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Development and validation of a prediction model for the prolonged length of stay in Chinese patients with lower extremity atherosclerotic disease: a retrospective study

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ABSTRACT

Objectives This study aims to develop and internally validate a prediction model, which takes account of multivariable and comprehensive factors to predict the prolonged length of stay (LOS) in patients with lower extremity atherosclerotic disease (LEAD).

Design This is a retrospective study.

Setting China.

Participants, primary and secondary outcomes Data of 1694 patients with LEAD from a retrospective cohort study between January 2014 and November 2021 were analysed. We selected nine variables and created the prediction model using the least absolute shrinkage and selection operator (LASSO) regression model after dividing the dataset into training and test sets in a 7:3 ratio. Prediction model performance was evaluated by calibration, discrimination and Hosmer-Lemeshow test. The effectiveness of clinical utility was estimated using decision curve analysis.

Results LASSO regression analysis identified age, gender, systolic blood pressure, Fontaine classification, lesion site, surgery, C reactive protein, prothrombin time international normalised ratio and fibrinogen as significant predictors for predicting prolonged LOS in patients with LEAD. In the training set, the prediction model showed good discrimination using a 500-bootstrap analysis and good calibration with an area under the receiver operating characteristic of 0.750. The Hosmer-Lemeshow goodness of fit test for the training set had a p value of 0.354. The decision curve analysis showed that using the prediction model both in training and tests contributes to clinical value.

Conclusion Our prediction model is a valuable tool using easily and routinely obtained clinical variables that could be used to predict prolonged LOS in patients with LEAD and help to better manage these patients in routine clinical practice.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ A multivariable risk prediction model for predicting prolonged length of stay (LOS) was established in lower extremity atherosclerotic disease patients with (LEAD).
⇒ Risk factors included in the prediction model are accessible from hospital's information systems.
⇒ The established prediction model for the prolonged LOS of LEAD can be used as a good prediction tool in clinical practice.
⇒ There was only one centre in which we conducted our study, limiting the generalisability of our findings to other centres and countries.
⇒ The results may be influenced by other factors unevaluated by the data sources.

INTRODUCTION

Lower extremity atherosclerotic disease (LEAD) is a manifestation of peripheral arterial disease (PAD), which acts as a systemic type of atherosclerosis affecting the peripheral arteries.[1] According to the latest epidemiological data, LEAD affects more than 230 million adults worldwide.[2] LEAD has a wide range of clinical manifestations, including asymptomatic individuals and those with leg symptoms.[3] Clinically, the most severe outcome is critical limb ischaemia, which involves rest pain, ulcers, gangrene and possible amputation.[4 5] In spite of its widespread prevalence and clinical significance, LEAD was historically underestimated by patients and healthcare professionals. Some patients with symptomatic and more severe LEAD require hospitalisation for vascular treatment. However, a previous study showed that patients with LEAD with similar symptoms and signs had a less consistent length of stay (LOS).[6] These discrepancies merit further investigation.

LOS is one of many metrics being considered in the current effort to deliver healthcare more efficiently.[7] A protracted LOS is an obvious cost-containment target, as it is an indicator of efficiency and quality. The early and accurate prediction of the LOS allows for more efficient bed management, enables

better resource allocation, shapes patient expectations and facilitates discharge planning. This prediction can provide a reference for patients who require the most aggressive early intervention and those who require moderate intervention for possible approaches to prevent prolonged LOS.

Growing evidence indicates that some risk factors are single independent predictors of prolonged LOS in patients with PAD. According to Siracuse *et al*, severe PAD indicators (eg, previous arterial surgery) were a significant predictor of prolonged LOS after bypass surgery for patients with severe PAD with critical limb ischaemia.[8] A study by Seo *et al* showed that prolonged postoperative LOS in patients with PAD was related to the severity of the disease.[9] Researchers found that factors such as diabetes mellitus and bypass surgery predict increased LOS in patients with PAD.[10] Additionally, Lüders *et al* revealed that anaemia is the driver of longer LOS.[11] While the above-mentioned and other factors were found as independent predictors for predicting prolonged LOS in patients with LEAD, and there is still no multivariable and comprehensive model to systematically predict prolonged LOS for patients with LEAD. Additionally, with the advancement of medicine, studies have confirmed that clinical events are affected mainly by a series of factors, and there is a relatively complex interaction between the factors. Based on the above factors, we developed a prediction model to help identify inpatients' diagnosis with LEAD or LEAD was included as one of several ancillary diagnoses at admission who are likely to have a prolonged LOS.

