Construction and Validation of a Risk Prediction Model for Adverse Prognosis in Alzheimer' s Disease Complicated by Community-Acquired Pneumonia: A Post-print Study

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Abstract

Background: As China enters an aging society, the incidence of Alzheimer' s disease (AD) has been increasing year by year. AD is prone to be complicated by community-acquired pneumonia (CAP), which ultimately leads to adverse outcomes for patients. Therefore, constructing a precise risk prediction model helps medical personnel identify high-risk patients early and intervene, thereby reducing the burden on families and society. Objective: To construct a risk prediction model for adverse prognosis in patients with AD complicated by CAP, analyze the high-risk factors for adverse outcomes in these patients, and provide a basis for formulating targeted treatment measures. Methods: Data retrieval was conducted relying on the dementia database platform established by Hubei Provincial Hospital of Traditional Chinese Medicine. Inpatients diagnosed with AD complicated by CAP from January 2020 to August 2025 were selected as research subjects (n=371). Data related to demographics and baseline characteristics, comorbidities and behavioral risk factors, assessment scales, and laboratory test indicators were collected. The dataset was randomly split into a training set (n=259) and a validation set (n=112) at a ratio of 7:3. LASSO regression with 10-fold cross-validation was used to screen the optimal predictive variables. Logistic regression was employed to establish the final prediction model and construct a nomogram. Model performance was evaluated using the area under the receiver operating characteristic (ROC) curve, calibration curves, and decision curve analysis (DCA). Results: The incidence of adverse outcomes in patients with AD complicated by CAP was 27.76% (103/371). Four potential predictors were selected from 20 candidate variables using LASSO regression: CDR score, CURB-65 score, ADL score, and dysphagia. Further multivariate Logistic regression analysis showed that CDR score (OR=2.304, 95%CI=1.486-3.572), CURB-65 score (OR=2.263,

95%CI=1.477-3.468), ADL score (OR=2.337, 95%CI=1.033-5.287), and dysphagia (OR=2.042, 95%CI=1.036-4.023) were influencing factors for adverse outcomes in patients with AD complicated by CAP (P<0.05). A clinical prediction model was constructed based on the four predictive variables screened by multivariate Logistic regression. The area under the ROC curve for the prediction model in the training and validation sets was 0.835 (95%CI=0.777-0.892) and 0.902 (95%CI=0.835-0.968), respectively, suggesting good model discrimination. Hosmer-Lemeshow test results showed: training set $ $2=7.046 (P=0.531) and validation set $ $2=7.781 (P=0.455). The Brier scores of the calibration curves for the two datasets were 0.137 and 0.108, respectively, indicating significant consistency between predicted and actual values. DCA results showed that when the threshold was 0.10-0.75, using the nomogram model to predict the risk of adverse outcomes could provide clinical benefits to patients. Conclusion: The nomogram model constructed in this study can predict the risk of adverse outcomes in patients with AD complicated by CAP, facilitating early identification of high-risk populations by clinicians and the formulation of individualized intervention measures to improve patient prognosis.

Full Text

Preamble

Chinese General Practice

Abstract

In the context of the ongoing transformation of the global healthcare landscape, the discipline of general practice (family medicine) has emerged as a cornerstone of sustainable healthcare systems. This paper examines the current state, challenges, and future trajectories of general practice in China. By analyzing the integration of machine learning and deep learning technologies within primary care settings, we explore how digital health interventions can enhance diagnostic accuracy and patient management. Our findings suggest that while significant progress has been made in training general practitioners (GPs) and establishing community-based health centers, systemic barriers regarding resource allocation and inter-institutional coordination remain. We propose a framework for strengthening the gatekeeper role of GPs through enhanced clinical decision support systems and integrated care pathways.

Introduction

The development of general practice is a strategic priority for the modernization of China' s medical service system. As the population ages and the burden of chronic non-communicable diseases increases, the traditional hospital-centric model is becoming increasingly unsustainable. General practice offers a comprehensive, continuous, and coordinated approach to health management that is essential for achieving the goals of "Healthy China 2030."

1. The Current State of General Practice in China

Over the past decade, China has implemented a series of policies to bolster the primary healthcare workforce. The "5+3" standardized residency training program has become the gold standard for cultivating qualified GPs. However, the distribution of these professionals remains uneven, with a significant concentration in urban eastern regions compared to rural western areas.

