Patient Preference and Adherence

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ORIGINAL RESEARCH

Developing and Validating a Nomogram for Non-Adherence to Inhaler Therapy Among Elderly Chronic Obstructive Pulmonary Disease Patients Based on the Social Ecological Model

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Purpose: This study aimed to identify the risk predictors of non-adherence to inhaler therapy and construct a nomogram prediction model for use in Chinese elderly patients with chronic obstructive pulmonary disease (COPD).

Patients and Methods: A cross-sectional study was conducted with 305 participants recruited from a tertiary care hospital in Anhui, China. Adherence was analyzed using the Test of Adherence to Inhalers. Potential predictive factors were incorporated based on the social ecological model, and data were collected through a questionnaire method. R version 4.3.3 was utilized to perform the least absolute shrinkage and selection operator regression model and multivariable logistic regression analysis to identify risk factors and establish a nomogram prediction model.

Results: The results of the multivariable analysis revealed that medication beliefs, illness perception, the COPD Assessment Test score, smoking status, and education level were significant risk factors for non-adherence to inhaler therapy in elderly COPD patients (all $P < 0.05$). The nomogram prediction model for non-adherence to inhaler therapy in elderly COPD patients demonstrated a good discriminative ability, with an area under the receiver operating characteristic curve of 0.912. The C-index was 0.922 (95% CI: 0.879 to 0.965), and the Brier value was 0.070, indicating good consistency and calibration. Decision curve analysis indicated that the use of the nomogram would be more beneficial in clinical practice when the threshold probability of non-adherence exceeds 17%.

Conclusion: This study identified predictive factors regarding non-adherence among elderly patients with COPD and constructed a predictive nomogram. By utilizing the nomogram model healthcare professionals could swiftly calculate and comprehend the non-compliance level of COPD patients, thus guiding the development of personalized interventions in clinical practice.

Keywords: chronic obstructive pulmonary disease, inhaler therapy, nomogram, non-adherence, social ecological model

Introduction

Chronic obstructive pulmonary disease (COPD) stands as the most prevalent chronic respiratory disorder.[1] In China, the prevalence of COPD ranges from 1.20% to 8.87%, making it the third leading cause of death among residents.[2] This condition imposes a significant economic burden, with direct healthcare costs ranging from $72 to $3565 per capita annually, accounting for 33.33% to 118.09% of the average annual income.[2]

Inhalation therapy, offering a quicker onset of action and fewer side effects compared to oral therapy, plays a key role in preventing acute exacerbations and serves as the foundation of maintenance treatment for COPD.[3] Through the use of inhalers such as long-acting β2-agonists, long-acting anticholinergics, and inhaled corticosteroids alone or in combination, inhalation

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therapy aims to improve forced expiratory volume in 1 second (FEV1) and alleviate overinflation that contributes to respiratory distress.[4,5]

Adherence to inhaler therapy significantly correlates with clinical health outcomes in COPD patients. Previous studies have shown that patients with good adherence to inhaler therapy experience lower susceptibility to acute exacerbations and reduced overall mortality rate.[6] Effective inhaler adherence can prevent exacerbations, control disease progression, reduce hospitalizations, and decrease healthcare expenditures associated with hospitalizations or emergency care.[6,7] However, the Global Initiative for Chronic Obstructive Lung Disease in 2023 emphasized that inhaler adherence among COPD patients tends to be generally low, with rates falling below 50%,[8] posing significant challenges in COPD disease management. To enhance inhaler adherence in COPD patients, the primary task at present is to comprehensively understand the factors contributing to non-adherence, identify non-adherent individuals at an early stage, and develop targeted intervention strategies.

The Social Ecological Model(SEM) proposes that the dynamic interaction between individuals and their environment is a determinant of health-related behaviors.[9] The SEM addresses limitations of previous research, which solely focused on analyzing influencing factors at a single level, by providing a more systematic and comprehensive perspective. It emphasizes that individual behavior is shaped by multi-level factors, including personal trait, behavioral characteristics, interpersonal relationship, life and work conditions, policy environment.[10] Recommended by the American Heart Association and the American Society of Hypertension for understanding medication adherence factors, SEM has been successfully utilized by Mehdi et al to construct a conceptual model of compliance among hypertensive patients.[11] Therefore, this study aims to explore the factors influencing adherence in COPD patients based on the SEM.

Nomogram model is a feasible tool for describing individual prognosis or clinical event risk, aiming to provide the likelihood of a specific event occurrence.[12] In recent years, multiple studies have reported the benefits of survival curve models in predicting medication adherence among patients with chronic diseases, such as chronic kidney disease and diabetes.[13,14] In contrast to the complex formulas of risk prediction models, nomograms offer the advantage of delivering more personalized risk assessment in an intuitive graphical format, thereby providing clear value in clinical practice.

