A Risk Prediction Model of Readmission after coronary artery bypass grafting (CABG) in China

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Abstract

Background At present, there is no risk prediction model suitable for the Chinese population after coronary artery bypass grafting (CABG), this study aims to analyze the risk factors related to readmission after CABG and to construct a risk prediction model of readmission for patients with CABG in China.

Methods A total of 1983 patients who had undergone CABG at Wuhan Asian Heart Hospital from 2017 to 2019 were selected to collect general patient information. Univariate analysis was performed on the data of 825 patients in the modeling group to determine potential risk factors, and then independent risk factors of readmission after CABG were determined by multivariate logistic regression. Hosmer-Lemeshow （H-L） test, calibration curve and the area under the receiver operating characteristic （ROC） curve are used to test the calibration and discrimination of the model.

Results Six preoperative variables （age≥65, female, Private insurance, diabetes, hypertension level2,3, congenital heart disease）were independent risk factors of readmission after CABG. Our risk prediction model has high application value （the area under the ROC curve of the modeling group is 0.876, and of the validation group is 0.865, H-L test: P=0.561（0.05）.

Conclusion The risk prediction model in our study can be used to predict the risk of readmission in CABG patients in clinical work, providing a basis for more effective perioperative treatment and care to prevent patients from being readmitted to hospital.

1. Background

Coronary heart disease is one of the most common heart disease that harms people's health. Coronary artery bypass grafting (CABG) has developed rapidly in recent years, and it is currently the main treatment for coronary heart disease. Although the effect of surgical treatment is obvious,coronary restenosis after CABG, adverse cardiovascular and cerebrovascular events, and new stenosis due to progression of atherosclerosis will still cause patients to be admitted to hospital again[1–2]. Therefore, if we can predict the readmission risk of patients at the eraly stage and take comprehensive intervention measures for patients,, it is possible to reduce the patients' readmission risk[3].

In recent years, there have been many studies on risk factors related to CABG readmission[4–7], however, few studies have established a complete model to predict the risk of CABG readmission[8–10]. At present, the risk prediction models of readmission after CABG are mainly from western countries such as the United States and Canada, but previous studies have shown that these models cannot be well applied to Chinese and the other Asian populations[11–12]. In consideration of that the epidemiological characteristics of coronary heart disease, ethnicity, genetics and medical security system in the Chinese population may be different from those in western developed countries, it is necessary to establish a risk prediction model suitable for the Chinese population.

In this study, we aimed to analyze the risk factors associated with readmission after CABG of patients in China and establish a risk prediction model for readmission after CABG based on the Chinese population.

2. Methods

1.1 Study population

- Our study has been reviewed by the Medical Ethics Committee. The members of this research group all keep the information of the research object. In this study, we collected data from 1990 patients who had undergone CABG at Wuhan Asian Heart Hospital from January 2017 to October 2019. Inclusion criteria: age ≥ 18 years;patients underwent CABG. Exclusion criteria: suffering from organic diseases that may lead to mental disorders (0)，incomplete data (7). After applying the inclusion and exclusion criteria, a total of 1983 patients were collected retrospectively from the medical record database. Among eligible research subjects, 825 cases from January 2017 to December 2017 who had undergone CABG were used as the modeling group while the data of 1158 cases from January 2018 to October 2019 was used as the verification group. In the modeling group, we compared the variables of readmitted and non-readmitted patients.
- Among all variables, there are 13 preoperative variables and 8 postoperative variables. Preoperative variables included age, gender, insurance type, diabetes, hypertension, hyperlipidemia, congenital heart disease, history of angina, heart failure classification, coronary artery muscle bridge, valvular heart disease, previous myocardial infarction, obsolete brain Infarction. Postoperative variables included abnormal liver function, abnormal renal function, pleural effusion, ascending aorta dilation, cerebral artery stenosis, renal artery stenosis, vertebral artery stenosis, arrhythmia.

1.2 Discharge criteria on initial admission and readmission criteria

- The regular discharge criteria for CABG are no perioperative myocardial infarction, no disturbance of consciousness, no severe organ dysfunction, no serious infection, normal vital signs and other parameters such as heart sounds, arterial blood oxygen and carbon dioxide levels. "Readmission" is defined as the patient's second admission within 30 days after CABG because of obvious clinical manifestations.