As shown in , the ratio of GPs per 10,000 residents has seen a steady increase, yet it still falls short of the targets set by developed nations. The primary challenge lies not only in the quantity of practitioners but also in the quality of clinical services and the public' s trust in community-level care.

2. Technological Integration and Innovation

The integration of advanced computational methods is revolutionizing general practice. Machine learning algorithms are now being utilized to predict disease risks and optimize treatment plans at the community level.

2.1 Application of Machine Learning Machine learning models, particularly those based on longitudinal electronic health records (EHRs), allow for the early identification of high-risk patients. For instance, the probability of a patient developing complications from Type 2 Diabetes can be modeled using a function $\mathcal{F}$ such that:

$$P(\text{complication}) = \mathcal{F}(x_1, x_2, \ldots, x_n)$$

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Construction and Validation of a Risk Prediction Model for Poor Prognosis in Patients with Alzheimer' s Disease Complicated by Community-Acquired Pneumonia

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Abstract

Objective: To analyze the clinical characteristics of patients with Alzheimer' s disease (AD) complicated by community-acquired pneumonia (CAP) and to construct and validate a risk prediction model for poor prognosis in this population.

Methods: A retrospective analysis was conducted on clinical data from 308 patients with AD complicated by CAP admitted to the Hubei Provincial Hospital of Traditional Chinese Medicine between January 2021 and June 2023. Patients were divided into a training set ($n = 216$) and a validation set ($n = 92$) at a 7:3

ratio. Based on their prognosis 30 days after admission, patients were categorized into a good prognosis group and a poor prognosis group. Least Absolute Shrinkage and Selection Operator (LASSO) regression and multivariate Logistic regression analysis were employed to identify independent risk factors for poor prognosis. A nomogram prediction model was subsequently constructed. The model' s performance was evaluated using the Area Under the Receiver Operating Characteristic Curve (AUC), the Hosmer-Lemeshow test, and Calibration curves. Decision Curve Analysis (DCA) was used to assess the clinical utility of the model.

Results: Multivariate Logistic regression analysis identified age, CURB-65 score, albumin (ALB), D-dimer (D-D), and the Fast Assessment of Thoracic Ultrasound (FATHU) score as independent risk factors for poor prognosis in patients with AD complicated by CAP (all $P < 0.05$). The AUC for the nomogram model was 0.895 (95% CI: 0.849–0.941) in the training set and 0.864 (95% CI: 0.778–0.950) in the validation set. The Calibration curves showed good agreement between the predicted and observed probabilities, and the Hosmer-Lemeshow test indicated a good fit ($P > 0.05$). DCA demonstrated that the nomogram model provided significant clinical net benefit.

Conclusion: The clinical prediction model developed in this study demonstrates high accuracy and utility.

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Abstract

Background

As China enters an aging society, the incidence of Alzheimer' s disease (AD) has been increasing annually. Patients with AD are highly susceptible to comorbid community-acquired pneumonia (CAP), which ultimately leads to adverse outcomes. Therefore, constructing a precise risk prediction model is essential to help medical personnel identify and intervene with high-risk patients early, thereby alleviating the burden on families and society.

Objective

To construct a risk prediction model for adverse prognosis in patients with AD complicated by CAP, analyze the high-risk factors associated with adverse outcomes in this population, and provide a scientific basis for formulating targeted therapeutic interventions.

Methods

Data were retrieved from the dementia database platform established by the Hubei Provincial Hospital of Traditional Chinese Medicine. Inpatients diagnosed with AD and CAP between January 2020 and August 2025 were selected

as the research subjects (n = 371). Data regarding demographics, baseline characteristics, comorbidities, behavioral risk factors, clinical assessment scales, and laboratory indicators were collected. The dataset was randomly split into a training set (n = 259) and a validation set (n = 112) at a 7:3 ratio. Least Absolute Shrinkage and Selection Operator (LASSO) regression with 10-fold cross-validation was employed to select the optimal predictive variables. A final prediction model was established using multivariable Logistic regression and visualized as a nomogram. Model performance was evaluated using the area under the receiver operating characteristic (ROC) curve (AUC), calibration curves, and decision curve analysis (DCA).

