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RESEARCH

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Development of a predictive model for postoperative major adverse cardiovascular events in elderly patients undergoing major abdominal surgery

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Abstract

Objective To investigate the predictive value of a Short Physical Performance Battery (SPPB) for postoperative major adverse cardiovascular events(MACEs) in elderly patients undergoing major abdominal surgery and to develop a nomogram risk prediction model.

Methods A total of 427 elderly patients aged ≥ 65 years who underwent major abdominal surgery at our hospital between June 2023 and March 2024 were selected for the study, and 416 patients were ultimately included. The preoperative SPPB score was measured, and the patients were divided into two groups: a high SPPB group (≥ 10) and a low SPPB group (< 10). The subjects' clinical datasets and postoperative major adverse cardiovascular event (MACEs) occurrence data were recorded. LASSO regression analysis was performed to screen predictor variables and develop a nomogram risk prediction model for predicting MACEs. The area under the receiver operating characteristic (ROC) curve (AUC), calibration curve, and decision curve analysis (DCA) were used to evaluate the model's clinical efficacy.

Results The incidence of postoperative MACEs in elderly patients who underwent major abdominal surgery was 5%. LASSO regression analysis revealed that arrhythmia, creatine kinase, SPPB, anesthesia duration, age, intraoperative minimum heart rate, BMI, and coronary artery disease were significant predictors of MACEs. The nomogram risk prediction model based on SPPB and clinical indicators can better predict the occurrence of MACEs and can guide preoperative interventions and help to improve perioperative management.The decision curve indicated encouraging clinical effectiveness, the calibration curve demonstrated good agreement, and the area under the curve (AUC) was 0.852 (95% CI, 0.749–0.954).

Conclusion The nomogram risk prediction model based on SPPB and clinical indicators can better predict the occurrence of MACEs and can guide preoperative intervention and help to improve perioperative management.

Keywords LASSO regression, Major abdominal surgery, Major adverse cardiovascular events, Short Physical Performance Battery, Prediction model

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Introduction

As the population ages, a growing number of elderly patients necessitate elective surgical procedures [1]. Although there is a diminishing trend in the incidence of perioperative adverse events, cardiovascular complications remain among the principal causes of perioperative mortality in patients undergoing major abdominal surgery [1, 2]. The capacity to efficaciously identify the preoperative existence of risk factors in patients is of critical importance in relation to the occurrence of major adverse cardiovascular events (MACEs) during the postoperative phase. Thus, screening high-risk patients can be conducive to perioperative management and enhance patients' postoperative outcomes [3].

The Short Physical Performance Battery (SPPB) represents a methodology for appraising the level of physical functioning and encompasses three components: the standing balance test, the walking test, and the sitting and standing test, with a scoring range spanning from 0 to 12 [4]. In initial investigations, a low SPPB score was correlated with a less favorable prognosis (such as extended hospital stays, readmissions, disability, and mortality) among patients with decompensated heart failure [5, 6]. Pavasini et al. reported that an SPPB score of ≤6 was associated with a twofold elevation in the risk of all-cause mortality, and even when the SPPB score was ≤9, the risk of death remained 1.5-fold [7]. Multiple studies have indicated that the SPPB serves as a predictor of adverse postoperative outcomes in cardiac surgery patients [8, 9]; however, its application in forecasting the occurrence of MACEs in elderly patients undergoing major abdominal surgery is still in the exploratory phase. Consequently, the present study endeavored to explore the clinical value of the SPPB in predicting the occurrence of MACEs in elderly patients undergoing major abdominal surgery and to formulate a novel nomogram integrating preoperative and intraoperative factors to predict the occurrence of MACEs and enhance patients' perioperative outcomes.

Methods

Study population

This study included 427 elderly patients who underwent major abdominal surgery at our hospital between June 2023 and March 2024. The inclusion criteria for the study were as follows: (1) aged 65 years or older, (2) underwent major abdominal surgery, (3) had undergone surgery for more than 120 min, and (4) had undergone a preoperative SPPB test with no communication barriers. The exclusion criteria were (1) refusal to undergo the SPPB test and (2) loss to follow-up within 30 days of surgery. Ultimately, a total of 416 patients were included in this study. This study was conducted according to the Declaration of Helsinki and was approved by the Ethics Committee of the Third Affiliated Teaching Hospital (Cancer Hospital) of Xinjiang Medical University.

Variables

Based on our prior clinical experience, we screened the following variables: gender, age, body mass index (BMI), educational attainment, smoking history, alcohol consumption history, history of preoperative blood transfusion, hypertension, coronary heart disease, preoperative arrhythmia (encompassing tachycardia, bradycardia, and other arrhythmias), lactate dehydrogenase (IU/L), creatine kinase (IU/L), Short Physical Performance Battery (SPPB), operative duration (in minutes), anesthesia duration (in minutes), American Society of Anesthesiologists (ASA) classification, surgical procedure, type of anesthesia, intraoperative maximum and minimum blood pressure, intraoperative blood loss, intraoperative maximum heart rate, intraoperative minimum heart rate, and major adverse cardiac events (MACEs). The SPPB was assessed one day prior to surgery, and the preoperative laboratory indices were collected within a three-day window. In this study, MACEs were defined as the occurrence of myocardial infarction, cardiac arrest, heart failure, or stroke within 30 days following surgery.

Definition of MACEs

In accordance with the systematic review on defining the MACEs composite endpoint [10], MACEs were defined as the occurrence of myocardial infarction, cardiac arrest, heart failure, or stroke within 30 days following surgery. The postoperative outcomes were retrieved from the electronic medical records. Additionally, the frequency of occurrence of each individual component of MACEs was characterized (Supplementary Table 1).

