Predictive nomogram models for atrial fibrillation in COPD patients: A comprehensive analysis of risk factors and prognosis

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Abstract. The aim of the present study was to identify the independent risk factors and prognostic indicators for atrial fibrillation (AF) in patients with chronic obstructive pulmonary disease (COPD) and to develop predictive nomogram models. This retrospective study included a total of 286 patients with COPD who were admitted to the Second Affiliated Hospital of Guilin Medical College between January 2020 and May 2022. The average age of the patients was 77.11±8.67 years. Based on the presence or absence of AF, the patients were divided into two groups: The AF group (n=87) and the non-AF group (n=199). Logistic regression analysis was conducted to identify variables with significant differences between the two groups. Nomogram models were constructed to predict the occurrence of AF in COPD patients and to assess prognosis. Survival analysis was performed using the Kaplan-Meier method. The follow-up period for the present study extended until April 31, 2023. Survival time was defined as the duration from the date of the interview to the date the participant succumbed or the end of the follow-up period. In the present study, age, uric acid (UA) and left atrial diameter (LAD) were found to be independent risk factors for the development of AF in patients diagnosed with COPD. The stepwise logistic regression analysis revealed that age had an odds ratio (OR) of 1.072 [95% confidence interval (CI): 1.019-1.128; P=0.007], UA had an OR of 1.004 (95% CI: 1.001-1.008; P=0.010) and LAD had an OR of 1.195 (95% CI: 1.098-1.301; P<0.001). Univariate and multivariate Cox regression analysis revealed that LAD and UA were independent prognostic factors for long-term mortality in COPD patients with AF. LAD had a hazard ratio (HR) of 1.104 (95% CI: 1.046-1.165; P<0.001) and UA had an HR of 1.004 (95% CI: 1.000-1.008; P=0.042). Based on these findings, predictive nomogram models were developed for AF in COPD patients, which demonstrated good discrimination ability with an area under the curve of 0.886. The prognostic nomogram for COPD patients with AF also showed good predictive accuracy with a concordance index of 0.886 (95% CI: 0.842-0.930). These models can provide valuable information for risk assessment and prognosis evaluation in clinical practice. Age, UA and LAD are independent risk factors for AF in COPD patients. The developed nomogram models provide a reliable tool for predicting AF in COPD patients and for prognosis assessment.

Introduction

Chronic obstructive pulmonary disease (COPD) is a prevalent and devastating global health issue, placing a substantial strain on both population health and healthcare resources (1). This disease is characterized by persistent respiratory symptoms and irreversible airflow limitation (2). COPD is closely linked to chronic bronchitis and emphysema, which are the primary underlying conditions leading to the development of COPD, often presenting with overlapping features (3). Epidemiological data from 2015 estimated that ~299 million individuals worldwide were affected by COPD, with >3 million deaths attributed to this chronic ailment (4). COPD not only exacts a significant economic toll on society but also poses a grave threat to the physical and psychological well-being of individuals (5).

In recent years, comorbidity has emerged as a global concern, referring to the coexistence of two or more chronic diseases. COPD is a systemic ailment commonly associated with various chronic conditions, such as atrial fibrillation (AF), cardiovascular disease, diabetes, lung cancer, osteoporosis and depression (6-8). AF, a significant complication of COPD, is known to worsen the quality of life and increase all-cause mortality, thereby imposing a substantial disease and economic burden on COPD patients (9-11). Currently, AF is the most prevalent supraventricular arrhythmia, affecting an estimated 8 million patients in China alone (12). A meta-analysis

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involving 4.2 million COPD patients revealed that 13% of them had concurrent AF (13). Furthermore, Goudis *et al* (14) demonstrated that COPD patients face a twofold increased risk of developing AF compared to non-COPD patients, with severe COPD patients exhibiting a fourfold higher incidence. Although the risk factors for COPD combined with AF remain unclear, a study involving 2,352 AF patients identified left atrial enlargement and decreased left ventricular ejection fraction as potential risk factors for this comorbidity (15). A meta-analysis conducted in 2020 revealed that advanced age (>65), male gender and Caucasian ethnicity are associated with an increased risk of AF in patients with COPD (16). Furthermore, independent risk factors for COPD-induced AF include myocardial infarction, coronary artery disease, chronic heart failure, pulmonary infections, acute respiratory failure, mechanical ventilation, chronic kidney disease and the use of ipratropium bromide. Notably, the administration of β-adrenergic agonists and theophylline during acute exacerbation of COPD was found to elevate cardiac instability, which is an independent risk factor for COPD-induced AF (17). However, no significant association was observed between hypertension, hyperlipidemia, diabetes, liver failure and the risk of new-onset AF in the present study. Conversely, literature reports have identified diabetes, hypertension, peripheral vascular disease and liver failure as independent risk factors for the development of AF in non-COPD patients (16). Given the current controversy surrounding the identification of risk factors for COPD combined with AF, it is imperative to establish a diagnostic model for this condition.