Currently, there is no established inhaler adherence nomograms prediction tool for COPD patients based on the SEM. This study aims to identify independent risk factors for medication non-adherence among Chinese COPD patients based on the SEM and establish a risk model using the nomogram. This model can assist clinicians in screening high-risk non-adherent patients and devising personalized treatment strategies to improve inhaler adherence behavior.

Methods

Design

This was a cross-sectional study.

Participants

From June 2022 to December 2023, recruitment was conducted in the Department of Respiratory Medicine of a tertiary care hospital in Anhui, Mainland China. A total of 305 participants were enrolled, meeting the following criteria:(1) aged≥60years; (2) had FEV1/ force vital capacity (FVC) < 0.7 on spirometry and diagnosed with COPD according to the Guidelines for the Diagnosis and Treatment of Chronic Obstructive Pulmonary Disease (Revised 2021);[15] (3) treated with an inhaler; (4) conscious, with good comprehension and communication skills (Mini-Mental State Examination score ≥27, which was represented they are able to provide valid response to the questionnaires[16]); and (5) voluntarily participating in the study and willing to provide informed consent. Patients with severe hepatic or renal insufficiency, malignant tumors or psychiatric diseases were not allowed to participate in the study. The study was conducted in accordance with the Declaration of Helsinki and received approval and consent from the Ethics Committee of Bengbu Medical College. All participants provided written informed consent.

Sample Size

According to the EPV (Events Per Variable) principle for estimating the sample size of logistic regression, it is recommended to have an EPV of 10–20 to ensure robustness of the regression analysis results.[17] Previous studies have shown that the adherence rate to inhaler therapy among COPD patients is 50% or lower.[8] In this study, we assume a 70% probability of non-adherence among COPD patients.[18]

In this study, we incorporated various factors based on the SEM. Under the domain of biological characteristics, we included gender and age of the patients. Lifestyle and behavioral habits encompassed factors such as medication beliefs, illness perception, smoking status, and the impact of diseases on life. Healthcare utilization factors included the number of hospitalizations, length of hospital stay, and hospitalization expenses in the past year. Interpersonal relationships were considered by including factors such as the current residence (urban, rural, or town), living condition (living with spouse, children, alone, or other), and family support scores. Social and cultural factors included patients' monthly income and education level. Lastly, in the policy environments domain, we primarily focused on studying factors related to medical payment method.

Considering an EPV of 10, and including 15 factors based on the SEM, we would need a sample size of 150 patients with non-adherence to inhaler therapy for detection. Therefore, the total required sample size would be 150/70%=215 cases. With the inclusion of 305 patients in this study, we can ensure the stability of the regression results.

Measurements

Demographics

Data were collected from the participants, encompassing information on age, gender, smoking status, number of hospitalizations, length of hospital stay, hospitalization expenses in the past year, current residence (urban, rural, or town), living condition (living with spouse, children, alone, or other), monthly income, education level, and medical payment method.

Medication Adherence to Inhaler Therapy

The Chinese version of the Test of Adherence to Inhalers (TAI) was employed in this study to assess patient adherence to inhaled medication.[19] The TAI evaluates various aspects, including how frequently patients forget to use their inhaled medication, the impact of patient mood, improvement, interference of medication with life, adverse drug reactions, efficacy, dose, and cost on adherence to inhaled medication. The TAI comprises 10 items, each rated on a 5-point Likert scale. Total scores ranged from 10 to 50. Adherence levels were categorized as good (TAI = 50), moderate (TAI = 46–49) or poor (TAI < 46).[20]

Beliefs About Medicines

The Belief about Medicines Questionnaire (BMQ), developed by Horne in 1999,[21] was utilized to assess patients' medication beliefs. The questionnaire comprises two dimensions: necessity beliefs and concerns beliefs, totaling 10 items. Each item is rated on a 5-point Likert scale, where higher scores indicate stronger beliefs in medication necessity or greater concerns about medication. Computed by subtracting the concerns score from the necessity score. This study employed the Chinese version of the BMQ.[22]

Illness Perception

In this study, the Chinese version of the Brief Illness Perception Questionnaire (BIPQ) was used to evaluate COPD patients' perception of their illness. The scale consists of assessing patients' perceptions of disease consequences, timeline of illness, personal control, treatment control, symptoms, illness worries, understanding of illness, emotions, and etiology. The questionnaire consists of 9 subscales, the first 8 subscales are rated on a scale of 0–10. The ninth subscale was an open-ended question and was not scored. Higher scale scores indicate a more pronounced negative perception of the disease by the patient.[23]

Family Support

The assessment of patients' family support was performed using the Family Support Scale, which was translated by Zhang J et al[24]. The scale comprises 15 items, a with each item scored using a binary method, where "yes" is assigned a score of 1 and "no" is assigned a score of 0. The total score ranges from 0 to 15, with higher scores indicating stronger levels of family support.