METHODS

Patients and study design

We included patients who had the admitting diagnosis of LEAD or LEAD was included as one of several ancillary diagnoses on a patient admitted to the hospital with another primary diagnosis and who were treated at the vascular thyroid surgery department of the First Hospital of China Medical University (tertiary teaching hospital) between January 2014 and November 2021. The definitive diagnosis of LEAD is made by the physician(s) based on the patient's symptoms, signs, examination results and according to the Chinese LEAD diagnostic criteria (Version 2007).[12] Most patients were discharged home, others were discharged to a skilled nursing facility or rehabilitation facility. The discharge criteria are target vessel lesion opening with no significant complications.[13]

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Collection of demographic and laboratory data

Patient data were obtained from the electronic medical records system of the First Hospital of China Medical University by a trained abstractor using the International Classification of Diseases-10 (ICD-10) codes (I70.203) for LEAD. The demographic data included gender, age, systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse rate, surgery, lesion site, symptoms and signs, and existing disease diagnosis. According to the patient's symptoms and signs, Fontaine classification was performed.[14] Additionally, we calculated the age-adjusted Charlson Comorbidity Index (ACCI)[15] based on age and existing disease diagnosis. The ACCI is used to assess the impact of comorbidities (eg, diabetes, myocardial infarction, chronic kidney disease, etc) on the prognosis of patients except for the diseases currently being treated. The laboratory indicators included urea, total bilirubin (TBIL), triglyceride (TG), C reactive protein (CRP), low-density lipoprotein cholesterol (LDL-C), homocysteine (Hcy), high-density lipoprotein cholesterol (HDL-C), cystatin C (CysC), fibrinogen (FIB), D-dimer, activated partial thromboplastin time (APTT), thrombin time (TT), prothrombin (PT) and prothrombin time international normalised ratio (PT-INR). All demographic and laboratory data were collected at the time of admission, and biochemical parameters were measured by the clinical laboratory at the First Hospital of China Medical University (Shenyang, China). We included the variables based on the prior studies[5 16 17] and clinically relevant to LEAD and LOS in the prediction model as candidate predictors. The following 23 variables were finally identified: gender, age, SBP, DBP, pulse rate, type of surgery, lesion site, Fontaine classification, ACCI, urea, TBIL, TG, CRP, LDL-C, Hcy, HDL-C, CysC, FIB, D-dimer, APTT, TT, PT and PT-INR. The outcome variable of LOS was calculated based on the number of days from admission to discharge date. The median LOS for all patients was 10 days (IQR=7–14 days). As most studies of prolonged LOS in patients with PAD have used the median LOS as the segmentation point for prolonged LOS.[18 19] The data of LOS in this study showed a non-normal distribution, so we defined the outcome variable of prolonged LOS as longer than the median LOS of 10 days.

Statistical analysis

The dataset was then divided randomly into training and test sets in a 7:3 ratio, and variables were compared between the two sets. Numbers and percentages were used for categorical variables, and differences between binary variables were compared using the χ^2 test. The Wilcoxon rank sum test was performed to analyse the ordered categorical variable (Fontaine classification). Kolmogorov-Smirnov test was used to determine the normality of continuous variables. There was no normal distribution of continuous variables, and the median and IQR were presented. We then used Mann-Whitney Wilcoxon U tests to compare continuous variables.