Myocardial Infarction: Patients were considered to have had a myocardial infarction if they exhibited electrocardiographic changes indicative of such an event and were diagnosed as such by the supervising physician within the medical record system.

Cardiac Arrest: Instances of cardiac arrest were documented by the physician in charge within the medical record system.

Heart Failure: Diagnosis of heart failure was based on echocardiographic evidence of abnormalities in heart size, ventricular wall thickness, valve function, and left heart ejection fraction, as determined by the physician in charge and recorded in the medical record system.

Stroke: Patients were diagnosed with stroke if they had a head CT, MRI, or cerebral angiogram suggestive of a stroke and were so diagnosed by the supervising physician within the medical record system.

Statistical analysis

All data were analyzed using Python 3.12 and Free Statistical Software version 1.9. Descriptive statistics were carried out on the patients' baseline characteristics, with normally distributed continuous variables represented as mean ± standard deviation and non-normally distributed ones as median (interquartile range). In comparing the high and low Short Physical Performance Battery (SPPB) groups, t-tests were applied for continuous variables following a normal or near-normal distribution, and Mann-Whitney U-tests for those with skewed distributions. Categorical variables were analyzed via chi-square tests or Fisher's exact tests. Univariate and multivariate logistic regression analyses were conducted to analyze risk factors. The Least Absolute Shrinkage and Selection Operator (LASSO) regression analysis was utilized to screen predictor variables and develop a nomogram risk prediction model for major adverse cardiac events (MACEs). This model was internally validated by subject operating characteristic curves (AUC) to evaluate its accuracy and verified by decision curve analysis (DCA) to confirm its clinical benefits. Additionally, a further sensitivity and specificity analysis of the model was performed, and the results were presented in box plots. All tests were two-sided, and a P-value less than 0.05 was regarded as statistically significant.

Results

Patient characteristics

We collected clinical information from 427 patients who underwent major abdominal surgery between June 2023 and March 2024. Eleven patients met the exclusion criteria, and 416 patients were ultimately included in the analysis, as shown in the nadir flow chart (Fig. 1). A total of 274 (58.2%) patients were male, the median (interquartile spacing) age of patients was 71 (67, 75) years, and significant postoperative adverse cardiovascular events occurred in 26 (5%) patients. (Table 1)

Comparing baseline information between the high and low SPPB groups

We chose 10 as the optimal cutoff value based on previous studies. We also made a fitting curve to choose the best cutoff value.(Supplementary Fig. 1).Moreover, those with an SPPB ≥ 10 were considered the high SPPB group (274) [11], while those with an SPPB < 10 were considered the low SPPB group (142). MACEs occurred in 14 (9.9%) patients in the low SPPB group and 7 (2.6%) in the high