To identify COPD patients at high risk of developing AF and with poor survival rates, the present study aimed to construct a diagnostic model for predicting the risk of COPD combined with AF. Additionally, a prognostic model was developed to predict the prognosis of COPD combined with AF. This was achieved by utilizing demographic and common hematological parameters of COPD patients admitted to the Second Affiliated Hospital of Guilin Medical University between January 2020 and May 2022. The ultimate goal was to identify specific patient subgroups and tailor personalized treatment strategies, leading to improved clinical outcomes and enhanced quality of life.

Materials and methods

Study population. This retrospective study analyzed patients with COPD who were admitted to the Second Affiliated Hospital of Guilin Medical College (Guilin, Guangxi Zhuang Autonomous Region, P.R. China) between January 2020 and May 2022. Based on the presence or absence of AF, the study population was divided into the AF group (COPD with AF) and the non-AF group (COPD without AF). The study was approved by the Ethics Committee of The Second Affiliated Hospital of Guilin Medical University (approval no. NO.YJS-2021011). The inclusion criteria were as follows: i) Patients aged 40 years or older, of any gender, admitted for the treatment of dyspnea, cough, or exacerbation of sputum in COPD; ii) COPD diagnosis in accordance with the 2021 Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines (1); iii) completion of electrocardiography or 24-h Holter monitoring, echocardiography, pulmonary function tests, blood gas analysis and renal function tests; iv) alert and able to communicate effectively. The exclusion criteria were as follows: i) Patients with concomitant valvular heart disease and recurrent AF after catheter radiofrequency ablation; ii) presence of active chronic respiratory diseases such as obstructive sleep apnea syndrome, bronchial asthma, severe pneumonia, bronchiectasis, tuberculosis, or pulmonary malignancies; iii) presence of other systemic diseases such as rheumatic autoimmune diseases or severe hepatic or renal failure; iv) need for tracheal intubation and invasive mechanical ventilation, or concomitant multiple organ failure; v) incomplete research data. The definition and diagnostic criteria for COPD were based on the 2018 GOLD guidelines (1). The diagnostic criteria for AF were the presence of AF on surface electrocardiography or single-lead electrocardiographic recording lasting >30 sec (18). The diagnosis of pulmonary arterial hypertension was based on the 2022 European Respiratory Society and European Society of Cardiology guidelines for the diagnosis of pulmonary hypertension (19).

Data collection. Clinical data were collected, including age, gender, height, weight, systolic and diastolic blood pressure upon admission, duration of COPD, smoking and alcohol history, comorbidities and respiratory medication history. Laboratory test results upon admission included complete blood count, renal function and blood gas analysis (Table I). Transthoracic echocardiography was performed to measure relevant parameters such as left atrial diameter (LAD), right atrial diameter, left ventricular ejection fraction and pulmonary artery systolic pressure. Pulmonary function tests were conducted using a Master Screen spirometer by trained technicians. Prior to the tests, the height and weight of patients were measured in a standing position and the tests were conducted according to the guidelines established by the Pulmonary Function Group of the Chinese Medical Association Respiratory Branch. Patients received 1-2 practice sessions before the tests and there were no absolute contraindications to pulmonary function testing in any of the patients. The main outcome measures collected were forced expiratory volume in one second (FEV1), FEV1 as a percentage of predicted (FEV1%Pred) and the FEV1/forced vital capacity (FVC) ratio. The follow-up period for the study extended until April 31, 2023. Survival time was defined as the duration from the date of the interview to the date of the participant succumbing or the end of the follow-up period.

Construction of diagnostic and prognostic models. A stepwise backward logistic regression analysis was employed to identify key factors for constructing a diagnostic model for the coexistence of COPD and AF and a visually appealing nomogram was generated. Univariate and multivariate Cox regression analyses were conducted to select factors influencing the prognosis of COPD combined with AF and a prognostic nomogram was constructed using the identified factors. The accuracy of the models was evaluated using the concordance index (c-index), receiver operating characteristic (ROC) curve and area under the curve (AUC), with higher values indicating superior accuracy. The predictive ability of the models was assessed using calibration curves, where a well-calibrated model would align closely with the 45-degree diagonal line.

Table I. Comparison of baseline data between AF group and non-AF group.