Impact of Diseases on Life

The COPD Assessment Test (CAT) was used to comprehensively evaluate the disease symptoms and their impact on the lives of COPD patients.[25] It consists of eight items, including cough, sputum production, chest tightness, sleep, energy levels, exercise tolerance, confidence in going out, and the impact on daily activities at home. Each item is scored on a scale of 0 to 5, with a total score ranging from 0 to 40. Higher scores on the CAT indicate a greater severity of impact of COPD symptoms on the patient's life.

Data Collection

The questionnaire was collected through face-to-face surveys conducted by trained researchers in an offline setting. Upon obtaining informed consent from the patients, social demographic data and scores from various scales including TAI, CAT, BMQ, BIPQ, and the family support scale were collected. Relevant demographic data, such as age, gender, and medical payment methods, were supplemented through the electronic medical record system.

Before completing the questionnaire, researchers provided standardized instructions to explain the questionnaire guidelines, ensuring that patients could independently complete the survey. For illiterate patients, researchers conducted one-on-one interviews and selected appropriate answers based on the patients' responses. The completion of the survey took approximately 15 to 30 minutes, and all questionnaires were collected and verified on-site.

Statistical Analysis

Data description was performed using SPSS 27.0. Categorical variables were presented as frequency and percentage, while normally distributed continuous variables were described using mean ± standard deviation. Non-normally distributed continuous variables were described using median (interquartile ranges).

For the least absolute shrinkage and selection operator (LASSO) regression analysis to select predictive factors, the glmnet function in R version 4.3.3 software was utilized. Cross-validation was employed to calculate the lambda (λ) value, and the λ value with the smallest error was used as the criterion for selecting the predictive factors.[26] Logistic regression analysis was then applied to the potential predictive factors selected by LASSO regression and included in the prediction model. A risk prediction model for non-adherence to inhaler use in COPD patients was constructed based on the regression coefficients, and the model was visually presented using a nomogram. The predictive ability of the nomogram was quantified using Harrell's C-index. The C-index indicates the probability of agreement between the predicted and observed outcomes, with a range of 0.5 to 1.0.[27]

The calibration curve of the nomogram was used to assess the agreement between the observed and predicted non-adherence.[28] A calibration curve close to the 45° diagonal reference line indicates good predictive consistency. Internal validation of the model was performed using the area under the receiver operating characteristic (ROC) curve (AUC) to evaluate the predictive performance.[29] Net benefit at each threshold probability was calculated, and a decision curve was constructed to assess the clinical utility of the risk scoring model.[30,31]

Results

General Information About the Participants

A total of 305 elderly COPD patients were included in this study, with 48 patients (15.7%) being adherent to inhaler device use and 257 patients (84.2%) being non-adherent. The distribution of adherence and non-adherence among elderly COPD patients, stratified by different variables, is illustrated in Table 1.

Table 1 Distribution of Adherence and Non-Adherence Among COPD Patients Based on Different Variables

Variables		n(%)/ $\bar{x}\pm$ s/median(IQR)		
		Good/Moderate adherence (n=48)	Poor adherence (n=257)	Total (n=305)
Biological characteristics	Age	69.38(11)	71.25(12)	71(12)
	Gender			
	Male	35(72.9)	178(69.3)	213
	Female	13(27.1)	79(30.7)	92
Lifestyle and behavioral habits	Medication beliefs	2.65(6)	0.61(4)	1(5)
	Illness perception	50.4(7)	43.54(7)	45(8)
	CAT	19.23±10.79	19.62±8.08	19.56±8.55
	Smoking			
	Yes	38(79.2)	223(86.8)	261
	No	10(20.8)	34(13.2)	44
Healthcare utilization	Number of hospitalizations in the past year	1.87(3)	1.47(2)	1(2)
	Hospitalization expenses	10518.75(13,750)	7341.25(7000)	1500(7000)
	Length of hospital stay	10 (24)	5 (20)	7(20)
Interpersonal relationships	Residence			
	Rural	35(72.9)	194(75.5)	229
	Urban	6(12.5)	22(8.6)	28
	City	7(14.6)	41(16.0)	48
	Living condition			
	Living alone	8(16.7)	29(11.3)	37
	Living with children	9(18.8)	70(27.2)	79
	Living with spouse	31(64.6)	155(60.3)	186
	Other	0	3(1.2)	3
	Family support score	10.35(4)	9.93(2)	10(3)
Social and cultural	Monthly income			
	Below 1000 yuan	13(27.1)	102(39.7)	115
	1000~3000 yuan	20(41.7)	102(39.7)	122
	3001~5000 yuan	13(27.1)	42(16.3)	55
	Above 5000 yuan	2(4.2)	11(4.3)	13
	Education level			
	Primary school or below	14(29.2)	91(35.4)	105
	Junior high school	14(29.2)	89(34.6)	103
	Senior high school	14(29.2)	61(23.7)	75
	College or above	6(12.5)	16(6.2)	22
Policy environments	Medical payment method			
	Urban resident medical insurance	32(66.7)	194(75.5)	226
	Urban employee medical insurance	14(29.2)	58(22.6)	72
	Free medical care	1(2.1)	3(1.2)	4
	Self-payment	1(2.1)	0	1
	Other	0	2(0.8)	2