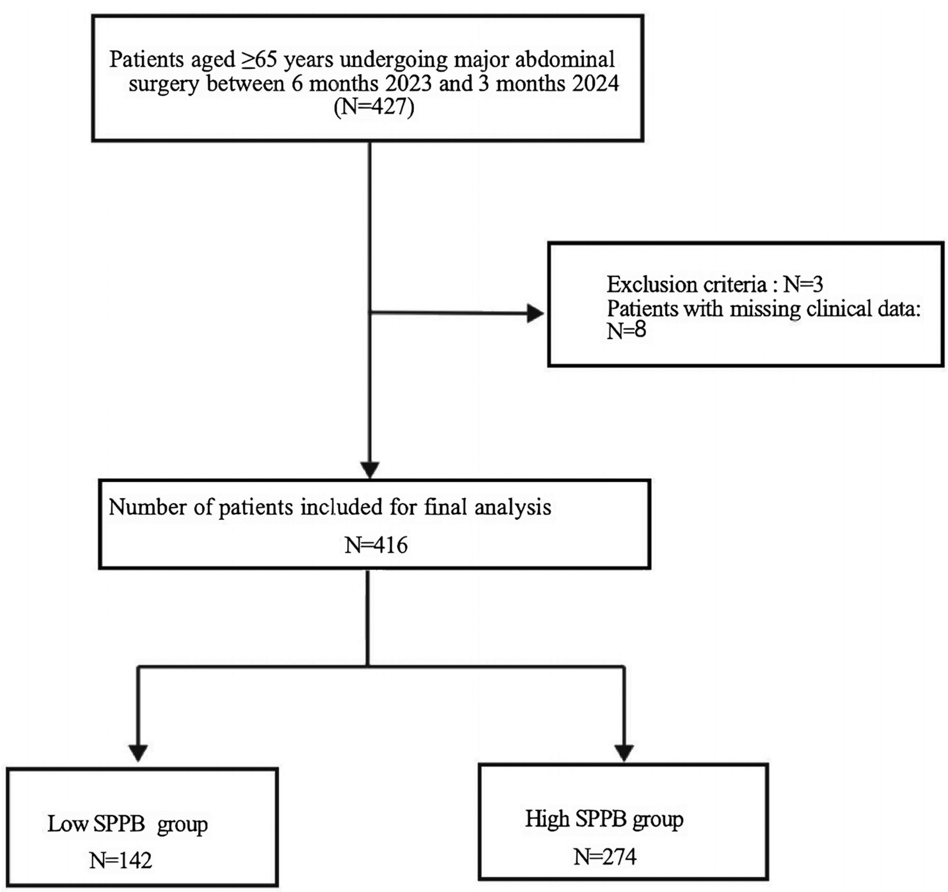

Fig. 1 Flowchart of inclusion-exclusion criteria for study participants

Table 1 Patient characteristics

Variables	Total (n = 416)	SPPB-Low Group (<10 ,n = 142)	SPPB-High Group(⩾10,n=274)	P-value
Gender,n (%)				0.111
Famale	174 (41.8)	67 (47.2)	107 (39.1)	
Male	242 (58.2)	75 (52.8)	167 (60.9)	
Age, Median (IQR)	71.0 (67.0, 75.0)	73.0 (69.0, 78.0)	69.0 (66.0, 74.0)	< 0.001
BMI(kg/m2), n (%)				0.004
<24	187 (45.0)	50 (35.2)	137 (50)	
⩾24	229 (55.0)	92 (64.8)	137 (50)	
Education, n (%)				0.019
High school and below	324 (77.9)	120 (84.5)	204 (74.5)	
Bachelor and above	92 (22.1)	22 (15.5)	70 (25.5)	
Tobacco use, n (%)				0.732
No	336 (80.8)	116 (81.7)	220 (80.3)	
Yes	80 (19.2)	26 (18.3)	54 (19.7)	
Alcohol use,n (%)				0.065
No	350 (84.1)	126 (88.7)	224 (81.8)	
Yes	66 (15.9)	16 (11.3)	50 (18.2)	
Preoperative blood transfusion,n (%)				0.712
No	378 (90.9)	128 (90.1)	250 (91.2)	
Yes	38 (9.1)	14 (9.9)	24 (8.8)	
Hypertension, n (%)				0.454
No	239 (57.5)	78 (54.9)	161 (58.8)	
Yes	177 (42.5)	64 (45.1)	113 (41.2)	
Coronary heart disease, n (%)				0.105
No	340 (81.7)	110 (77.5)	230 (83.9)	
Yes	76 (18.3)	32 (22.5)	44 (16.1)	
Preoperative arrhythmia, n (%)				< 0.001
No	326 (78.4)	96 (67.6)	230 (83.9)	
Yes	90 (21.6)	46 (32.4)	44 (16.1)	
LDH (IU/L), Mean ± SD	194.3 ± 49.6	189.6 ± 51.9	196.8 ± 48.2	0.16
CK (IU/L), Median (IQR)	58.0 (39.0, 81.0)	63.5 (49.0, 81.0)	52.5 (37.2, 80.8)	0.022
Surgery time (Min), Mean ± SD	231.2 ± 94.3	233.6 ± 112.9	230.0 ± 83.3	0.712
Anesthesia time(Min), Mean ± SD	265.5 ± 93.2	263.5 ± 97.2	266.5 ± 91.2	0.754
ASA, n (%)				< 0.001
>3	178 (42.8)	41 (28.9)	137 (50)	
⩽3	238 (57.2)	101 (71.1)	137 (50)	
Surgical method, n (%)				0.077
Lumpectomy	290 (69.7)	92 (64.8)	198 (72.3)	
Open surgery	122 (29.3)	47 (33.1)	75 (27.4)	
Combined open surgery with a lumpectomy	4 (1.0)	3 (2.1)	1 (0.4)	
Type of anesthesia, n (%)				0.268
General anesthetic	401 (96.4)	136 (95.8)	265 (96.7)	
Extravertebral anesthesia	2 (0.5)	2 (1.4)	0 (0)	
General anesthesia with Intravertebral	9 (2.2)	3 (2.1)	6 (2.2)	
General anesthesia with nerve block	4 (1.0)	1 (0.7)	3 (1.1)	
Intraoperative blood loss, mL,Mean ± SD	219.9 ± 361.3	185.9 ± 220.0	237.4 ± 415.4	0.168
Highest blood pressure during surgery,Mean ± SI	159.5 ± 17.5	158.2 ± 17.3	160.2 ± 17.7	0.263
Lowest blood pressure,during surgery,Mean ± SD	92.5 ± 14.2	92.5 ± 13.6	92.5 ± 14.5	0.989
Maximum heart rate, durng surgery,Mean ± SD	86.4 ± 13.8	86.5 ± 14.5	86.4 ± 13.5	0.919
Minimum heart rate during surgery, Median (IQR)	55.0 (49.0, 60.2)	56.5 (49.2, 61.0)	54.0 (48.0, 60.0)	0.202
MACE, n (%)				0.001
No	395 (95.0)	128 (90.1)	267 (97.4)	
Yes	21 (5.0)	14 (9.9)	7 (2.6)	

BMI, body mass index; LDH, lactate dehydrogenase; CK, creatine kinase; ASA, American Society of Anesthesiologists; SPPB, Short Physical Performance Battery.

SPPB group. The chance of MACEs was more significant in the low SPPB group than in the high SPPB group (P=0.001). (Table 1)

Variable screening for predictive modeling

LASSO is suitable for high-dimensional data regression because it extracts the most essential predictors from the raw data and helps avoid overfitting. The 22 variables were reduced to 8 potential predictors using the LASSO regression model, and coefficient trajectory plots were generated (Fig. 2a). Through cross-validation, we selected 8 variables with optimal lambda nonzero coefficients: arrhythmia, creatine kinase, SPPB, duration of anesthesia, age, intraoperative minimum heart rate, BMI, and coronary artery disease (Table 2; Fig. 2b).