Results

The incidence of adverse outcomes among patients with AD complicated by CAP was 27.76% (103/371). Four potential predictors were selected from 20 candidate variables using LASSO regression: Clinical Dementia Rating (CDR) score, CURB-65 score, Activities of Daily Living (ADL) score, and dysphagia. Further multivariable Logistic regression analysis demonstrated that CDR score (OR=2.304, 95% CI=1.486-3.572), CURB-65 score (OR=2.263, 95% CI=1.477-3.468), ADL score (OR=2.337, 95% CI=1.033-5.287), and dysphagia (OR=2.042, 95% CI=1.036-4.023) were independent risk factors for adverse outcomes in patients with AD and CAP ($P < 0.05$). A clinical prediction model was constructed based on these four variables. The AUC values for the prediction model in the training and validation sets were 0.835 (95% CI=0.777-0.892) and 0.902 (95% CI=0.835-0.968), respectively, indicating good discriminative ability. The Hosmer-Lemeshow test yielded $\chi^2 = 7.046$ ($P = 0.531$) for the training set and $\chi^2 = 7.781$ ($P = 0.455$) for the validation set. The Brier scores for the calibration curves of the two datasets were 0.137 and 0.108, respectively, suggesting significant consistency between predicted and actual values. DCA results showed that when the threshold probability ranged from 0.10 to 0.75, using the nomogram model to predict the risk of adverse outcomes provided clinical benefit to patients.

Conclusion

The nomogram model constructed in this study can predict the risk of adverse outcomes in patients with Alzheimer's disease (AD) complicated by community-acquired pneumonia (CAP). This tool facilitates the early identification of high-risk populations by clinicians, thereby enabling the development of individualized intervention measures to improve patient prognosis.

Keywords: Alzheimer' s disease; Community-acquired pneumonia; Adverse prognosis; Predictive model; Nomogram; Logistic regression

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Development and Validation of a Risk Prediction Model for Poor Prognosis in Alzheimer' s Disease Patients with Community-acquired Pneumonia

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Abstract

Background: Alzheimer' s disease (AD) is a common neurodegenerative disorder in the elderly, and community-acquired pneumonia (CAP) is one of the leading causes of death in this population. Currently, there is a lack of specialized tools to predict the prognosis of AD patients complicated by CAP.

Objective: To develop and validate a clinical risk prediction model for poor prognosis in AD patients with CAP, providing a basis for early clinical intervention and personalized management.

Methods: A retrospective analysis was conducted on clinical data from AD patients diagnosed with CAP at the Affiliated Hospital of Hubei University of Chinese Medicine. Patients were divided into a training set and a validation set. Least Absolute Shrinkage and Selection Operator (LASSO) regression and multivariate Logistic regression analysis were employed to identify independent risk factors for poor prognosis. Based on these factors, a nomogram prediction model was constructed. The model' s performance was evaluated using the Area Under the Receiver Operating Characteristic Curve (AUC), calibration curves, and Decision Curve Analysis (DCA).

Results: A total of 456 patients were included in the study. Multivariate Logistic regression analysis identified age, CURB-65 score, serum albumin levels, and the presence of dysphagia as independent predictors of poor prognosis in AD patients with CAP. The nomogram model demonstrated high predictive accuracy, with an AUC of 0.845 (95% CI: 0.792–0.898) in the training set and 0.821 (95% CI: 0.754–0.888) in the validation set. Calibration curves showed good agreement between predicted and observed outcomes, and DCA indicated significant clinical utility.

Conclusion: The developed risk prediction model, incorporating age, CURB-65 score, albumin, and dysphagia, effectively predicts the risk of poor prognosis in AD patients with CAP. This tool can assist clinicians in identifying high-risk patients early and optimizing treatment strategies.

Keywords: Alzheimer' s disease; Community-acquired pneumonia; Prognosis; Risk prediction model; Nomogram; Machine learning

Introduction

Alzheimer' s disease (AD) is the most prevalent form of dementia worldwide, characterized by progressive cognitive decline and loss of functional independence. As the global population ages, the number of patients is expected to reach 27.65 million in China by 2050, and the corresponding direct economic burden is projected to reach 2.5448 trillion RMB [**?**]. Notably, AD patients face a significantly higher risk of community-acquired pneumonia (CAP) due to factors such as cognitive impairment, comorbidities, swallowing disorders, and the use of antipsychotic drugs.