Note: Urban resident medical insurance: Targeted at minors and unemployed urban residents. Urban employee medical insurance: Targeted at employees of work units. Free medical care: Limited only to civil servants. Self-payment: Medical costs borne entirely by the patient. Other: Commercial medical insurance and low-income medical aid. Commercial medical insurance: Insurance companies provide a certain amount of medical expenses. Low-income medical aid: Mainly targeted at low-income households, five-guarantee elderly, and priority groups with difficulties in China.

Factor Selection

The LASSO regression analysis and cross-validation produced a range of λ values depicted between the two dashed lines in Figure 1A. Within this range, the model's predictive bias variation is relatively small. The number of influential factors corresponding to the λ value with the smallest error (left dashed line) was 7. Figure 1B illustrates that, with the exception

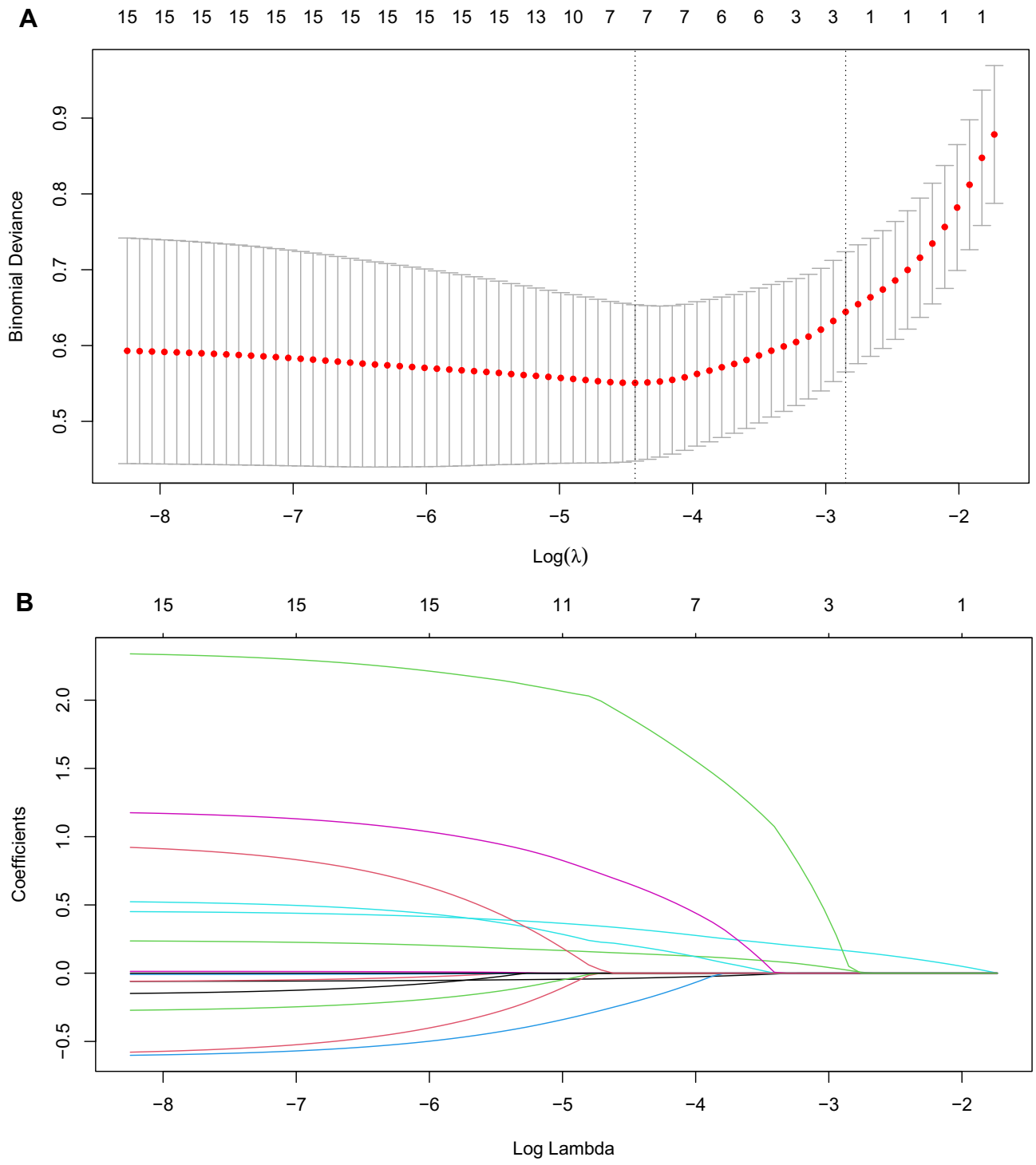

Figure 1 Factor selection using the LASSO regression. (**A**) Selection of tuning parameter (λ) using LASSO regression analysis and cross-validation. (**B**) LASSO coefficient profiles for candidate factors.