Results of univariate and multivariate logistic regression analysis of risk factors for MACEs

We performed logistic regression analysis of the included variables, and SPPB was analyzed as a continuous variable. The results of univariate regression analysis showed that age (OR=1.1 (1.03–1.19) p=0.005), BMI (OR=1.2 (1.07–1.34) p=0.002),coronary heart disease (OR=2.96 (1.18–7.42) p=0.021), preoperative arrhythmia (OR=4.4 (1.8-10.73 p=0.001), SPPB (OR=0.77 (0.66–0.9) p=0.001), LDH (OR=0.98 (0.97–0.99) p=0.003), surgery time (OR=1 (1-1.01) p=0.039), anesthesia time (OR=1 (1-1.01) p=0.039) may be associated with the development of MACEs.We performed a multifactorial regression analysis of predictor variables screened by LASSO regression analysis, which showed BMI (OR=1.2 (1.05–1.37) p=0.08), coronary artery disease (OR=3.13 (1.14–8.55) p=0.026), and preoperative arrhythmia (OR=3.6 (1.2-10.82) p=0.022), SPPB (OR=0.8 (0.64–0.98) p=0.036), CK (OR=1.01 (1-1.01) p=0.02), and anesthesia time (OR=1 (1-1.01) p=0.047) were independent risk factors. Although age (OR=1.07 (0.98–1.16) p=0.122) and intraoperative minimum heart rate (OR=1.02 (1-1.05) p=0.064) were not independent risk factors, we chose to include them among the predictor variables based on LASSO regression analysis and clinical experience.(Table 3).

Development and validation of nomograms

Based on LASSO regression analysis, we developed a nomogram incorporating eight screened variables (Fig. 3). For instance, consider a 72-year-old patient scheduled for major abdominal surgery, who presents with arrhythmia, a creatine kinase level of 250 U/L, an SPPB score lower than 10, an estimated anesthesia duration of 300 min, and a predicted lowest intraoperative heart rate of 90 beats per minute. Using the nomogram, the scoring is as follows: 10 points for age, 16 points for arrhythmia, 32.5 points for a creatine kinase level of 250 U/L, 17.5 points for an SPPB score of less than 10, 16 points for a 300-minute anesthesia duration, and 19 points for a lowest intraoperative heart rate of 90 beats per minute, resulting in a total score of 111, which corresponds to an event risk value of 0.11. This score facilitates discussions between clinicians and the patient's family regarding surgical risks. A multidisciplinary team is involved, with anesthesiologists optimizing the anesthesia plan and surgeons detailing the surgical approach. The model demonstrated good accuracy, with an area under the ROC curve (AUC) of 0.852 (95% CI 0.747, 0.956) (Fig. 4a). The calibration curve indicated strong

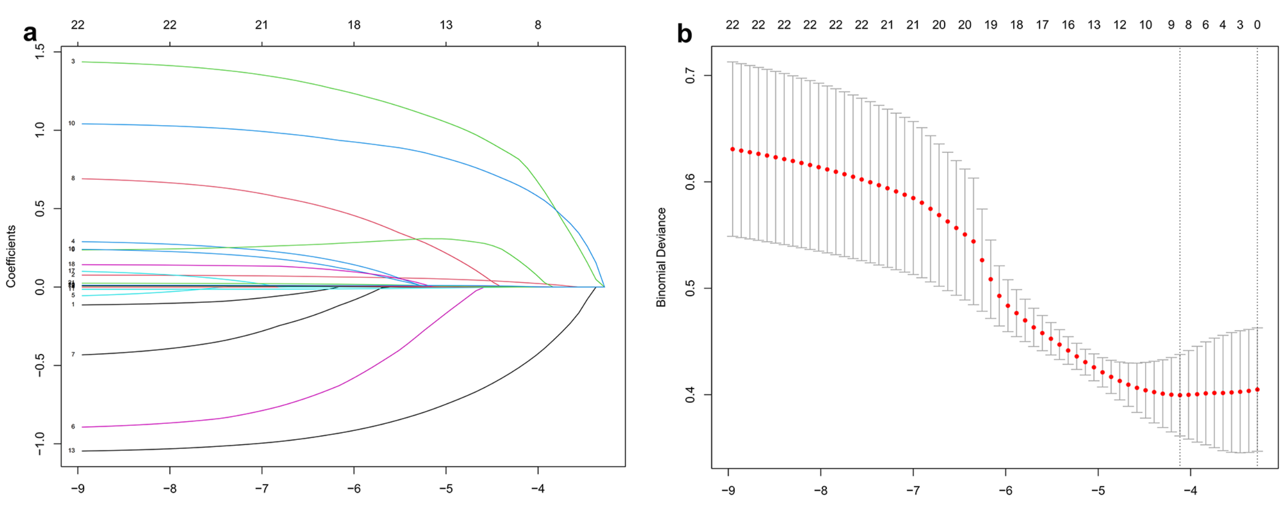

Fig. 2 Application of LASSO regression analysis for predictor variable selection: **a**) LASSO coefficient trajectory path diagram, each line represents the trajectory of the coefficients of each independent variable. **b**) LASSO regression analysis cross-validation curve, the dashed line on the left side corresponds to the log (λ) with the minor mean-square (MSE) error, and eight variables with non-zero coefficients were identified by selecting log (λ) with the minor MSE