We developed a prediction nomogram for prolonged LOS using the least absolute shrinkage and selection operator (LASSO) logistic regression in selecting the significant predictive factors. The prediction model in this study was developed based on the logistic regression

model. The multivariate logistic regression analysis was performed across the training set to identify the associations between the predictors and outcome. We calculated the proportion of missing data for each predictor variable (online supplemental table 1), and then missing data were imputed by multiple imputations using linear regression for continuous variables and logistic regression model for binary variables. Prediction model performance was evaluated by calibration and discrimination. A receiver operating characteristic (ROC) curve was used to determine the model's discriminatory ability.[20] For the calibration of the prediction model, a visual calibration plot was used to compare the predicted and actual probabilities that the LOS>10 days would be below the predefined threshold. Additionally, 500 bootstraps resamples were conducted for internal validation to evaluate the predictive accuracy of the model. We analysed the training and test datasets using decision curve analysis to estimate the prediction model's clinical utility at different threshold probabilities.[21]

Analyses were conducted with two-tailed tests, and a value of p<0.05 was considered statistically significant. We analysed the data using Stata V.16.0 (StataCorp, College Station, Texas, USA) and R V.3.6.0 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Characteristics of the training and test sets

There were 1696 patients diagnosed with LEAD. After excluding two patients without LOS data, a total of 1694 patients were finally included in this study. The median LOS for patients with open surgery was 10 days (IQR=7–14 days), endovascular surgery was 16 days (IQR=12–21 days) and no surgery was 8 days (IQR=6–11 days). By using multivariate logistic regression analysis with the predictors in the training set, this study found that female and type of surgery were significantly associated with the LOS (all p<0.05) (online supplemental table 2). A total of 1186 patients were assigned to the training set and 508 to the test set (see figure 1 for details). A summary of the baseline characteristics of patients in the training and test datasets can be found in table 1. Test and training sets had no significant differences (all p>0.05). No apparent differences were found between LOS≤10 days and LOS>10 days except for gender and type of surgery among the test set (p<0.05).

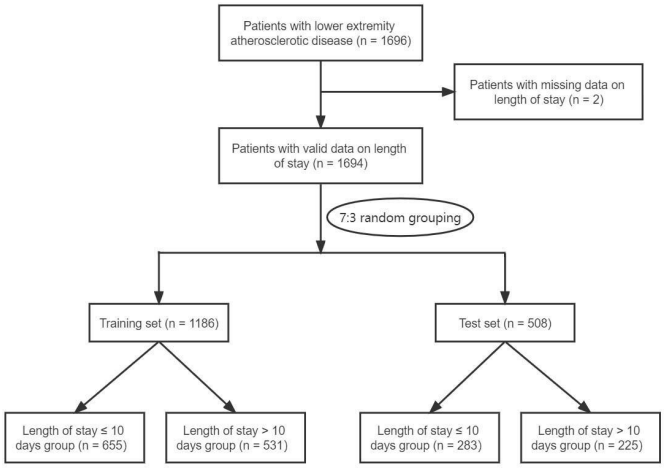

Figure 1 Flow chart of study participants.

Predictor variables and construction of the model

Nine potential predictors were obtained after incorporating the 23 variables listed in table 1 into the LASSO regression model. The coefficient profile plot was then constructed (figure 2A). A cross-validation plot for the LASSO regression model is shown in figure 2B. The final predictive model included nine independent predictors (FIB, PT-INR, CRP, type of surgery, lesion site, Fontaine classification, SBP, gender and age).

Development of a nomogram

The nomogram was developed based on the above independent predictors (figure 3). The sum of the points assigned to each factor in the nomogram can be used to calculate the risk of prolonged LOS. A high total point score was associated with a prolonged LOS.

Performance of the prediction model

The prediction model demonstrated good discrimination in the training set with an area under the ROC curve of 0.750 (figure 4A). According to the calibration plot for the probability of prolonged LOS, the points are close to the 45° line, indicating good agreement between the prediction and observation (online supplemental figure 1A). As shown in the test set, the prediction model showed an area under the ROC curve of 0.708 with satisfactory discrimination for prolonged LOS (figure 4B). A relatively good calibration was also found in the test set for risk estimation (online supplemental figure 1B). Additionally, decision curve analysis estimates the net benefit of screening at all possible thresholds. The results of DCA in the training set and the test set show that the threshold probabilities are 35%–69% and 37%–74%, both of which show high threshold ranges and present certain clinical values (online supplemental figure 2).

