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Construction of an Amputation Risk Prediction Model for Patients with Diabetic Foot (DF) in a Civil Aviation Hospital

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Abstract: *Objective:* To construct a prediction model to predict the amputation risk of patients with diabetic foot (DF) in a civil aviation hospital, identify key influencing factors of amputation risk, and predict the probability of amputation, thereby providing a reference for condition evaluation and medical management of DF patients. *Methods:* Basic data, DF data, and laboratory index data were collected from 48 DF patients (selected based on inclusion and exclusion criteria) who visited a civil aviation hospital in Chaoyang District, Beijing, from 2023 to 2024. Descriptive statistics were performed to establish baseline characteristics, followed by univariate analysis (comparison between groups). Variables with P-values less than 0.05 were selected for multivariate binary logistic regression analysis to form a regression model. The prediction performance of the model was analyzed to establish a robust prediction model that provides a reference for predicting amputation risk in DF patients. *Results:* Whether the Wagner score is greater than 3, the presence of PAD, and abnormal CRP levels were identified as independent risk factors for amputation in DF patients. A prediction model was formed with an AUC of 0.970, indicating good performance. This model can serve as an effective tool for predicting amputation risk in DF patients and provide a reference for clinical decision-making.

Keywords: Diabetic foot; Amputation risk; Prediction model; Regression model

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1. Introduction

Diabetic foot (DF) is a common complication among diabetic patients, which can easily progress to amputation, thereby affecting the quality and duration of patients' lives [1]. Statistics show that among a large number of diabetic patients, nearly 10% suffer from DF. DF is prone to recurrence and has a high amputation rate, with one DF patient undergoing amputation every 20 seconds globally [2]. Therefore, it is of great significance to effectively predict the risk of amputation in DF patients. This study

aims to identify the risk factors that affect amputation in DF patients, construct a prediction model, and forecast the risk of amputation, thereby providing a reference for early clinical prediction of patients' amputation probability. This study can assist in the accurate selection of treatment plans and improve treatment effectiveness, as well as offer guidance for patients' daily care and other aspects.

2. Materials and methods

2.1. Clinical data

A total of 48 DF patients who visited the Civil Aviation General Hospital in Chaoyang District, Beijing, from 2023 to 2024 were selected. Among them, 29 were male (60.42%) and 19 were female (39.58%). The patients' ages ranged from 40 to 89 years, with an average age of (68.58 ± 12.14) years old. The study was approved by the ethics committee.

Inclusion criteria: (1) Met the diagnostic criteria for DF published by the International Working Group on the Diabetic Foot (IWGDF) in 2015 [3]; (2) aged ≥ 18 years old; (3) had complete relevant data.

Exclusion criteria: (1) aged < 18 years old; (2) foot ulcers caused by non-diabetic conditions; (3) history of lower limb amputation; (4) comorbidity with other severe systemic diseases such as cancer, severe liver or kidney failure, etc., and (5) mental or cognitive disorders that prevent cooperation with the study.

2.2. Collection of research variables

This is a retrospective study that collects clinical data of patients with DF through the medical record system of Civil Aviation General Hospital, including but not limited to basic information such as age [4] and gender [5]; DF disease course [6], Wagner classification [7], comorbidities (such as peripheral arterial disease), wound condition, necrosis, amputation, and other disease information; as well as laboratory indicators such as uric acid, CRP [8], and N%.

Data definition and preprocessing: Amputation includes major amputation and foot amputation. Researchers are divided into amputation and non-amputation groups. Wagner is bounded by a median of 3, divided into >3 and ≤ 3 groups, represented by 1 and 0, respectively; comorbidities are indicated by 0 or 1; wound condition and necrosis are evaluated by experts and divided into 0 and 1; uric acid, CRP, and N% are divided into abnormal and normal values based on medical standards, also represented by 0 and 1. After data collection, they are imported into the research database. The import process is verified by two people. After data collection, preprocessing operations such as data cleaning are performed.