Table 2 Variable filtering

Variable.num	Variable.name	Coefficient	lambda.type	lambda.value
0	(Intercept)	-7.047	lambda.min	0.016
1	Gender,		lambda.min	0.016
10	Arrhythmia	0.618	lambda.min	0.016
11	LDH (IU/L)		lambda.min	0.016
12	CK (IU/L)	0.002	lambda.min	0.016
13	SPPB	-0.476	lambda.min	0.016
14	Surgery time (Min)		lambda.min	0.016
15	Anesthesia time(Min)	0.001	lambda.min	0.016
16	ASA		lambda.min	0.016
17	Surgical method		lambda.min	0.016
18	Type of anesthesia		lambda.min	0.016
19	Highest blood pressure during surgery,		lambda.min	0.016
2	Age	0.027	lambda.min	0.016
20	Lowest blood pressure,during surgery		lambda.min	0.016
21	Maximum heart rate durng surgery		lambda.min	0.016
22	Minimum heart rate during surgery	0.003	lambda.min	0.016
3	BMI	0.758	lambda.min	0.016
4	Education		lambda.min	0.016
5	Tobacco use		lambda.min	0.016
6	Alcohol use		lambda.min	0.016
7	Preoperative blood transfusion		lambda.min	0.016
8	Hypertension		lambda.min	0.016
9	Coronary heart disease	0.126	lambda.min	0.016

agreement between predicted and actual values for major adverse cardiovascular events (MACEs) (Fig. 4b). Additionally, the decision curve analysis (DCA) confirmed the clinical utility of the nomogram, showing a favorable net benefit across a range of threshold probabilities, suggesting its applicability in clinical practice (Fig. 4c).Additionally, we conducted a further sensitivity and specificity analysis of the model, with the results presented in box plots. The average sensitivity of the model was 0.802 (with a standard deviation of 0.028), and the average specificity was 0.770 (with a standard deviation of 0.022). The box plots display the distribution of sensitivity (with a median of 0.825, Q1 of 0.820, and Q3 of 0.830) and specificity (with a median of 0.825, Q1 of 0.820, and Q3 of 0.830), which are valuable for evaluating the model's performance.(Supplementary Fig. 2).

Discussion

Significant advances in medicine have led to a growing elderly population and an increased burden of elderly patients, resulting in a higher number of older adults undergoing elective surgery. Consequently, perioperative cardiovascular events have become a challenge for both perioperative physicians and patients [10]. Currently, there is considerable heterogeneity in the composite endpoints of major adverse cardiovascular events (MACEs).

Table 3 Univariate and multivariate logistic regression analysis

Variable	OR_95CI	P_value	adj.OR (95%CI)	adj.P value
Gender				
Famale				
Male	0.78 (0.32-1.88)	0.582		
Age	1.1 (1.03-1.19)	0.005	1.07 (0.98-1.16)	0.122
BMI(kg/m2)	1.2 (1.07-1.34)	0.002	1.2 (1.05-1.37)	0.008
<24				
⩾24				
Education				
High school and below				
Bachelor and above	1.82 (0.71-4.66)	0.21		
Tobacco use				
No	0.69 (0.2-2.4)	0.557		
Yes				
Alcohol use				
No	0.25 (0.03-1.92)	0.185		
Yes				
Preoperative blood transfusion				
No	0.48 (0.06-3.71)	0.485		
Yes				
Hypertension				
No				
Yes	1.86 (0.77-4.51)	0.171		
Coronary heart disease				
No				
Yes	2.96 (1.18-7.42)	0.021	3.13 (1.14-8.55)	0.026
Preoperative arrhythmia				
No				
Yes	4.4 (1.8-10.73)	0.001	3.6 (1.2-10.82)	0.022
SPPB	0.77 (0.66-0.9)	0.001	0.8 (0.64-0.98)	0.036
LDH (IU/L)	0.98 (0.97-0.99)	0.003		
CK (IU/L)	1 (1-1.01)	0.07	1.01 (1-1.01)	0.02
Surgery time (Min)	1 (1-1.01)	0.039		
Anesthesia time(Min)	1 (1-1.01)	0.039	1 (1-1.01)	0.047
ASA				
>3	2.56 (0.92-7.14)	0.072		
⩽3	0 (0-Inf)	0.989		
Surgical method				
Lumpectomy	1.5 (0.6-3.7)	0.385		
Open surgery	0 (0-Inf)	0.991		
Combined open surgery with a lumpectomy				
Type of anesthesia				
General anesthetic	20.11 (1.21-333.91)	0.036		
Extravertebral anesthesia	2.51 (0.3-21.13)	0.396		
General anesthesia with Intravertebral	0 (0-Inf)	0.991		
General anesthesia with nerve block				
Intraoperative blood loss, mL	1 (1-1)	0.841		
Highest blood pressure during surgery	1 (0.97-1.02)	0.909		
Lowest blood pressure,during surgery	1.02 (0.99-1.05)	0.274		
Maximum heart rate, durng surgery	1.01 (0.98-1.04)	0.367		
Minimum heart rate during surgery	1.02 (1-1.05)	0.091	1.02 (1-1.05)	0.064

BMI, body mass index; LDH, lactate dehydrogenase; CK, creatine kinase; ASA, American Society of Anesthesiologists; SPPB, Short Physical Performance Battery.