This study aims to construct a risk prediction model based on inpatient data that is suitable for primary healthcare settings. The goal is to assist primary care medical staff in the early identification of high-risk patients and the timely initiation of interventions or referrals to higher-level hospitals, thereby improving patient outcomes.

1 Subjects and Methods

1.1 Data Source and Study Population

Inpatient data for patients diagnosed with AD complicated by CAP between January 2020 and August 2025 were retrieved from the Dementia Database of Hubei Provincial Hospital of Traditional Chinese Medicine. A total of 386 patients were screened. After excluding 15 individuals due to missing critical information such as age or cognitive function assessments, 371 patients meeting the research requirements were ultimately included.

Patients were randomly divided into a training set ($n = 259$) and a validation set ($n = 112$) at a ratio of 7:3. The study flowchart is shown in Figure 1 [Figure 1: see original paper]. This study protocol was approved by the Ethics Committee of Hubei Provincial Hospital of Traditional Chinese Medicine (HBZY2025-C48-02).

Inclusion criteria: AD was diagnosed according to the diagnostic criteria in the "Guidelines for the Diagnosis and Treatment of Alzheimer' s Disease (2020 Edition)" [**?**]; CAP was diagnosed according to the "Guidelines for the Diagnosis and Treatment of Community-Acquired Pneumonia in Chinese Adults (2016

Edition)" [?]. Exclusion criteria: Patients with other types of dementia or those with missing critical data were excluded.

1.2 Research Methods

This study employs a retrospective cohort design, utilizing a composite endpoint of in-hospital mortality or the occurrence of respiratory failure as the primary outcome measure. Based on evidence from existing literature and clinical experience, we have preliminarily identified several potential predictive variables across multiple dimensions. These variables were specifically selected because they can be routinely obtained in primary care hospital settings.

1.2.1 Demographics and Baseline Characteristics Demographic indicators included gender and age. Body Mass Index (BMI) was calculated as weight (kg) divided by height squared (m^2). Following the criteria established in the *Guidelines for the Prevention and Control of Overweight and Obesity in Chinese Adults* [?], BMI was categorized into three groups: underweight (< 18.5 kg/m^2), normal weight (18.5–23.9 kg/m^2), and overweight. For the purpose of statistical analysis, the overweight category combined both overweight (24.0–27.9 kg/m^2) and obese (≥ 28.0 kg/m^2) individuals.

1.2.2 Comorbidities and Behavioral Risk Factors Comorbidities included chronic obstructive pulmonary disease (COPD), hypertension, and diabetes. Behavioral risk factors included smoking and alcohol consumption history. For the purposes of this study, smoking was defined as a cumulative consumption of ≥ 100 cigarettes. Alcohol consumption was defined as regular drinking occurring at least once per week for a duration of ≥ 6 months.

1.2.3 Assessment Scales **Swallowing Function:** Swallowing function was evaluated using the Watada Water Swallow Test. Patients were instructed to drink 30 mL of warm water, and their performance was graded as follows: Grade I (swallowed in one attempt without choking); Grade II (swallowed in two attempts without choking); Grade III (swallowed in one attempt with choking); Grade IV (swallowed in two attempts with choking); and Grade V (frequent choking and unable to finish the water). A score of Grade III or higher was defined as the presence of dysphagia [?].

Activities of Daily Living (ADL): ADL was assessed using the Barthel Index. An ADL impairment (indicating total or conditional dependence) was defined as a total score of <60 points [?].

Cognitive Function: Cognitive function was evaluated using the Clinical Dementia Rating (CDR) scale. Dementia severity was graded based on the global CDR score as follows: 0 (none), 0.5 (suspected), 1 (mild), 2 (moderate), and 3 (severe) [?].

Severity of Community-Acquired Pneumonia: The severity of community-acquired pneumonia was assessed using the CURB-65 scoring system. Total scores were categorized as low risk (0–1 point), intermediate risk (2 points), or high risk ($ $3 points) [**?**].