2.3. Statistical analysis

Data is entered using EXCEL, processed using SPSS 29.0 software, and graphs are drawn using R 4.5. Descriptive statistical process: For continuous variables, according to the normal distribution compliance, mean ± standard deviation (SD) and M(IQR) are used to represent them respectively. Categorical variables are represented by frequency. In the comparison between groups, independent sample *t*-tests, x^2-tests, Mann-Whitney U tests, and Fisher's exact tests are used according to different situations. Variables with statistically significant differences in univariate analysis ($P < 0.05$) are further included in multivariate binary logistic regression analysis to screen independent predictors ($P < 0.05$) to form a prediction model. ROC curves are drawn, AUC is used to evaluate the model effect, DCA curves are drawn using R, and the full intervention curve and the overall intervention curve are compared to evaluate clinical practicality.

3. Results

3.1. Baseline characteristics of participants and results of univariate analysis

The study sample consisted of 48 cases, including 29 males (60.42%) and 19 females (39.58%). The age range was 40 to 89 years, with an average age of (68.58 ± 12.14) years old. There were 36 amputation cases (75.00%) and 12 non-

amputation cases (25.00%). In the amputation samples, males were more numerous than females, while in the non-amputation samples, the male-female ratio was balanced (**Table 1**). In the univariate analysis, variables with statistically significant differences between the two groups ($P < 0.05$) were: Wagner grade > 3, presence of Pad, abnormalities in N%, abnormalities in CRP, necrosis, and wound condition.

Table 1. Baseline characteristics of participants and results of univariate analysis

Variable	Amputation Group ($n = 36$)	Non-amputation group ($n = 12$)	t/z/χ^2	*P*-value
Age (years)	71.00 ± 11.46	67.78 ± 12.41	0.793	0.432
Gender (Male/Female)	23/13	6/6	-	0.501
Wagner Grade > 3 (Y/N)	34/2	3/9	-	< 0.001
PAD (Y/N)	33/3	5/7	-	< 0.001
Abnormal Neutrophil% (Y/N)	28/8	4/8	-	0.011
Abnormal Uric Acid (Y/N)	16/20	5/7	-	0.569
Abnormal CRP (Y/N)	34/2	4/8	-	< 0.001
DF Duration (days)	35 (IQR = 158)	75 (IQR = 254)	-0.526	0.599
Gangrene (Y/N)	19/17	2/10	4.769	0.029
Large Wound (Y/N)	26/10	4/8	-	0.036

3.2. Prediction model construction

Using the variables with $P < 0.05$ from the univariate analysis (Wagner grade > 3, presence of Pad, abnormalities in N%, abnormalities in CRP, necrosis, and wound condition) as independent variables, and amputation status as the dependent variable, a multivariate binary logistic regression was performed. The results are shown in Table 2. As can be seen from **Table 2**, Wagner grade >3, presence of Pad, and abnormalities in CRP are independent risk factors for predicting the risk of amputation in patients with DF.

Table 2. Results of multivariate binary logistic regression analysis

Variable	B	SE	Wald χ^2	*P*-value	OR (95% CI)
Wagner Grade > 3 (Y/N)	3.412	1.600	4.547	0.033	30.34
PAD (Y/N)	3.970	1.995	3.959	0.047	52.98
Abnormal Neutrophil% (Y/N)	2.043	1.751	1.361	0.243	7.72
Abnormal CRP (Y/N)	4.377	2.210	3.924	0.048	79.58
Gangrene (Y/N)	1.530	1.649	0.861	0.353	4.62
Large Wound (Y/N)	-1.085	1.567	0.480	0.488	0.34
Constant	-8.344	3.799	4.823	0.028	0.00

3.3. Prediction model performance analysis

The Hosmer-Lemeshow test value for this model was 0.742, indicating good model fit. The ROC curve for this model is shown in **Figure 1** (due to step size and sample size effects, the ROC curve has a significant turn), with an AUC of 0.970. The model demonstrates good discrimination and performance.