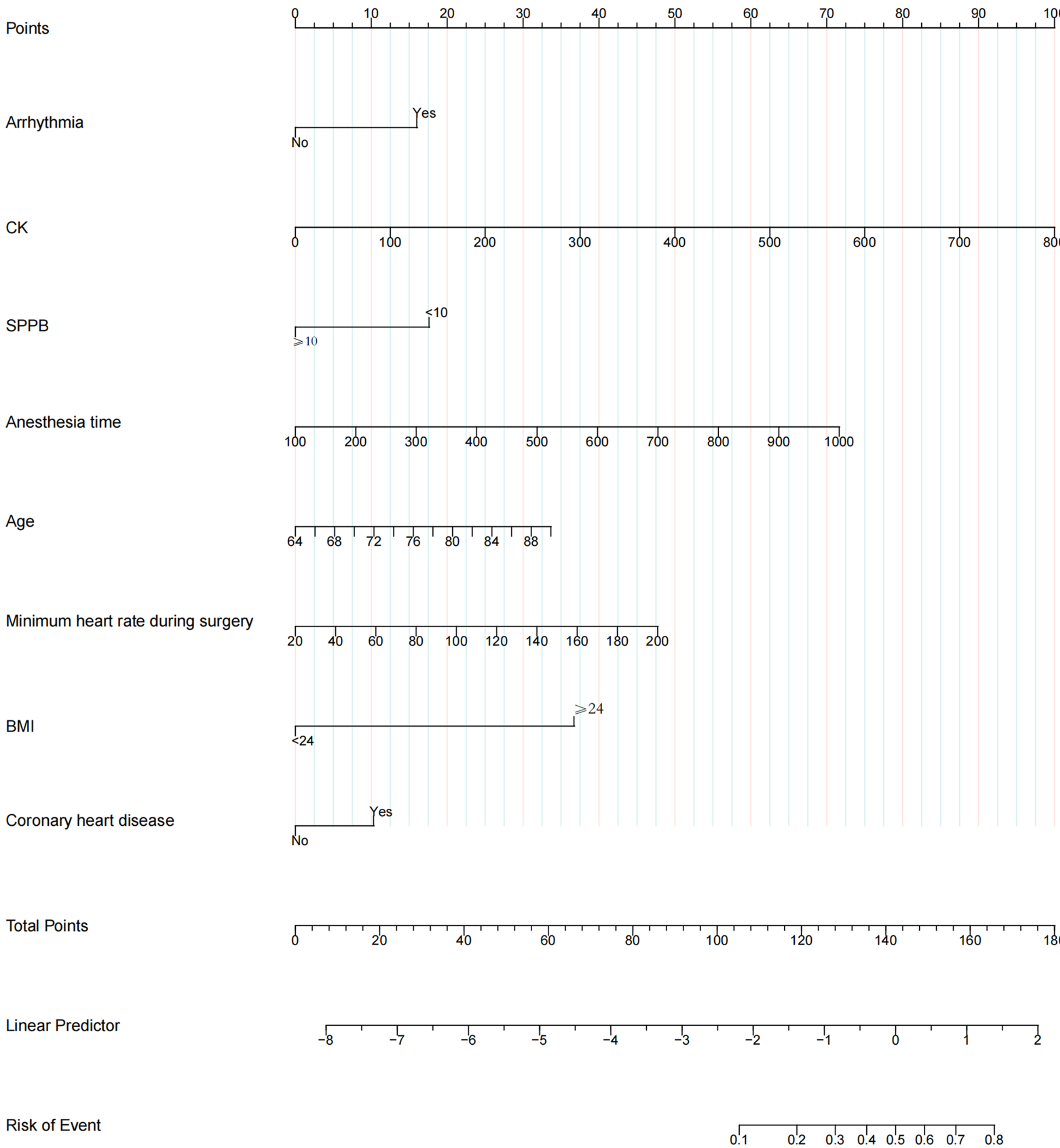

Fig. 3 Nomograms constructed for predicting MACEs

We defined MACEs based on relevant literature and the specific context of the patient's condition, recognizing that each component of this composite can adversely affect the cardiovascular system and even lead to death. Therefore, it is essential to identify patients at high risk for MACEs as early as possible [10, 12]. In our study, the incidence of MACEs was 5%, which aligns closely with the 6.3% incidence reported in an international prospective cohort study by P.J. Devereaux et al. [12]In this research, we developed a new, easy-to-use nomogram to predict MACEs in elderly patients undergoing major abdominal surgery, demonstrating good accuracy and discriminatory power.

Furthermore, intraoperative low heart rate was identified as a predictor of major adverse cardiovascular events (MACEs) in our model, with a heart rate cut-off value of 60–90 beats per minute. A low heart rate can result in insufficient cardiac output, exacerbating myocardial