DISCUSSION

To our knowledge, this study is the first to develop a multivariable and comprehensive prediction model based on widely and routinely available clinical data to predict prolonged LOS for patients with LEAD. The prediction model integrates nine main predictors, including age, gender, SBP, Fontaine classification, lesion site, surgery, CRP, PT-INR and FIB. The validation and test sets showed good discrimination and satisfactory calibration. In our study, the calibration plots showed good agreement between the model predictions and actual observations, further verifying the mode's reliability.

When hospitalisation was required, patients stayed for a long time (median of 10 days). It reflects the vulnerability

Table 1 Characteristics of the patients in the total, training and test sets

Variables	Total	Training set (n=1186)			Test set (n=508)			P value
		LOS≤10 days	LOS>10 days	P value	LOS≤10 days	LOS>10 days	P value	
n	1694	655	531		283	225		
Gender, n (%)				0.019			0.030	0.323
Male	1366 (80.64)	508 (77.56)	441 (83.05)		223 (78.80)	194 (86.22)		
Female	328 (19.36)	147 (22.44)	90 (16.95)		60 (21.20)	31 (13.78)		
Age (years), median (IQR)	70.00 (64.00–78.00)	71.00 (64.00–78.00)	69.00 (63.00–78.00)	0.035	70.00 (64.00–78.00)	68.00 (63.00–76.00)	0.065	0.704
SBP (mm Hg), median (IQR)	146.00 (131.00–160.00)	145.00 (131.00–160.00)	148.00 (132.00–160.00)	0.480	147.50 (132.00–161.00)	140.00 (126.00–155.50)	0.090	0.781
DBP (mm Hg), median (IQR)	78.00 (69.00–86.00)	77.00 (67.00–85.00)	80.00 (71.00–87.00)	0.013	79.00 (69.50–88.00)	76.00 (67.50–85.50)	0.291	0.361
Pulse rate (beats per minute), median (IQR)	81.00 (75.00–92.00)	80.00 (75.00–93.00)	81.00 (71.00–91.00)	0.412	82.00 (76.00–90.50)	84.00 (77.50–92.50)	0.531	0.400
Type of surgery, n (%)				<0.001			<0.001	0.140
No	370 (23.43)	188 (31.39)	82 (16.24)		68 (26.15)	32 (14.88)		
Open	247 (15.64)	32 (5.34)	147 (29.11)		15 (5.77)	53 (24.65)		
Endovascular	962 (60.92)	379 (63.27)	276 (54.65)		177 (68.08)	130 (60.47)		
Lesion site, n (%)				0.123			0.273	0.597
Unilateral lower limb	740 (47.31)	271 (45.62)	250 (50.30)		114 (44.02)	105 (49.07)		
Bilateral lower limbs	824 (52.69)	323 (54.38)	247 (49.70)		145 (55.98)	109 (50.93)		
Fontaine classification, n (%)				0.004			0.456	0.466
Class I	68 (4.66)	30 (5.34)	21 (4.75)		9 (3.56)	8 (3.96)		
Class II	1187 (81.36)	471 (83.81)	343 (77.60)		211 (83.40)	162 (80.20)		
Class III	34 (2.33)	15 (2.67)	9 (2.04)		8 (3.16)	2 (0.99)		
Class IV	170 (11.65)	46 (8.19)	69 (15.61)		25 (9.88)	30 (14.85)		
ACCI (Score), median (IQR)	3.00 (2.00–4.00)	3.00 (2.00–4.00)	3.00 (2.00–4.00)	0.190	3.00 (2.00–4.00)	2.00 (1.00–4.00)	0.187	0.387
Urea (mmol/L), median (IQR)	6.12 (4.83–7.69)	6.44 (5.02–7.97)	5.94 (4.67–7.40)	0.003	6.35 (4.92–7.75)	6.07 (4.60–7.72)	0.170	0.911
TBIL (mmol/L), median (IQR)	9.60 (7.10–13.20)	9.80 (7.30–13.20)	9.60 (7.00–12.70)	0.145	9.60 (7.10–14.50)	9.45 (7.00–13.00)	0.256	0.889
TG (mmol/L), median (IQR)	1.35 (0.97–1.96)	1.40 (0.96–1.99)	1.33 (0.99–1.88)	0.247	1.35 (0.97–1.99)	1.37 (1.01–2.11)	0.924	0.521
CRP (mg/L), median (IQR)	6.70 (3.20–26.70)	6.00 (2.80–24.30)	6.70 (3.60–30.10)	0.112	7.90 (3.30–30.20)	6.80 (3.36–26.55)	0.768	0.340
LDL-C (mmol/L), median (IQR)	2.81 (2.18–3.43)	2.78 (2.18–3.41)	2.79 (2.12–3.35)	0.381	2.90 (2.37–3.54)	2.89 (2.22–3.43)	0.368	0.074
Hcy (µmol/L), median (IQR)	13.32 (10.58–17.9)	12.88 (10.40–16.94)	13.65 (11.01–18.64)	0.016	14.02 (10.16–19.94)	13.51 (11.07–17.20)	0.895	0.310
HDL-C (mmol/L), median (IQR)	0.98 (0.82–1.19)	0.98 (0.82–1.20)	0.98 (0.80–1.19)	0.810	0.98 (0.84–1.18)	0.98 (0.83–1.18)	0.917	0.954
CysC (mg/L), median (IQR)	1.11 (0.93–1.41)	1.14 (0.94–1.43)	1.08 (0.92–1.38)	0.070	1.11 (0.94–1.38)	1.11 (0.93–1.42)	0.638	0.724
FIB (g/L), median (IQR)	3.97 (3.24–5.22)	3.89 (3.20–4.91)	4.05 (3.30–5.64)	0.020	3.86 (3.19–5.02)	4.11 (3.33–5.29)	0.116	0.876
D-dimer (mg/L), median (IQR)	0.66 (0.39–1.25)	0.62 (0.38–1.15)	0.73 (0.42–1.59)	0.011	0.61 (0.36–1.14)	0.61 (0.41–1.35)	0.439	0.133