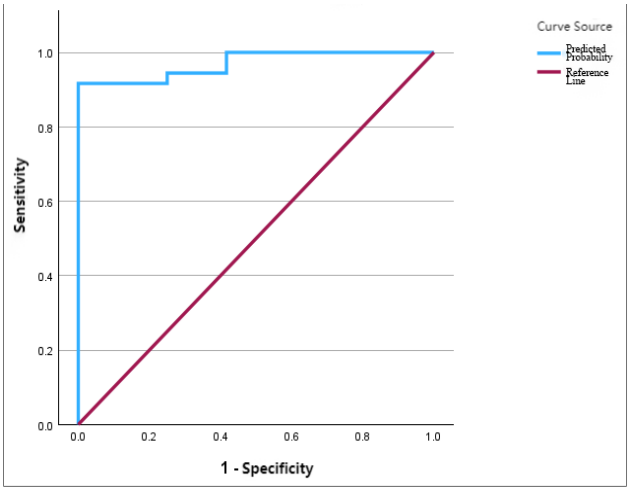

Figure 1. ROC curve.

The DCA curve in **Figure 2** illustrates that within the probability threshold range of 0.1 to 0.5, the model curve is higher than the benchmark curves for both full intervention and no intervention (thresholds greater than 0.5 are not considered, as treatment is required in this range). This suggests that using this model to guide clinical decision-making within this threshold range can yield a positive net benefit. Specifically, at the commonly used 30% threshold in clinical practice, the net benefit of the model is higher than both the full intervention and no intervention strategies, indicating the model's overall strong clinical utility.

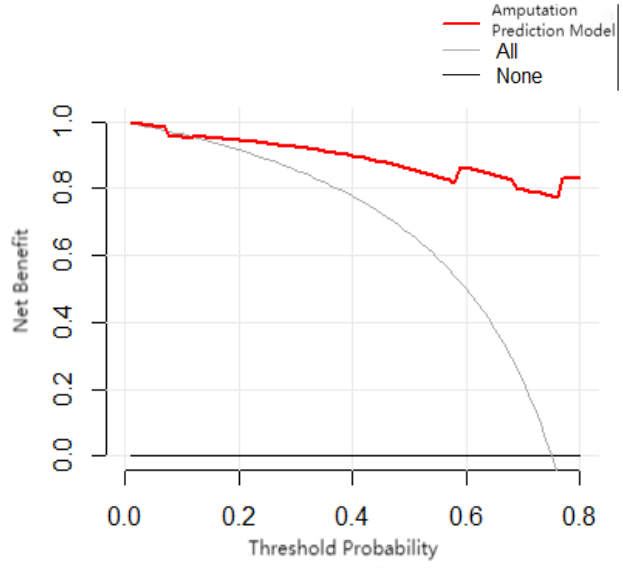

Figure 2. DCA curve.

4. Discussion

Diabetic foot (DF) refers to foot infections, ulcers, or tissue damage in diabetic patients due to factors such as infection, peripheral neuropathy, or vascular disease. It is characterized by high morbidity, mortality, and recurrence rates. For DF patients who do not respond well to conservative treatment, amputation is the ultimate therapeutic approach to avoid disease progression. Statistics show that the 5-year mortality rate after amputation for DF patients is > 70%, and the 10-year survival rate is only 24% [9], indicating that amputation has a significant impact on patients' survival duration and

quality of life. To provide early assessment of amputation risk for DF patients, develop individualized assessment tools, formulate early intervention strategies, optimize resource allocation, and improve medical decision-making, this study constructed a predictive model for amputation risk in DF patients. The model identified three independent risk factors: Wagner score (whether > 3), peripheral artery disease (PAD) status, and C-reactive protein (CRP) level. The Wagner score assesses the severity of DF PAD can cause local ischemia, infection, necrosis, etc., and elevated CRP levels indicate active inflammatory responses closely related to infection. These risks have also been suggested in other studies in the field [10,11,12]. The performance and clinical effectiveness of the model constructed in this study suggest that it can help identify high-risk patients early, enabling intervention measures to reduce amputation rates and improve patients' survival duration and quality of life. Additionally, this study provides a foundation for further optimizing prediction models, integrating multi-center data, improving prediction accuracy, and realizing prediction tooling in the future.

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Disclosure statement

The authors declare no conflict of interest.

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