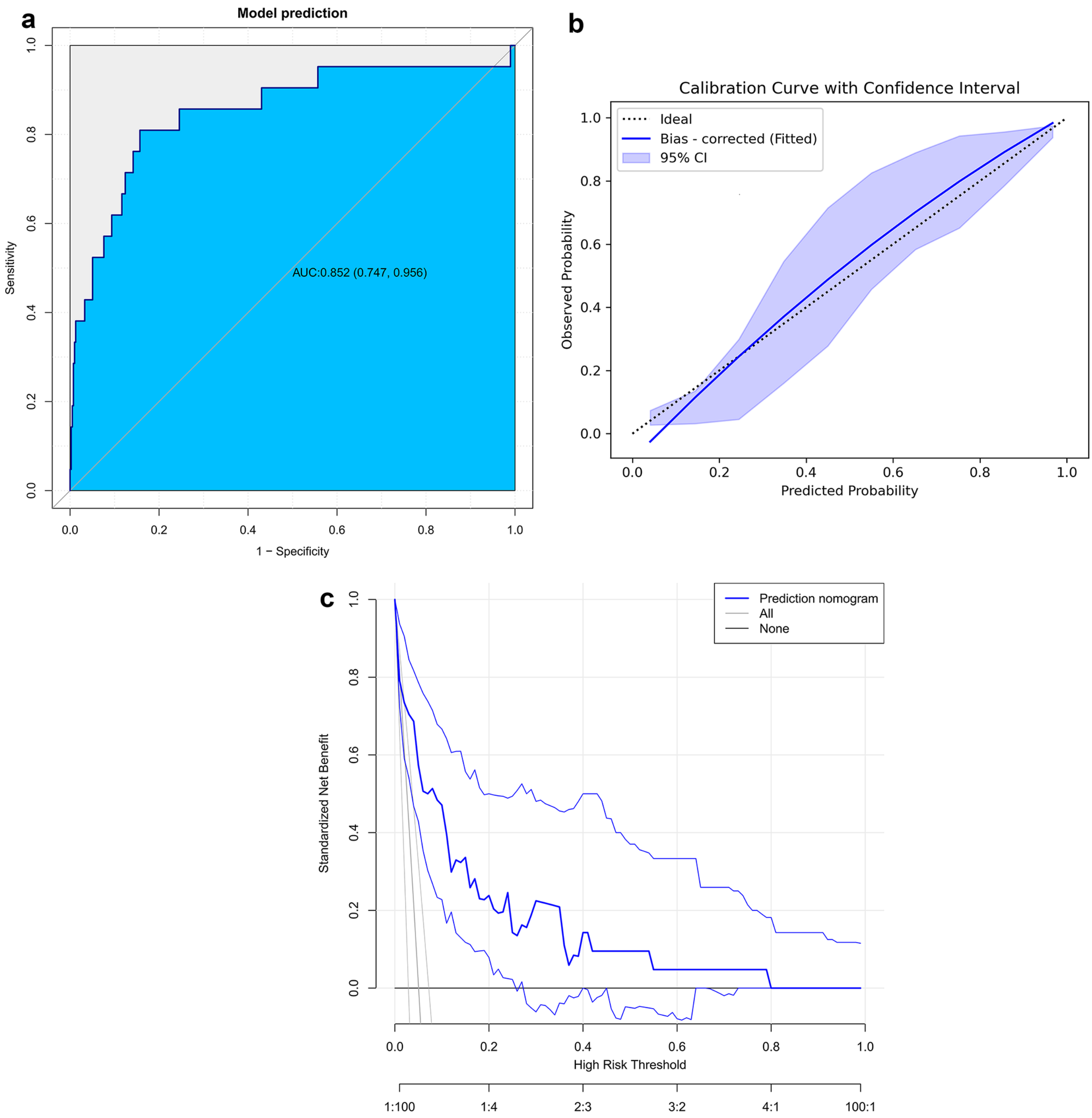

Fig. 4 Validation of Nomograms: **a**) Validation of nomograms using the area under the receiver operating characteristic (ROC) curve (AUC). **b**) Calibration curves verify the consistency of predicted and actual probabilities. **c**) Decision curves assessed that the model has clinical efficacy

ischemia and potentially leading to myocardial infarction and heart failure. Additionally, it can indirectly affect cerebral blood flow and may even result in cardiac arrest [13, 14]. Therefore, perioperative management of heart rate and blood pressure is crucial. The Chinese Expert Consensus on Perioperative Cardiovascular Disease Management in Non-Cardiac Surgery (2023) suggests that the preoperative administration of β-blockers may help reduce the incidence of cardiovascular events such as perioperative myocardial infarction; however, it does not appear to decrease the risk of mortality. Moreover, high doses of β-blockers could potentially increase all-cause mortality and the risk of postoperative stroke, which underscores the importance of not stopping long-term β-blocker therapy prior to surgery [15].

We selected LASSO regression analysis to screen predictor variables for model development. LASSO regularization is a statistical technique designed to address overfitting while facilitating variable selection. Unlike traditional stepwise regression methods that employ forward and backward variable selection, LASSO regression can effectively handle smaller sample sizes and efficiently screen a larger number of variables. This approach has been widely utilized in various predictive models and machine learning algorithms [16].

Rajagopalan et al. applied cardiac biomarkers, such as BNP and troponin, to predict major adverse cardiovascular events (MACEs) and demonstrated a high correlation with outcomes [17, 18]. In another study, the sensitivity of cardiac biomarkers, including cTNT, cTNI, and CK, was compared for predicting MACEs. The results indicated that while CK was less sensitive than cTNT and cTNI, it still showed some potential predictive value, with an area under the curve (AUC) of 0.70 (95% CI: 0.55–0.84) [19]. It has been reported that patients undergoing non-cardiac surgery often have multiple comorbidities, which contributes to a higher risk of MACEs. Notably, the presence of preoperative comorbidities, such as coronary artery disease, in elderly patients is a critical predictor of MACEs [20]. Additionally, a prospective study found that the risk of MACEs increased with age [21]. These findings suggest that multiple factors influence the occurrence of MACEs, highlighting the importance of developing a simple and user-friendly assessment tool for risk evaluation.

The Short Physical Performance Battery (SPPB) is a straightforward and easily applicable preoperative tool for assessing physical function. A study involving elderly patients who underwent lung resection indicated that low SPPB scores are predictive of postoperative pulmonary complications. Surgery-induced disruption of lung function, coupled with poorer physical function associated with low SPPB scores, can lead to breathing difficulties, hypoxia, and increased cardiac workload, potentially harming cardiac health in the long term. Furthermore, inflammation may spread, impacting blood vessels and promoting atherosclerosis, which can increase the risk of major adverse cardiovascular events (MACEs) [22]. Ryohei et al. identified low SPPB scores as a risk factor for postoperative delirium in older adults, as surgical stress can negatively impact those with compromised physical function. Delirium may trigger a sympathetic stress response, which can affect blood pressure and cardiac rhythm, while also limiting mobility, thereby raising the risk of clot formation, leading to MACEs and hindering both recovery and cardiac compensation [23]. In elderly patients undergoing mitral valve surgery, SPPB has demonstrated prognostic value for mid-term outcomes. The impact of surgery on cardiac function is significant, with mid-term prognosis being closely related to cardiovascular health, where MACEs are a critical concern. Low SPPB scores reflect impaired physical function, which can reduce postoperative activity levels and adversely affect the recovery of the heart and lungs, ultimately increasing the risk of heart failure and arrhythmias. This underscores the importance of SPPB as a predictor of MACEs [24].