Continued

Table 1 Continued

Variables	Total	Training set (n=1186)			Test set (n=508)			P value
		LOS≤10 days	LOS>10 days	P value	LOS≤10 days	LOS>10 days	P value	
APTT (s), median (IQR)	39.20 (35.80–43.20)	39.00 (35.80–43.00)	38.80 (35.30–43.40)	0.882	39.60 (36.00–43.10)	40.10 (36.05–43.75)	0.441	0.153
TT (s), median (IQR)	16.70 (16.00–17.60)	16.70 (16.00–17.60)	16.60 (15.90–17.50)	0.111	16.90 (16.20–17.70)	16.80 (16.00–17.70)	0.230	0.089
PT (s), median (IQR)	13.30 (12.80–14.20)	13.30 (12.70–14.10)	13.40 (12.80–14.20)	0.212	13.30 (12.80–14.00)	13.40 (12.80–14.30)	0.469	0.811
PT-INR, median (IQR)	1.02 (1.00–1.09)	1.01 (1.00–1.09)	1.02 (1.00–1.10)	0.055	1.01 (1.00–1.08)	1.02 (1.00–1.11)	0.104	0.713

Total percentages within categories may not equal 100% due to rounding.
ACCI, age-adjusted Charlson Comorbidity Index; APTT, activated partial thromboplastin time; CRP, C reactive protein; CysC, cystatin C; DBP, diastolic blood pressure; FIB, fibrinogen; Hcy, homocysteine; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; PT, prothrombin; PT-INR, prothrombin time international normalised ratio; SBP, systolic blood pressure; TBIL, total bilirubin; TG, triglyceride; TT, thrombin time.