1.2.4 Laboratory Indicators Nutritional Status: The Control of Nutritional Status (CONUT) score was calculated based on serum albumin levels, total lymphocyte counts, and total cholesterol levels. Total scores are categorized as follows: 0–1 indicates normal nutritional status, 2–4 indicates mild malnutrition, 5–8 indicates moderate malnutrition, and $\geq$ 9 indicates severe malnutrition [**?**].

Inflammatory Indicators: These included white blood cell count (WBC), neutrophil count (NEUT), and high-sensitivity C-reactive protein (hsCRP). Additionally, D-dimer was included in the analysis. Although D-dimer is a key indicator of a hypercoagulable state, elevated concentrations can also indirectly reflect the severity of systemic inflammation [**?**].

Stress Indicators: N-terminal pro-B-type natriuretic peptide (NT-proBNP) was utilized as a marker. In acute infectious diseases such as severe pneumonia or sepsis, factors such as inflammation and hypoxia can cause NT-proBNP levels to surge, making it a significant indicator of the systemic stress response [**?**].

Other Physiological and Organ Function Indicators: Hemoglobin (HGB) was used to assess anemia, oxygen delivery, and hemoconcentration status. The estimated glomerular filtration rate (eGFR) was used to evaluate renal functional reserve and the risk of acute kidney injury [**?**]. Furthermore, eGFR levels serve as a critical basis for adjusting the dosage of antimicrobial drugs primarily excreted by the kidneys, directly impacting the efficacy and safety of treatment [**?**]. According to the staging criteria for chronic kidney disease, eGFR values are classified as follows: ≥ 90 mL$\cdot$min$^{-1}\cdot(1.73$ m$^2)^{-1}$ is normal; 60 to < 90 mL$\cdot$ min$^{-1}\cdot(1.73$ m$^2)^{-1}$ is mildly decreased; 30 to < 60 mL$\cdot$min$^{-1}\cdot(1.73$ m$^2)^{-1}$ is moderately decreased; 15 to < 30 mL$\cdot$min$^{-1}\cdot(1.73$ m$^2)^{-1}$ is severely decreased; and < 15 mL$\cdot$min$^{-1}\cdot(1.73$ m$^2)^{-1}$ indicates kidney failure.

1.3 Statistical Methods

Data analysis and visualization were performed using SPSS 25.0 and R 4.4.2 software. Categorical data are presented as frequencies and percentages, with intergroup comparisons conducted using the chi-square test. The dataset was randomly partitioned into a training set and a validation set at a 7:3 ratio.

The Least Absolute Shrinkage and Selection Operator (LASSO) regression with 10-fold cross-validation was employed to select the optimal predictive variables. Subsequently, a final predictive model was constructed via multivariate logistic regression using backward stepwise selection, and a nomogram was developed to visualize the model. Internal validation was performed using the Bootstrap method. The discriminative ability of the model was evaluated using the Area

Under the Receiver Operating Characteristic (ROC) curve. Model calibration was assessed via calibration curves and the Hosmer-Lemeshow test. Finally, the clinical utility of the model was evaluated using Decision Curve Analysis (DCA). A P-value < 0.05 was considered statistically significant.

2 Results

2.1 Baseline Characteristics

Among the 371 patients included in the study, 185 were male (49.87%) and 186 were female (50.13%), with an overall adverse outcome rate of 27.76% (103/371). There were no statistically significant differences between the training and validation sets ($P > 0.05$) regarding sex, age, CDR score, CURB-65 score, ADL score, CONUT score, BMI, dysphagia, hypertension, diabetes, COPD, smoking status, alcohol consumption, WBC, NEUT, HGB, hs-CRP, D-dimer, NT-proBNP, and eGFR, as shown in .

2.2 Variable Selection Based on LASSO Regression

The occurrence of death or respiratory failure was defined as the dependent variable. A total of 20 independent variables were included in the analysis; the specific assignments for each variable are detailed in . Variables were screened using LASSO regression with 10-fold cross-validation. The optimal regularization parameter (λ) was selected based on the "one standard error" rule (lambda.1se), as illustrated in [Figure 2: see original paper]. The results indicate that the optimal λ is 0.0958. Under this λ value, four potential predictor variables were identified: CDR score, CURB-65 score, ADL score, and dysphagia.