of one factor with a coefficient of 0, the absolute values of the coefficients for each influential factor decrease as the λ value increases. The results indicate that 8 variables were excluded, resulting in the reduction of the initial set of 15 variables to 7 potential predictive factors. These factors, namely CAT, BMQ, BIPQ, living condition, education level, monthly income, and smoking status, exhibit non-zero coefficients in the LASSO regression model.

Table 2 Results of Logistic Regression Analysis for Predicting Non-Adherence to Inhaler Therapy in COPD Patients

Variables	Coef	S.E	WaldZ	P	OR (95% CI)
Intercept	22.2566	3.1287	7.11	<0.001	4.633(16.632,28.974)
BIPQ	−0.4304	0.0638	−6.75	<0.001	6.502(−0.567,-0.316)
BMQ	−0.1974	0.0699	−2.82	0.0047	8.208(−0.338,-0.062)
CAT	0.0558	0.0271	2.06	0.0392	1.057(0.003,0110)
Education level	0.5245	0.2658	1.97	0.0485	1.689(0.018,1.067)
Smoking	−1.4499	0.6037	−2.40	0.0163	2.345(−2.652,-0.265)
Living condition	0.3779	0.3095	1.22	0.2221	1.459(−0.239,0.984)
Monthly income	−0.4676	0.2641	−1.77	0.0766	6.265(−0.998,0.043)

Note: For the assignment of values to the predictor variables, the following categorizations were used: Education level: Primary school or below = 1, Junior high school = 2, Senior high school = 3, College or above = 4. Smoking status: Smoker = 1, Non-smoker = 2. Living condition: Living alone = 1, Living with children = 2, Living with spouse = 3, Other = 4. Monthly income: Below 1000 yuan = 1, 1000–3000 yuan = 2, 3001–5000 yuan = 3, Above 5000 yuan = 4.

Development of a Nomogram Prediction Model

Table 2 displays the outcomes of the multivariate analysis utilizing logistic regression, integrating the 7 predictor variables selected through LASSO regression analysis. Furthermore, Figure 2 illustrates the risk prediction nomogram for non-adherence to inhaler therapy in elderly COPD patients. Within the plot's axes, points associated with each variable for elderly COPD patients requiring inhaler devices are identified. The points along the horizontal axis denote the respective scores. At the intersection of the lines on the score axis, the score for each variable is represented, with the total score being the summation of all individual scores. Upon inputting the relevant patient data, the corresponding point on the total score axis can be utilized to determine the associated risk probability for non-adherence.

Model Validation and Evaluation

The predictive model for non-adherence to inhaler therapy in elderly COPD patients exhibits a C-index of 0.922 (95% CI: 0.879 to 0.965), signifying excellent predictive accuracy. Additionally, the calibration curve of the risk prediction plot for elderly COPD patients' non-adherence to inhaler therapy is close to the ideal 45-degree dashed line, and the Brier value for the nomogram prediction model was 0.070, strong consistency between the predicted values and the actual observed values (refer to Figure 3). Subsequent internal validation utilizing the AUC (refer to Figure 4) yielded an AUC of 0.912, further affirming the model's high predictive performance.

Clinical Application of the Risk Prediction Model

To evaluate the clinical utility of the risk prediction model, decision curve analysis was performed by validating the net benefit at various threshold probabilities. The decision curve, depicted in Figure 5, comprises three lines: "None"