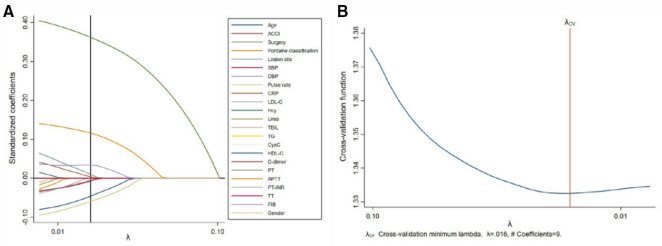

Figure 2 Coefficient path and cross-validation plot. (A) Coefficient path plot. (B) Cross-validation plot. ACCI, age-adjusted Charlson Comorbidity Index; APTT, activated partial thromboplastin time; CRP, C reactive protein; CysC, cystatin C; DBP, diastolic blood pressure; FIB, fibrinogen; Hcy, homocysteine; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; PT, prothrombin; PT-INR, prothrombin time international normalised ratio; SBP, systolic blood pressure; TBIL, total bilirubin; TG triglyceride; TT, thrombin time.

of specific older adult populations with other medical problems requiring treatment, which may significantly prolong the LOS. This long hospitalisation stay is a result of a combination of other associated medical problems and various social reasons.

During patient hospitalisation, LOS is the mainstay of quality assessment of care delivered.[22] The LOS can serve as a benchmark for improving care and is an easy metric to measure for administrators.[23] Predicting patients at risk of prolonged LOS using this prediction model with nine variables is also helpful for vascular care teams and patients. When a patient is most likely to require prolonged LOS, resource planning and psychological preparation for the patient and their caregivers can be performed.

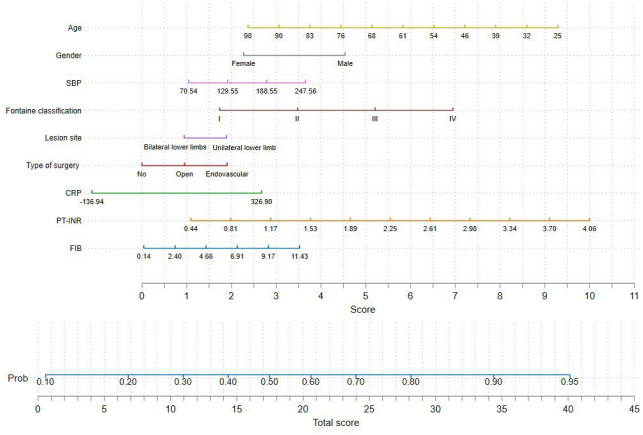

Figure 3 Establishment of a nomogram for the prediction of prolonged length of stay. The nomogram was developed in training set by incorporating the following nine variables: age (years), gender (male, female), SBP (mm Hg), Fontaine classification (I, II, III, IV), lesion site (unilateral lower limb, bilateral lower limbs), type of surgery (no, open, endovascular), CRP (mg/L), PT-INR and FIB (g/L). CRP, C reactive protein; FIB, fibrinogen; PT-INR, prothrombin time international normalised ratio; SBP, systolic blood pressure.

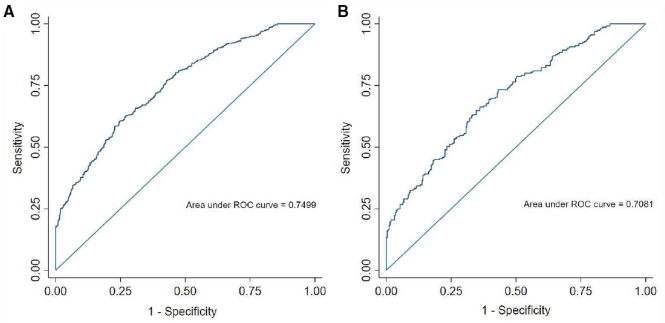

Figure 4 Receiver operating characteristic (ROC) curves of the lasso model in the training and test sets. (A) Training set. (B) Test set.