In our study, we performed LASSO regression based on SPPB to screen eight characteristic variables and developed a new nomogram prediction model. We evaluated the performance of the nomogram using the area under the ROC curve (AUC). The area under the ROC curve (AUC) was 0.852, indicating the model's accuracy. Calibration curves for the probability of major postoperative adverse cardiovascular events showed good agreement between the nomogram-predicted and observed values. A DCA curve was applied to assess the net benefit of nomogram to patients, and the results showed that the model could provide positive net benefits to patients at a threshold probability range of 0.05–0.80.Comparing our model with the RCRI model based on previous studies, the RCRI internally validated AUC=0.720 (0.659–0.781), our model is better [25].The results suggest that the model based on the SPPB can be used to predict adverse postoperative cardiovascular events, which will help clinicians screen patients at high risk for MACEs and enable clinicians to intervene effectively in patients preoperatively. Prehabilitation has been commonly used in clinical practice, and the model can be used to perform preoperative assessments through multidisciplinary and multidiagnostic means to provide better clinical services for patients and improve the quality of perioperative care.

In clinical practice, a comprehensive preoperative evaluation holds utmost significance. For patients identified as having high preoperative risks according to the nomogram, appropriate preoperative management strategies must be adopted, taking into account the specific circumstances. This involves assessing cardiovascular function by means of electrocardiogram (ECG) and echocardiography, and evaluating pulmonary function through spirometry and blood-gas analysis. Such evaluations allow for the precise determination of patients' cardiopulmonary conditions and furnish essential support for formulating subsequent management protocols [26, 27]. Central to this process is multidisciplinary cooperation. Rehabilitation physicians design personalized preoperative rehabilitation regimens, which might incorporate aerobic activities such as in-bed limb mobilizations and short-distance ambulation, along with strength-training exercises like resistance training with elastic bands. The objective is to augment muscle strength, balance, and stamina, thereby elevating the SPPB score [28]. Cardiologists modify drug prescriptions in line with patients' cardiovascular risks. In cases of arrhythmia or heart failure, guidelines like the 2020 ESC guidelines for heart failure and supraventricular tachycardia are employed to guide the administration of anti-arrhythmic and cardiac function-enhancing medications (e.g., diuretics, ACEI/ARB). This contributes to the stabilization of the patient's condition and the reduction of risks. This preoperative methodology transforms research findings into clinical directives, safeguarding surgical safety and improving prognoses.

Our study has several limitations. Firstly, due to resource constraints, troponin and BNP were excluded from the model. Smith et al. have shown that troponin is crucial for myocardial injury and MACEs in abdominal surgery patients, especially the elderly, while Johnson and colleagues have demonstrated that BNP, secreted by ventricular myocytes, is vital for cardiac function and related to MACEs risks during surgery. Their exclusion may reduce prediction accuracy. Secondly, the 200-replication bootstrap validation lacks external validation and clear separation of training and test sets. Different distributions of new patient data may overestimate the model's performance and affect prediction reliability. Previous research on model evaluation indicates that the data imbalance (26 MACEs events vs. many variables) causes overfitting risk that the bootstrap method can't fully address, potentially reducing the model's generalization and accuracy. Finally, our single-center study with 426 patients may have selection bias. Given the long-term nature of MACEs and potential risk changes, the 30-day follow-up is insufficient. Relevant studies on longitudinal study design suggest a longer-term follow-up is needed for better model evaluation. To address these, future research will conduct multicenter studies to increase sample size and diversity, reducing bias. The follow-up period will be extended. External datasets will be used for model validation, and the training and test sets will be better separated. If possible, troponin and BNP will be included to enhance the model's predictive power.

In conclusion, the Short Physical Performance Battery (SPPB) serves as a significant predictor of major adverse cardiac events (MACEs). We have developed a straightforward nomogram predicated upon it, which exhibits predictive capabilities regarding MACEs. In the realm of clinical practice, this nomogram can be effectively utilized for the preoperative assessment of patients and the stratification of risks. Preoperative interventions founded on this nomogram may prove instrumental in reducing MACEs, thereby making contributions to the enhancement of peri-operative management and the attainment of more favorable patient-centered outcomes. However, it should be borne in mind that its application ought to be integrated with clinical judgment, taking into account the potential limitations.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Author contributions

All the authors contributed to the study concept and design. Material preparation, data collection, and analysis were performed by Adilai Kurexi, Rui Yan, Tingting Yuan, Zhaenhaer Taati, Maimaiti Mijiti, and Dan Li. Adilai Kurexi is the first author, and Rui Yan, Tingting Yuan, Zhaenhaer Taati, Maimaiti Mijiti, and Dan Li are co-first authors. Adilai Kurexi wrote the first draft of the manuscript, and all authors commented on previous versions. All the authors have read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

This study was conducted according to the Declaration of Helsinki and was approved by the Ethics Committee of the Third Affiliated Teaching Hospital (Cancer Hospital) of Xinjiang Medical University.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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