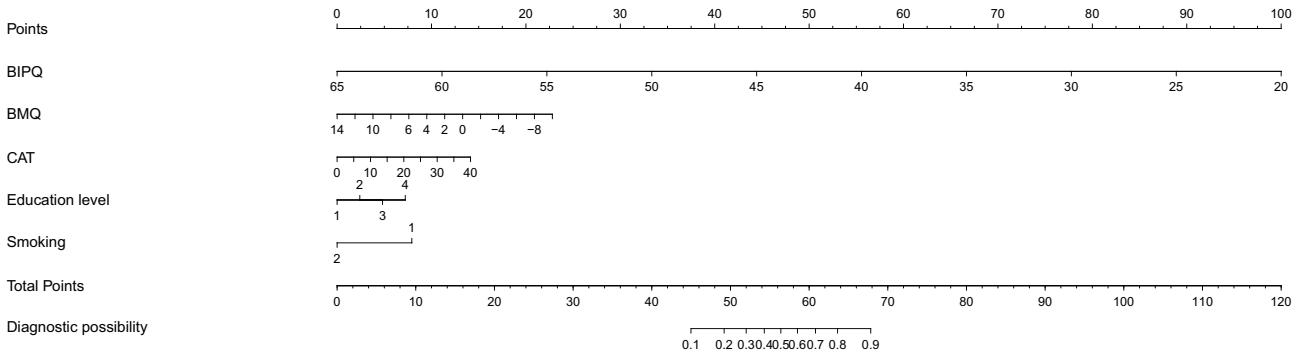

Figure 2 Nomogram for non-adherence to inhaler therapy in patients with COPD.

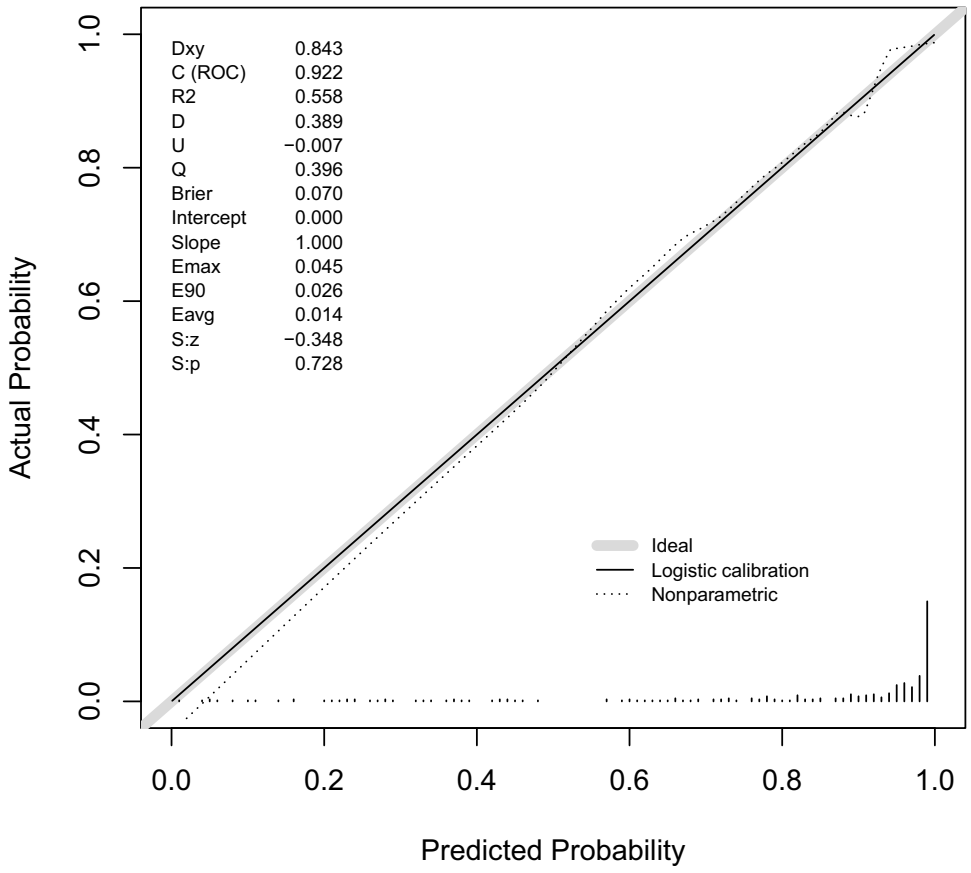

Figure 3 Calibration curves of the non-adherence to inhaler therapy nomogram in patients with COPD.

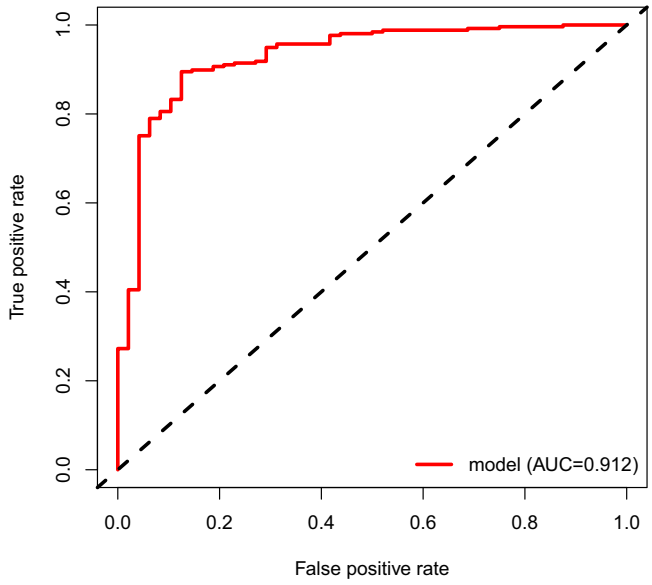

Figure 4 ROC curve of the non-adherence to inhaler therapy nomogram in patients with COPD.