2.3 Multivariate Logistic Regression Analysis

Using the occurrence of death or respiratory failure as the dependent variable, the four variables selected via LASSO regression were included in a multivariate logistic regression analysis. The results indicate that the CDR score (OR=2.304, 95% CI=1.486–3.572), CURB-65 score (OR=2.263, 95% CI=1.477–3.468), ADL score (OR=2.337, 95% CI=1.033–5.287), and dysphagia (OR=2.042, 95% CI=1.036–4.023) are independent risk factors for poor prognosis in patients with AD complicated by CAP ($P < 0.05$), as shown in .

2.4 Construction of the Nomogram Prediction Model

A nomogram prediction model was constructed based on the four variables identified through the Logistic regression analysis [Figure 3: see original paper]. By calculating the total score derived from these four indicators, a specific position can be identified on the probability scale to determine the individual risk of death or respiratory failure.

2.5 Validation of the Prediction Model

The model was evaluated and internally validated using data from the training and validation sets. ROC curve analysis revealed that the AUC was 0.835 (95% CI = 0.777–0.892) for the training set and 0.902 (95% CI = 0.835–0.968) for the validation set, indicating strong discriminatory power [Figure 4: see original paper].

The Hosmer-Lemeshow test results yielded $\chi^2 = 7.046$ ($P = 0.531$) for the training set and $\chi^2 = 7.781$ ($P = 0.455$) for the validation set, indicating good calibration. Calibration curves demonstrate strong agreement between predicted and observed outcomes [Figure 5: see original paper]. The Brier scores were 0.137 and 0.108, respectively. Decision Curve Analysis (DCA) results demonstrated that the nomogram model possesses strong clinical utility when the threshold probability ranges from 0.10 to 0.75 [Figure 6: see original paper].

3 Discussion

3.1 Current Status of Poor Prognosis in AD Complicated by CAP

As of 2023, the global population of patients living with dementia has exceeded 50 million, with AD accounting for 60% to 70% of these cases [**?**]. Previous research has identified pneumonia as a primary cause of mortality among dementia patients, with 12% to 70% of deaths being attributable to the condition. A meta-analysis demonstrated that the overall pneumonia-related mortality rate among patients with dementia reaches 24.68% [**?**]. The present study further confirms this high risk: the incidence of adverse outcomes among patients with AD combined with CAP was 27.76% (103/371). Specifically, 81 patients (21.83%) died, while 22 patients (5.93%) developed respiratory failure.

3.2 Analysis of Independent Risk Factors

3.2.1 CDR Score This study confirms that a higher CDR score is an independent risk factor for poor prognosis (OR = 2.304). As the gold standard for clinical staging, the CDR score reflects cognitive impairment severity [**?**]. Physiological dysfunctions in the elderly, such as a weakened cough reflex and difficulty in sputum expectoration [**?**], contribute to increased susceptibility and poor outcomes.

3.2.2 CURB-65 Score The CURB-65 score is a significant risk factor (OR = 2.263). It provides an objective framework for severity assessment based on mental status, urea nitrogen, respiratory rate, blood pressure, and age [**?**]. Each component reflects specific pathophysiological changes, such as impaired renal function or intensified systemic inflammatory response.

3.2.3 ADL Score Patients with ADL impairment face higher risks of adverse outcomes (OR = 2.337). A decline in ADL scores reflects physiological function

impairment and frailty [**?**]. When faced with acute stress like pneumonia, these patients have insufficient compensatory capacity.

3.2.4 Dysphagia Dysphagia is an independent risk factor (OR = 2.042). Aspiration caused by dysphagia is a primary etiology of CAP in AD patients and leads to malnutrition and dehydration, weakening immune function [**?**].

4 Conclusion

The nomogram model developed in this study effectively predicts the risk of adverse outcomes in AD patients with CAP. This tool facilitates early identification of high-risk populations by clinicians, enabling individualized interventions to improve patient prognosis.

Author Contributions: Li Jiao was responsible for data organization, statistical analysis, and drafting the manuscript; Zhou Jianjie for implementation and feasibility analysis; Peng Lang for data collection; Mei Yingbing for quality control and review; Tan Zihu for study design and guidance. The authors declare no conflicts of interest.

References

(See original text for citations [1] through [34])

Note: Figure translations are in progress. See original paper for figures.