment.

Our study developed a nomogram to predict the 2-year post-discharge risk of MACCE in ACS patients aged ≥ 65 years who underwent PCI. The nomogram demonstrated good discriminative and calibration abilities in both derivation and validation cohorts. It is noteworthy that the discriminative ability of the nomograms for 2-year MACCE was significantly higher than that of the GRACE risk score. Participants with higher predicted probability calculated by the nomogram showed a significantly increased rate of MACCE occurrence. The nomogram was derived from a single-center cohort and validated in a multi-center cohort, with large sample sizes in both cohorts, enhancing the reliability of the results. The nomogram incorporates ten clinically easily obtainable clinical variables, contributing to its broad applicability. Therefore, the nomogram developed in this study has good practical value for predicting 2-year MACCE in elderly patients with ACS who have undergone PCI. This study had some limitations. Our study included only elderly inpatients with ACS in China, and further validation is required in different populations. We collected observational data of the patient at only a single time point during hospitalization. However, long-term outcomes after discharge require multiple monitoring of various indicators. In the development of the nomogram, only commonly used clinical prognostic variables were included, whereas novel biomarkers (e.g., proteomics and metabolomics markers) or genetic data were not incorporated. Such biological data have potential value because they may enhance the discriminatory ability of the model and improve the precision of personalized prognosis. Future studies should consider integrating these data to optimize the prognostic models. Another limitation of this study was incomplete data on long-term secondary prevention. Data collection was restricted to prescriptions for DAPT and atorvastatin at the time of discharge. We were unable to follow up on long-term medication adherence or persistence post-discharge. Given that the long-term, consistent application of secondary prevention is a critical determinant of patient outcomes, the absence of such data limits our ability to assess the full impact of secondary prevention in our cohort. A notable limitation of our study was the lack of detailed information regarding the timing and urgency of PCI. Specifically, our original database did not capture whether PCI procedures were performed on an emergency or elective basis, nor did it consistently record the exact time elapsed from symptom onset to intervention. We acknowledge that the timing of revascularization is a critical prognostic factor, particularly in ACS, and its absence prevents us from fully evaluating its confounding or interacting effects on the outcomes presented. Future studies should aim to collect and incorporate these granular procedural timing metrics to provide a more complete assessment of prognostic variables.

CONCLUSIONS

In conclusion, we developed and externally validated a nomogram employing commonly used clinical variables to predict the risk of MACCE over 2-year post-discharge in elderly patients with ACS who underwent PCI. The nomogram performed better than the GRACE risk score and served to optimize the risk stratification for long-term adverse ischemic events in elderly patients with ACS in China, providing valuable guidance for subsequent precise treatment and preventive strategies.

ACKNOWLEDGMENTS

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