Characteristic	AF	non-AF	P-value	Statistic	Method
N	87	199			
Sex (Male/Female), n (%)			0.237	1.400	χ^2
Male	65 (74.7)	161 (80.9)			
Female	22 (25.3)	38 (19.1)			
Age, years (median IQR)	77 (70-81)	69 (63-76)	<0.001		Wilcoxon
Hypertension, n (%)	37 (42.5)	63 (31.7)	0.076	3.146	χ^2
Chronic heart failure, n (%)	61 (70.1)	58 (29.1)	<0.001	41.821	χ^2
History of myocardial infarction, n (%)	0 (0)	1 (0.5)	1		Fisher test
Chronic kidney disease, n (%)	23 (26.4)	15 (7.5)	<0.001	18.767	χ^2
Respiratory failure, n (%)	22 (25.3)	32 (16.1)	0.067	3.350	χ^2
Pulmonary infection, n (%)	87 (100)	196 (98.5)	0.603	0.271	Yates' correction
Cerebrovascular accident, n (%)	16 (18.4)	27 (13.6)	0.294	1.102	χ^2
Smoking, n (%)	37 (42.5)	105 (52.8)	0.111	2.537	χ^2
SBP, mmHg, (median IQR)	129 (114-143)	130 (116-142)	0.878		Wilcoxon
DBP, mmHg, mean ± standard deviation	78.977±14.487	80.477±12.73	0.380	-0.879	T test
Heart rate, beats per minute, (median IQR)	92 (78-101)	93 (82.5-102)	0.674		Wilcoxon
Respiratory rate, breaths per minute, (median IQR)	22 (20.5-23.5)	22 (21-23)	0.647		Wilcoxon
Duration of COPD, (median IQR)	10 (2-10)	8 (3-10)	0.750		Wilcoxon
Home oxygen therapy, n (%)	7 (8)	10 (5)	0.320	0.988	χ^2
ICS, n (%)	2 (2.3)	9 (4.5)	0.572	0.320	Yates' correction
Anticholinergic drugs, n (%)	33 (37.9)	63 (31.7)	0.301	1.068	χ^2
LABA, n (%)	28 (32.2)	59 (29.6)	0.668	0.184	χ^2
Xanthine drugs, n (%)	45 (51.7)	127 (63.8)	0.055	3.694	χ^2
ICS + LABA, n (%)	37 (42.5)	93 (46.7)	0.511	0.432	χ^2
WBC, (median IQR)	7.6 (5.905-11.28)	8.04 (6.26-10.125)	0.893		Wilcoxon
RBC, (median IQR)	4.34 (3.75-4.63)	4.43 (4.0625-4.8675)	0.057		Wilcoxon
Hb, (median IQR)	128 (114-142)	132 (122-144)	0.099		Wilcoxon
Plt, (median IQR)	208 (162-275)	230 (191-268)	0.103		Wilcoxon
Lymphocyte count, (median IQR)	1.34 (0.76-1.45)	1.305 (0.93-1.74)	0.062		Wilcoxon
Monocyte count, (median IQR)	0.66 (0.51-0.9)	0.65 (0.4925-0.8375)	0.318		Wilcoxon
Neutrophil count, (median IQR)	5.89 (3.96-9.35)	5.57 (3.885-7.9125)	0.640		Wilcoxon
Hematocrit, median, (median IQR)	39.5 (35.7-44)	40.7 (37.2-43.7)	0.232		Wilcoxon
CRP, (median IQR)	6.965 (4-21.828)	5.36 (4-28.265)	0.588		Wilcoxon
pH, (median IQR)	7.41 (7.39-7.445)	7.41 (7.3893-7.43)	0.302		Wilcoxon
PCO_2, (median IQR)	43 (37.3-51.25)	44.85 (39.825-52.75)	0.138		Wilcoxon
PO_2, (median IQR)	76.1 (61-88.85)	77.55 (67-89.8)	0.570		Wilcoxon
HCO_3, (median IQR)	27.1 (24.8-32)	27.9 (25.5-32)	0.276		Wilcoxon
FEV1, (median IQR)	1.05 (0.65-1.82)	1.3 (0.825-1.815)	0.201		Wilcoxon
Predicted FEV1, (median IQR)	48.3 (31-61)	48.6 (34.2-69.8)	0.329		Wilcoxon
FVC, (median IQR)	2.14 (1.62-2.875)	2.23 (1.71-2.93)	0.410		Wilcoxon
Predicted FVC, (median IQR)	56.7 (15.945-68.15)	53.2 (1.99-66.9)	0.108		Wilcoxon
FEV1/FVC, (median IQR)	57.04 (42.205-75.95)	64.14 (48.69-76.85)	0.233		Wilcoxon

Table I. Continued.

Characteristic	AF	non-AF	P-value	Statistic	Method
Predicted FEV1/FVC, mean ± standard deviation	59.174±17.409	59.296±13.334	0.953	-0.058	Welch t' test
Pulmonary hypertension, n (%)	58 (75.3)	75 (37.7)	<0.001	31.498	χ^2
Pulmonary artery pressure, (median IQR)	48 (37.5-59)	39 (31-46)	0.002		Wilcoxon
LAD, (median IQR)	38 (31.5-45)	28 (25-31)	<0.001		Wilcoxon
RAD, (median IQR)	38 (30-45.5)	29 (26-32)	<0.001		Wilcoxon
UA, (median IQR)	413 (329.5-484.5)	336.5 (274.25-396)	<0.001		Wilcoxon

IQR, interquartile range; SBP, systolic blood pressure; DBP, diastolic blood pressure; COPD, chronic obstructive pulmonary disease; ICS, inhaled corticosteroids; LABA, long-acting β agonists; WBC, white blood cell; RBC, red blood cell; Hb, hemoglobin; Plt, platelet; CRP, C-reactive protein; PCO_2, partial pressure of carbon dioxide; PO_2, partial pressure of oxygen; FEV1, forced expiratory volume in 1 sec; FVC, forced vital capacity; LAD, left atrial diameter; RAD, right atrial diameter; UA, uric acid.