representing no intervention for all patients (horizontal line segment), "All" representing intervention for all patients (gray curve), and "Nonadherence prediction nomogram" representing decision-making using the risk scoring model (blue curve). The common zero point of the x-axis and y-axis is the left vertex of "None", while the point with y-coordinate 0 and x-coordinate 1 is the right vertex of "None". The risk scoring model demonstrates higher net benefit when the

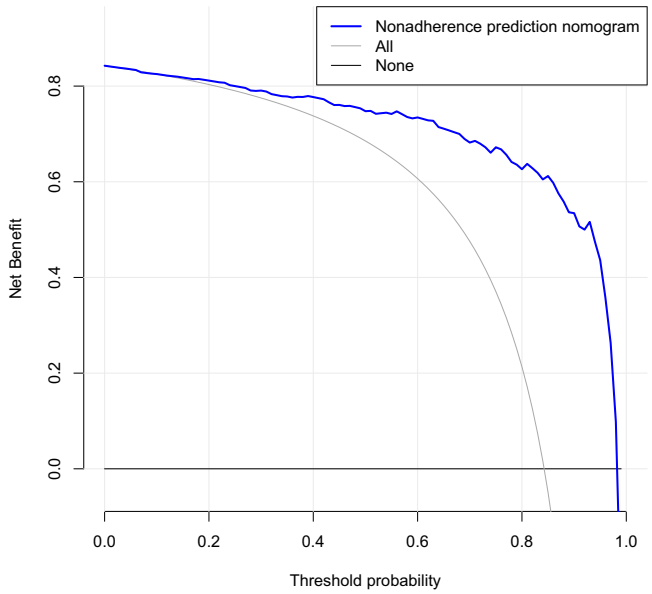

Figure 5 Decision curve of the non-adherence to inhaler therapy nomogram in patients with COPD.

threshold probability exceeds 17% compared to both intervening for all patients or not intervening for any patients. Therefore, it can be concluded that the utilization of this risk prediction model for intervention in the subset of elderly patients with COPD at risk for non-adherence to inhaler therapy holds clinical application value.

Discussion

The adherence to medical therapies has emerged as a growing concern, with the World Health Organization labeling it as "a new pharmacological problem"[32] The finding of this study unveiled that 84.3% of Chinese elderly patients with COPD exhibited poor adherence to inhalation, a percentage higher than previous studies.[33,34] This suggests that Chinese elderly COPD patients face significant challenges in adhering to medication regimens. Consequently, there is an urgent necessity to identify the factors contributing to nonadherence to medication in elderly COPD patients and to implement effective interventions.

However, an effective predictive model for forecasting non-adherence to inhaler therapy has not yet been established and validated among elderly COPD patients. This study collected pertinent clinical and personal data from elderly COPD patients based on the SEM, analyzed the factors influencing medication non-adherence, and constructed a nomogram model incorporating medication beliefs, illness perception, CAT, smoking, education level. The nomogram model combines risk factors related to personal trait, behavioral trait, life and work condition which facilitates individualized prediction of medication non-adherence in COPD patients.

This study developed a nomogram prediction model for the risk of non-adherence to inhaler therapy in elderly patients with COPD, utilizing five predictive factors. The nomogram integrates the impact of multiple clinical risk factors and visually presents the results, enabling quick, convenient, and accurate predictions. The model exhibited a high discriminative ability and predictive value, with a C-index of 0.922 and an AUC of 0.912. Moreover, the calibration curve also demonstrated good consistency, making it suitable for clinical practice. Additionally, decision curve analysis was introduced to guide clinical decision-making by maximizing net benefit.[35] The decision curve demonstrated the practical clinical utility of the model.

The research findings indicated that medication beliefs, illness perception, CAT, smoking status, education level significantly influence adherence to inhalers therapy. Notably, beliefs regarding disease treatment among elderly COPD patients emerged as the strongest predictors of adherence to inhalation therapy.[36] These results aligned with previous studies,[37,38] which indicated that lower medication beliefs scores correlate with poorer medication compliance. This association is often attributed to reduced belief in the necessity of using a specific medication for disease management and increased concerns about potential adverse effects. The results highlight the importance for healthcare providers to address any concerns and

obstacles related to inhaler usage, and to assist patients in mastering proper inhalation techniques.[39] Furthermore, it is crucial to educate patients about the significance of inhaler adherence for controlling COPD symptoms. By enhancing patients' belief in the necessity of medication, it is possible to improve medication compliance.