This study showed that younger age was one of the predictors to predict prolonged LOS in patients with LEAD. LEAD is primarily viewed as a problem for older adults since its prevalence is strongly related to age.[24 25] According to previous reports, younger patients may be more likely to have lesions affecting the more proximal circulation than older patients.[26 27] Additionally, compared with older patients, younger patients tend to have more aggressive disease processes, need multiple revascularisations, have a higher mortality rate and increased amputation rates.[28–30] Meanwhile, a study by Kim *et al* also indicated that younger patients with chronic limb-threatening ischaemia undergoing lower extremity revascularisation had a longer LOS during the perioperative period than older patients.[31] In addition, younger patients tend to be more active in treatment once they become ill and are more concerned and cautious about their health problems.[32 33] The comprehensive examination and diagnosis and treatment needs of patients may also be the reasons for the prolonged LOS of younger patients.

Our study found that gender was a significant predictor of prolonged LOS, and prolonged LOS was more common in males. Several studies have suggested that patients with PAD have different clinical outcomes depending on their gender. Men with symptomatic PAD had a higher risk of long-term adverse cardiovascular events and mortality.[34] Hicks *et al* also found that white men were at a greater risk of PAD-related hospitalisation than white women.[35] In another study, Al-Omran *et al* indicated that men were more likely to suffer major amputations after revascularisation procedures.[36] Similarly, Budtz-Lilly *et al* reported that men who underwent surgery for PAD had a high mortality risk and adverse cardiovascular events.[37] Furthermore, the longer LOS in men may be associated with more male smokers and the increased degree of vascular damage and associated complications related to this behaviour.[38 39]

There is a close correlation between SBP and a higher risk of adverse events for patients with PAD. A study of 13 885 participants with symptomatic PAD showed that high SBP increased the risk of ischaemic limb events.[40] Similarly, in another study of 8139 patients with symptomatic vascular disease, the risk of adverse limb events was related to SBP.[41] As adverse limb events were related to extended LOS,[42] the association of elevated SBP with an increased risk of adverse limb events may account for longer LOS.

Regarding the Fontaine classification, disease severity was also correlated with LOS. For instance, Seo *et al* found that the severity of critical limb ischaemia was associated with prolonged LOS between the milder and severe groups.[9] Moreover, Kohn *et al* showed that Fontaine classification III–IV PAD patients had a longer LOS than Fontaine classification I–II PAD patients.[19] It was also confirmed in a study conducted by Trenner *et al* that the median LOS increased from 2 days in Fontaine classification I or IIb to 14 days in Fontaine classification IV.[43] Therefore, the above-mentioned studies could support our findings that the Fontaine classification is an essential predictor of prolonged LOS in patients with LEAD.

Our results have also shown that lesion site and type of surgery are factors for predicting prolonged LOS. As patients who need surgery and have bilateral lower extremity lesions are in a relatively severe condition at admission. The surgical procedure causes additional trauma to the body, requiring more time to recover.[44] Therefore, patients with surgery (open or endovascular) had to undergo traumatic treatment and then have a longer LOS. The LOS in this study was similar to previous studies of PAD in China.[8 10 45] But it is longer than some studies from Western countries.[19 46] The research population of this study is individuals with a median age of 70 years. This specific population is often complicated with other chronic diseases, and these complicated chronic diseases may increase hospitalisation time. Additionally, in China, the LOS tends to be much longer than that in Western countries because of the difference in social and medical systems. Patients in China basically return home directly after discharge so that they tend to stay at the hospital until they get a substantial recovery and target vessel lesion opening with no significant complications. And medical insurance companies only pay for medical expenses during hospital stays in China.[47] Most of the comprehensive assessments were performed after patients were admitted to the hospital, which may significantly prolong the LOS.[48] This prolonged LOS is a result of a combination of the above associated medical issues.