Survival analysis. The Kaplan-Meier method was employed to plot the survival curves of the COPD + AF group and the COPD group (20). The log-rank test was utilized to compare the survival differences between these two patient groups.

Statistical analysis. Continuous variables were described using mean and standard deviation or median and interquartile range, depending on the distribution of the data. For variable comparisons, the two-sample t-test or Wilcoxon rank-sum test with continuous correction based on data normality and homogeneity of variance were employed. Categorical data were presented as absolute values and percentages and the χ^2 test was used to compare categorical variables between the two groups. Data were organized using Excel 16.0 (Microsoft Corporation) and analyzed using RStudio version 4.1.2 (21). In the R software, several packages were employed, including 'readxl', 'car', 'autoReg', 'dplyr', 'officer', 'foreign', 'moonBook', 'rrtable', 'survival', 'survivalROC', 'survminer', 'rms', 'foreign', and 'tableone'. P<0.05 was considered to indicate a statistically significant difference.

Results

Baseline data comparison. The present study enrolled a cohort of 286 patients, with a mean age of 77.11±8.67 years, including 226 males. Among them, 87 patients were classified in the AF group, with an average age of 75.36±7.51 years, while the remaining 199 patients were assigned to the non-AF group, with an average age of 69.25±8.50 years. Notably, the AF group exhibited significantly advanced age, elevated levels of UA, pulmonary artery pressure, as well as a higher prevalence of comorbidities such as chronic heart failure, pulmonary hypertension and chronic kidney disease. Moreover, the AF group displayed significantly enlarged LAD and right atrial diameter, with statistically significant differences (P<0.05). A comprehensive overview of the baseline demographic characteristics for both groups is presented in Table I.

Logistic regression analysis of risk factors for COPD with AF. To identify potential risk factors associated with COPD and AF, univariate and multivariate logistic regression analyses were conducted for variables demonstrating significant differences between the two groups (age, chronic heart failure, chronic kidney disease, UA, pulmonary hypertension, pulmonary artery pressure, LAD, right atrial diameter). Following stepwise regression analysis, age, UA and LAD were identified as independent risk factors (Table II).

Nomogram model for predicting COPD with AF. The present study developed a nomogram model to predict the occurrence of COPD with AF, incorporating age, UA and LAD as predictors (Fig. 1A). The ROC curve analysis revealed an AUC of 0.886, indicating excellent discriminative ability of the nomogram model (Fig. 1B). Furthermore, the calibration plot demonstrated a close agreement between the predicted and observed probabilities, indicating reliable calibration of the nomogram model (Fig. 1C). Additionally, the decision curve analysis (DCA) curve illustrated the clinical utility of the nomogram model (Fig. 1D).

Survival analysis. To assess the effect of AF on the prognosis of COPD patients, Kaplan-Meier analysis was performed to compare the all-cause mortality rate between individuals with COPD alone and those with COPD and AF. The findings revealed a significant difference in the all-cause mortality rate between the two groups. Notably, the COPD with AF group exhibited substantially lower survival rates compared to the COPD group (P<0.05; Fig. 2).

Prognostic model and nomogram. Univariate and multivariate Cox regression analyses were conducted to identify factors influencing the prognosis of patients diagnosed with both COPD and AF. As presented in Table III, both univariate and multivariate Cox regression analyses revealed that levels of uric acid (UA) and LAD were independent prognostic factors for COPD patients with concurrent AF. Based on these significant factors, a prognostic nomogram for COPD with AF was constructed (Fig. 3A), yielding a c-index of 0.886 (95% confidence interval: 0.842-0.930). The area under the receiver operating characteristic curve (AUC) values for predicting 5-month, 10-month and 15-month survival rates using the nomogram were 0.952, 0.851 and 0.881, respectively (Fig. 3B).

Table II. Stepwise logistic regression analysis assessing the risk of AF development in individuals diagnosed with chronic obstructive pulmonary disease COPD.

		Univariate analysis		Multivariate analysis	
Characteristics	Total, n	Odds Ratio (95% CI)	P-value	Odds ratio (95% CI)	P-value
Age	286	1.095 (1.058-1.133)	<0.001	1.072 (1.019-1.128)	0.007
Chronic heart failure	119	5.704 (3.286-9.901)	<0.001	2.122 (0.907-4.962)	0.083
Chronic kidney disease	38	4.408 (2.167-8.966)	<0.001	2.202 (0.704-6.889)	0.175
UA	271	1.006 (1.003-1.008)	<0.001	1.004 (1.001-1.008)	0.010
Pulmonary hypertension	133	5.047 (2.792-9.124)	<0.001	2.065 (0.678-6.295)	0.202
Pulmonary artery pressure	200	1.018 (1.002-1.034)	0.025	0.993 (0.964-1.023)	0.649
LAD	286	1.198 (1.143-1.256)	<0.001	1.195 (1.098-1.301)	<0.001
RAD	286	1.118 (1.081-1.156)	<0.001	1.014 (0.945-1.089)	0.691

AF, atrial fibrillation; COPD, chronic obstructive pulmonary disease; CI, confidence interval; LAD, left atrial diameter; RAD, right atrial diameter.