This study revealed that lower illness perception scores were associated with poorer medication adherence. Similar findings were reported by Akine et al,[40] while contrasting results were observed in the study conducted by Shiah-Lian Chen.[41] The discrepancy in analysis results may be attributed to the interpretation that a higher disease perception score implies patients perceive the disease as a greater threat to their health. Consequently, patients recognize COPD as a chronic condition with ongoing progression, necessitating medication for disease control, thereby increasing their belief in the necessity of medication. Conversely, lower illness perception scores may lead to a decline in patients' belief in the necessity of taking medicine, resulting in medication non-compliance.[42] Furthermore, the results found that patients with higher CAT scores tended to have poorer medication compliance, indicating that the disease severity and the impact on quality of life of elderly COPD patients can affect the compliance. This finding is consistent with previous studies,[33] and may be due to patients attributing the severe impact of the disease on their lives to treatment failure or drug side effects, thus leading to patients' non-adherence to inhalants. Moreover, the finding is consistent with Antonio et al 's result[36] that patients who smoke have worse inhaler adherence compared to non-smoking patients. Smokers with COPD should understand that smoking is related to their lung disease,[43] but they have not changed this harmful behavior, indicating a lack of awareness regarding the measures and importance of COPD treatment or poor self-management abilities. As a result, non-adherence to medication may occur.

Different from previous studies,[34,44] the results of this study showed that patients with higher education level exhibited worse medication compliance. This may be attributed to the fact that patients with higher education level tend to have stronger autonomy, leading them to seek second opinions on treatment plans and potentially change their treatment methods independently. On the other hand, patients with lower levels of education are more likely to adhere faithfully to the treatment plan prescribed by doctors.[45] This finding suggest health professional should establish a co-participative doctor-patient relationship with patients, taking into account patients' subjectivity based on their education levels. Collaborative discussions about medical records and decide treatment plans with patients,[46] which would improve inhaler adherence of COPD patients.

Previous studies have shown that health insurance is a significant influencing factor in patient medication adherence.[47,48] Patients with chronic diseases who have to bear higher medication costs (through out-of-pocket payment plans) are more likely to restrict their medication usage. In a study conducted in the United States, approximately one-fourth of elderly patients had to abandon their prescription drugs due to high costs.[48] However, in this study, the healthcare payment method was not included in the predictive model for inhaler adherence in patients with COPD, possibly due to the fact that only one patient in this study group had out-of-pocket payment. In the future, it is necessary to adapt the predictive models according to the specific situations in different countries and regions.

By establishing a predictive model, we can accurately identify the high-risk group of inhalant non-adherence and provide valuable insights for clinical decision-making. Guided by the SEM, healthcare professionals should comprehensively understand the reasons for non-compliance among elderly patients with COPD and intensify patient follow-up and health education. Empowering patients to acquire a correct understanding of their condition and medication will enhance inhaler adherence among elderly patients with COPD, thus improving treatment outcomes and overall quality of life.

Limitations

Firstly, data were collected solely from a hospital in the East China region of mainland China, the sample size was relatively small and no external verification was conducted. The generality of this study's findings is unclear and studies in a wider population are needed for external validation. Secondly, the use of self-reported questionnaires to assess inhaler adherence may introduce recall bias. However, previous findings indicate that self-reported questionnaires align with measurements from electronic monitoring devices,[49] and they are preferred in clinical practice due to their low cost, and ease of use in various healthcare settings.[50] Thirdly, the study did not include objective indicators, such as lung function, which may significantly impact inhaler adherence in COPD patients. Further attention and discussion on this should be given in future studies. Additionally, the inclusion of BIPQ and BMQ questionnaire results may increase the

workload of clinical practitioners to a certain extent. However, there are not many items in the questionnaire in this study, and previous studies have revealed that disease perception and drug belief play an important role in patients' treatment compliance behavior, which is worthy of routine clinical monitoring.

Conclusion

In summary, this study developed a risk prediction model with good discriminative ability for inhaler adherence among Chinese elderly patients with COPD, including five risk factors: medication beliefs, illness perception, CAT, smoking status and education level. The model has good consistency, differentiation and clinical applicability. Using the nomogram model healthcare professionals could quickly calculate and understand the non-compliance level of elderly COPD patients and guide the clinical development of personalized intervention.

Data and Materials Availability

The ethical approval document specifies that access to the data collected in this project is limited to core members of the project team to safeguard patient privacy.

Acknowledgments

An unauthorized version of the Chinese MMSE was used by the study team without permission, however this has now been rectified with PAR. The MMSE is a copyrighted instrument and may not be used or reproduced in whole or in part, in any form or language, or by any means without written permission of PAR (www.parinc.com).

Ethics Approval

The study was conducted in accordance with the Declaration of Helsinki and received approval and consent from the Ethics Committee of Bengbu Medical College. All participants provided written informed consent.

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Disclosure

The authors report no conflicts of interest in this work.

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