Furthermore, biological markers such as CRP, PT-INR and FIB were identified as predictors for predicting prolonged LOS. A systematic review indicated that high baseline CRP levels could predict adverse limb events in patients with PAD who underwent lower limb revascularisation.[49] Another systematic review also showed that plasma biomarkers such as high-sensitivity CRP and FIB were related to mortality and cardiovascular events in patients with PAD.[50] Moreover, there is evidence that PT-INR is related to increased bleeding risk. Additionally, a retrospective cohort study indicated that preoperative PT-INR is independently and significantly related to postoperative major bleeding and mortality.[51] Similarly,

Faisal *et al* found that elevated PT-INR was a risk factor for rebleeding in patients with acute variceal haemorrhage after band ligation.[52] Bleeding complications can lead to prolonged LOS.[53 54]

In addition, there may have other variables that can prolong LOS. For example, previous studies have found that non-Caucasian race,[8] Asian or Pacific Islanders[55] and depression[56] were related to increased LOS of patients with PAD. Some prehospital predictors (eg, emergency admission) have also been shown to increase LOS.[10 45] However, all the patients in this study are Asian, race did not apply to the study population. The mental health status and prehospital condition of the patients are not the contents of the hospital's routine medical records, and with the limitations of retrospective studies, so we did not include the above variables in this study. Future research on the prediction model of LEAD patients' prolonged LOS should include some other indicators that may potentially affect LOS.

Previous studies on the LOS of patients with PAD have used multivariate logistic regression models,[57 58] zero-truncated negative binomial regression,[59] multivariate stepwise regression analysis,[60] machine learning algorithms[61 62] to conduct forecasting models for predicting LOS. The above methods have their own applicability and characteristics. Based on the data characteristics of this study, we selected multivariate logistic regression, and other modelling methods may be considered in future studies.

Prior studies have shown that comorbidities (eg, diabetes mellitus,[10] dialysis dependence and severe cardiac and pulmonary disease[8]) can affect the LOS in patients with PAD. Considering ACCI's comprehensive assessment of patients' complications or comorbidities, we use it as a candidate predictor to build the predictive model.

Our prediction model fills a gap in the lack of comprehensive model knowledge for predicting prolonged LOS in patients with LEAD. The focus of previous studies on patients with LEAD or PAD has been mainly on long-term outcomes such as mortality and functional decline.[63 64] As mentioned above, this study explored a short-term outcome that might be easier to predict during LEAD treatment. The shorter interval between our baseline clinical assessments and the outcome of interest could have facilitated the high accuracy of our models since fewer confounders would have been identified than in long-term studies. Additionally, all variables included in our models are clinically available and routinely tested, and existing evidence indicates they are associated with patient-centred outcomes. For instance, CRP, FIB, age and male gender have been shown to predict adverse outcomes in patients with LEAD or PAD.[49 50 65]

Several limitations in the study may merit consideration. First, this study was conducted in only one centre despite being performed on a large cohort. The results cannot be generalised to other centres and countries, and additional studies are required to validate our prediction model at other centres worldwide. Second, due to the limitation of a retrospective study, some possible impact indicators (eg, depression, emergency admission) have not been included in this study. Third, although the internal validation dataset of this study showed moderate discrimination and calibration, the lack of external validation of our findings may cause the overfitting of the selected hyperparameters. It is essential of conducting further to validate the results in external cohort studies. Fourth, this study only used Fontaine classification to determine clinical stages, additional Wify or global limb anatomic staging system (GLASS) classification would be beneficial and should be performed in future studies. Finally, this study was a retrospective analysis, so further randomised controlled trials will be necessary to confirm the clinical benefits.

CONCLUSIONS

In conclusion, we have constructed a practical and personalised predictive tool for predicting prolonged LOS in patients with LEAD. The proposed prediction model considered nine independent risk factors including age, gender, SBP, Fontaine classification, lesion site, surgery, CRP, PT-INR and FIB. The prediction model showed its accuracy, demonstrating good discrimination and satisfactory calibration. Our model has potential significant clinical utility and can be easily implemented in clinical settings. With the application of this prediction model, physicians and nurses could identify patients who are more likely at a higher risk for prolonged LOS and facilitate the implementation of preventive strategies, such as multidisciplinary care coordination and individualised care pathways.

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