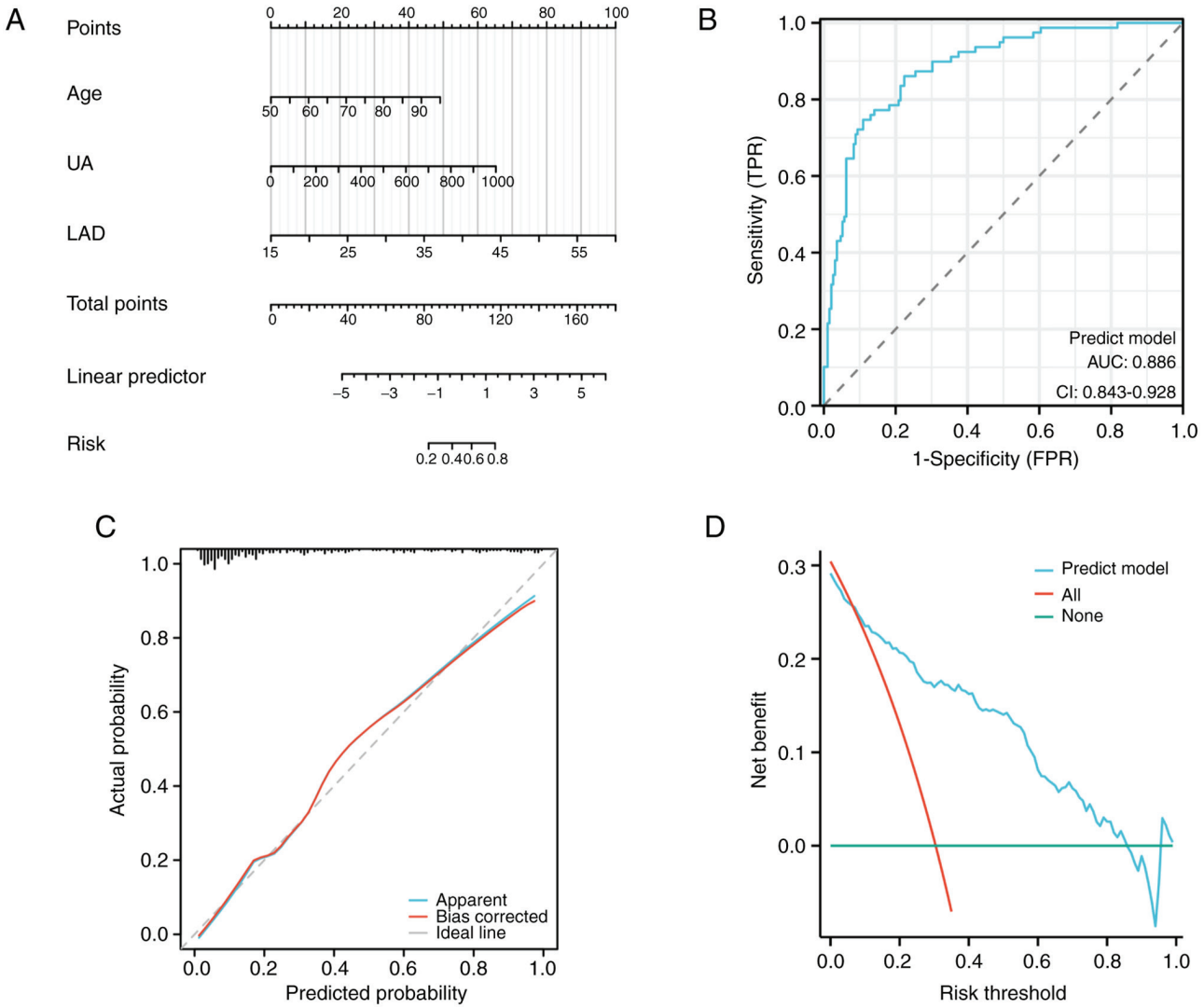

Figure 1. Performance evaluation of the nomogram model. (A) Nomogram results depicting the diagnostic model's utilization of age, UA and LAD. Each diagnostic factor corresponds to a specific score, which are then aggregated to derive the total score for predicting the risk of atrial fibrillation development in individual chronic 0 obstructive pulmonary disease patients. A linear line is plotted along the total score axis to facilitate risk prediction. (B) Receiver operating characteristic curve illustrating the diagnostic nomogram's performance. (C) Re-calibration curve demonstrating the diagnostic nomogram's accuracy. (D) Decision curve analysis curve. UA, uric acid; LAD, left atrial diameter; AUC, area under the curve; CI, confidence interval; TPR, true-positive rate; FPR, false-positive rate.

Table III. Univariate and multivariate Cox regression analysis predicting the long-term mortality rate associated with atrial fibrillation occurrence in patients diagnosed with COPD.

		Univariate analysis		Multivariate analysis	
Characteristics	Total, n	Hazard ratio (95% CI)	P-value	Hazard ratio (95% CI)	P-value
Pulmonary hypertension	77				
1	58	Reference			
0	19	1.981 (0.597-6.571)	0.264		
Pulmonary artery pressure	71	1.007 (0.971-1.044)	0.711		
LAD	87	1.120 (1.060-1.183)	<0.001	1.104 (1.046-1.165)	<0.001
RAD	87	0.989 (0.935-1.047)	0.708		
UA	79	1.006 (1.002-1.010)	0.005	1.004 (1.000-1.008)	0.042
Age	87	1.008 (0.940-1.082)	0.818		
Chronic Heart Failure	87				
0	26	Reference			
1	61	1.305 (0.413-4.126)	0.650		
Chronic kidney disease	87				
0	64	Reference			
1	23	0.571 (0.158-2.060)	0.392		

COPD, chronic obstructive pulmonary disease; CI, confidence interval; LAD, left atrial diameter; RAD, right atrial diameter; UA, uric acid.

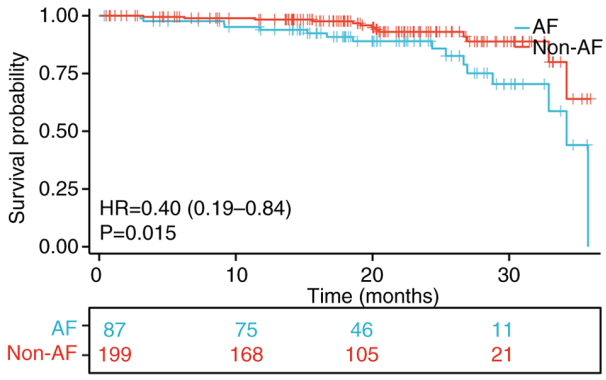

Figure 2. Kaplan-Meier survival curves of chronic obstructive pulmonary disease patients with and without AF. AF, atrial fibrillation; HR. hazard ratio.

Furthermore, the calibration curve demonstrated excellent agreement between the predicted and observed 5-month, 10-month and 15-month survival rates (Fig. 3C).

Discussion

The present study collected clinical data of patients with COPD admitted to the Second Affiliated Hospital of Guilin Medical College between January 2020 and May 2022. A practical nomogram was constructed to predict the risk of AF in COPD patients and predicted the 5-, 10- and 15-month survival rates of COPD patients based on available demographic, clinical and hematological parameters. The results showed that the model for predicting AF risk in COPD patients had an AUC of 0.886 and the models for predicting 5-, 10- and 15-month survival had AUCs of 0.952, 0.851 and 0.881, respectively. The present study, for the first time to the best of the authors' knowledge, identified age, UA levels and LAD as independent risk factors for the development of AF in patients with COPD. These findings fill a knowledge gap in the existing literature and provide new guidance for risk assessment of AF in COPD patients.

AF is the most common supraventricular arrhythmia in clinical practice and its prevalence is associated with age and gender. A study (12) indicated that the prevalence of AF in males under 60 years old was 0.43 and 0.44% in females, while in males >60 years old, the prevalence increased to 1.83 and 1.92% in females. A recent survey in China (22) showed that the prevalence of AF reached 10% in individuals >75 years old. Prospective studies from Japan and the United States have also confirmed the relationship between age and the incidence of new-onset AF, with an increased risk of AF with advancing age (23). As age increases, the lung function of COPD patients gradually declines, leading to worsened hypoxia, which is a key mechanism for AF development in COPD, causing atrial structural changes and intimal thickening (24,25). The present study found that COPD patients with AF were significantly older than those without AF and logistic regression analysis indicated age as an independent risk factor for COPD with AF. This finding is consistent with a meta-analysis report in 2020 (16), which showed that clinical characteristics of COPD with AF have significant demographic features such as age over 65, male gender and Caucasian ethnicity, indicating a higher risk of AF in these populations. Therefore, it was hypothesized that the risk of COPD with AF increases with age and clinicians should be more vigilant about the occurrence of AF in older COPD patients.

LAD, measured by echocardiography, plays an important role in the occurrence and development of AF (26,27). A cohort

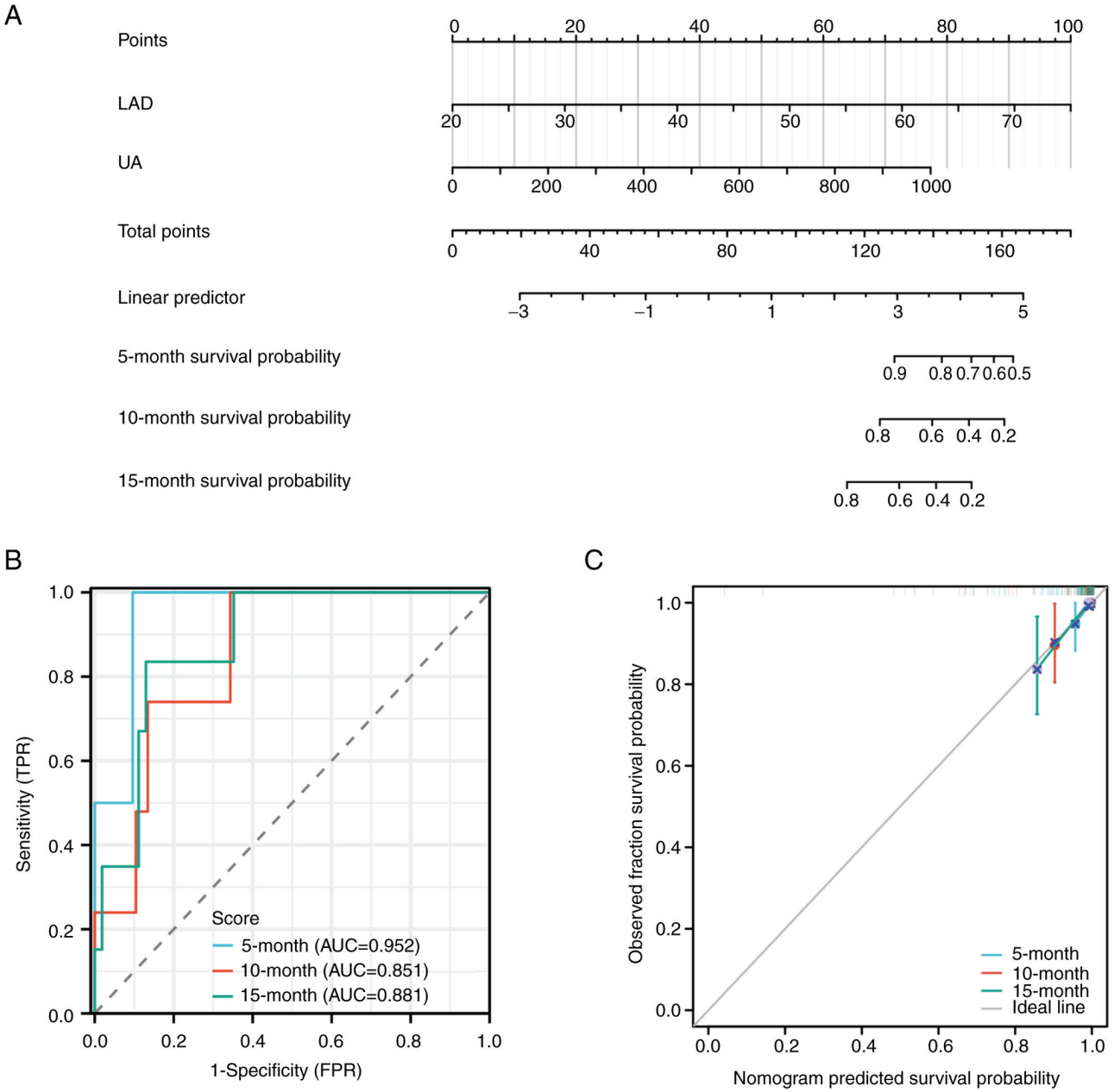

Figure 3. Construction and validation of the prognostic nomogram model. (A) Nomogram results of the prognostic model using UA and LAD. Each prognostic factor corresponds to a score and the individual scores are summed to obtain the total score for predicting the 5-, 10- and 15-month survival rates of COPD patients with AF. A straight line is drawn on the axis of the total score to predict the survival rates. (B) ROC curve of the prognostic Nomogram for predicting the 5-month, 10-month and 15-month survival rates of COPD patients with AF. (C) Re-calibration curve of the prognostic nomogram for predicting the 5-, 10- and 15-month survival rates of COPD patients with AF. UA, uric acid; LAD, left atrial diameter; COPD, chronic obstructive pulmonary disease; AF, atrial fibrillation; ROC, receiver operating characteristic; AUC, area under the curve; TPR, true-positive rate; FPR, false-positive rate.

study by Vaziri *et al* (28) showed that for every 5 mm increase in LAD, the risk ratio for AF was 1.39 and LAD enlargement was an independent risk factor for AF. Furthermore, univariate and multivariate Cox regression analysis results indicated that LAD enlargement was an independent prognostic factor for AF. It has been discovered that changes in the ultrastructure of atrial myocytes and atrial fibrosis are the main forms of atrial remodeling in AF patients (29,30). Enlarged atrial myocardium not only affects atrial mechanical function but also increases the pathological basis for the formation of reentrant arrhythmias in AF, as the enlarged atrial myocardium can accommodate more reentrant wavelets (31,32). Research has found that inflammatory reactions are closely related to pathological processes such as electrical remodeling, structural remodeling and autonomic nervous system remodeling (33,34).

COPD patients experience increased pulmonary vascular resistance due to the positive end-expiratory pressure, which leads to the invasion of the interventricular septum into the left ventricle, impairing left ventricular filling and resulting in elevated left atrial and pulmonary vein pressures (35). This process of left atrial remodeling is particularly pronounced in COPD patients with comorbidities such as AF (36). The inflammatory response triggered by chronic hypoxia in COPD patients contributes to the process of atrial

remodeling (37). Once AF occurs, the discordant contraction of atrial muscles further exacerbates atrial remodeling, creating a vicious cycle that promotes the development of AF and ultimately leads to further deterioration of cardiac structure and function (38). In the present study, LAD was found to be an independent risk factor for AF in COPD patients. Therefore, by controlling the pressure on LAD, it may be possible to reduce the risk of AF in COPD patients. Further research could explore interventions such as medication treatment or other measures to reduce pulmonary arterial hypertension or improve left ventricular function, thereby reducing the pressure on LAD and lowering the likelihood of AF in COPD patients.

UA plays an important role in the development and prognosis of COPD. The level of UA is directly proportional to the severity of tissue hypoxia. When tissue hypoxia occurs, ATP synthesis decreases, leading to increased degradation of adenine nucleotides and elevated UA levels (39,40). Plasma UA mainly originates from the metabolism of intracellular purine substances, with most of it being excreted by the kidneys and the remainder being degraded in the digestive tract (41). Existing research has indicated a close relationship between UA and oxidative stress (42). UA acts as a selective antioxidant and plays an important role in the plasma antioxidant mechanism by stabilizing serum vitamin C, preventing the oxidation inactivation of endothelial enzymes and maintaining vascular dilation capacity (43). Studies have found that serum UA levels are associated with inflammatory factors such as CRP, IL-1, IL-6 and TNF-α (44-46). UA may induce atrial cell apoptosis and fibrosis through the inflammatory pathway, leading to atrial remodeling and promoting the occurrence of AF. Studies have reported a close relationship between plasma UA levels and the occurrence and adverse prognosis of cardiovascular diseases (47,48). Furthermore, elevated plasma UA levels have been confirmed as an independent risk factor for AF, increasing the risk of AF occurrence (45,49). A study found that elevated plasma UA levels were an independent risk factor for new-onset AF and the plasma UA levels were even higher in patients with persistent AF, suggesting a correlation between UA and the severity and duration of AF (50). The present study found that UA levels were an independent risk factor for AF in COPD patients. Therefore, controlling UA levels may have significance in preventing AF in COPD patients. Further research could explore interventions to lower UA levels, such as medication or dietary adjustments and their impact on the occurrence and prognosis of AF in COPD patients.

The present study discovered that plasma UA levels were significantly higher in COPD patients with AF compared to those without AF and this difference was statistically significant. Furthermore, both univariate and multivariate Cox regression analyses revealed that plasma UA levels were an independent prognostic factor for AF. UA is a routinely measured biochemical marker, easily obtained through simple methods. Therefore, when elevated UA levels are found in COPD patients, it should not be simply interpreted as an increased risk of gout, but rather as a potential indicator for cardiovascular events.

However, the present study had certain limitations. First, the follow-up period was relatively short, only until May 2023, and it is necessary to ensure a sufficiently long follow-up duration. Second, the present study employed a retrospective clinical design with a small sample size, thus requiring larger-scale, multicenter prospective studies to confirm the diagnostic and prognostic efficacy of LAD and UA in COPD with AF. Additionally, the model constructed only validated the predictive performance using the data from the modeling itself and further validation of the model's accuracy is needed using external data. To improve the utility of the nomogram in predicting the risk and long-term prognosis of COPD with AF in clinical practice, more rigorous multicenter prospective studies are necessary to validate the model developed in the present study.

In summary, the present study has developed a nomogram to predict the risk of AF in COPD patients and predict the 5-, 10- and 15-month survival rates of COPD patients with AF. The nomogram can assist clinicians and patients in early identification of COPD with AF and predict their 5-, 10- and 15-month survival rates, providing appropriate clinical information for personalized treatment strategies and improving quality of life for patients.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

TH was responsible for conceptualization, methodology, resources, writing the original draft and reviewing and editing. XH was responsible for investigation, formal analysis, writing the original draft, reviewing and editing and supervision. XC was responsible for investigation, supervision and writing. QD was responsible for investigation, supervision, resources and writing. All authors read and approved the final manuscript. TH, XH, XC and QD confirm the authenticity of all the raw data.

Ethics approval and consent to participate

The Ethical Committee of The Second Affiliated Hospital of Guilin Medical University approved the present research (approval no. NO.YJS-2021011). The authors confirmed that all methods conform to the provisions of Helsinki Declaration. All participants signed informed consent.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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