1.3 Statistical analyses

All data analysis was performed by using SPSS 24.0 (IBM, Armonk, NY, USA). The measurement data and enumeration data are expressed by mean ± standard deviation and frequency, respectively. Measurement data was treated with the t-test and enumeration data was treated with the chi-square test. We entered variables with p□0.1 in univariate analysis into multivariate logistic regression model using forward step analysis. The discrimination of the model was tested by the area under the ROC curve□AUC□. we observed

the calibration of the model through H-L test and prediction model calibration curve. AUC≥0.7 means a good discriminative power of the model.

3. Results

2.1 Baseline characteristics

- This study population consisted of 1,983 patients who underwent CABG at Wuhan Asian Heart Hospital from January 2017 to October 2019. The average age of the study cohort was 61.7 years, with 1339(67.5%)males and 644（32.5%）females. A total of 96（4.8%）patients were readmitted after surgery, including 40 in the modeling group and 56 in the verification group. Of all the readmitted patients, 5 patients were readmitted more than one time. And there are 5 patients who were readmitted within 72 hours after surgery. The common cause of readmission were heart failure （22,22.9%）, arrhythmia （14,14.6%）, pleural effusion （12,12.5%）, lung infection （11,11.5%）, surgical incision infection （11,11.5%）, cerebral infarction （7,7.3%）, acute coronary syndrome （3,3.1%）, non-classifiable cause （16,16.7%）.

2.2 Predictors of readmission

- The univariate analysis of the modeling group showed that there were significant differences in 8 variables between readmitted and non-readmitted patients (Table 1). These 8 variables included 7 preoperative variables: age, gender, insurance type, diabetes, hypertension, congenital heart disease, history of angina, and one postoperative variable: abnormal renal function.

2.3 Final risk prediction model

That 8 variables with statistical significance in the univariate analysis were included in the multivariate logistic regression analysis, the corresponding assignment is shown in Table 2. The multivariate logistic regression model revealed that 6 variables: age ≥ 65, female, private insurance, diabetes, hypertension level 2,3, congenital heart disease (Table 3). Thus, the formula is logit（p）= − 4.582 + 0.9 × Gender （Female）+ 0.786 × Age ≥ 65 + 1.443 × Type of insurance （private）+0.855 × Diabetes + 0.845 × Hypertension level 2−0.604 × Hypertension level 3 + 1.935 × Congenital heart disease. Considering that the formula is not convenient for clinical application, we converted the model to a scoring system. As in previous studies, weighted scores were assigned to each categorical variable in the model[14] and the regression coefficient multiplied by 10 and rounded to the nearest integer. Table 4 showed the final risk prediction score. The lowest score is -6 points, the highest score is 19 points, and the score range is -6 to 68 points, we divided the scores into three groups according to tertiles, -6-18 were divided into low-risk group, 19−43 were divided into medium-risk group, 44−68 were divided into high-risk group.

The H-L test statistic of the model: χ^2 = 5.820, P = 0.561 and the calibration curve showed that the actual curve has the same trend as the best curve, without obvious deviation, indicating that the calibration of

the model is good (Fig. 1). The AUC of the modeling group and the verification group are 0.876 and 0.865 respectively, indicating that the model is well differentiated （Fig. 2）.

4. Discussion

Many CABG are performed annually around the world. In 2015, CABG was included in the US Hospital Readmission Reduction Program[15], since then, many scholars have studied the risk factors associated with postoperative readmission in patients after CABG, such as obstructive pulmonary disease, anemia, cirrhosis, and infection at the surgical site[1, 16]. There are also studies showed that readmission after cardiac surgery are related to the additional cost of surgery[17–18]. In 2017, Aleksander and other scholars used American patient data to establish a RAC risk assessment scale, which included 6 items: age, gender, race, insurance, type of admission, and complications[8]. This scale showed that patients over 80 years of age have a higher risk of readmission, however, in China, only a few readmission patients are older than 80, and the high risk of readmission is mainly for patients over 65 years old. Furthermore, the scale said that African American are at higher risk than white and Hispanic, obviously this item is not applicable in China. The model built by Benuzillo et al. used the data available soon after admission for isolated CABG surgery as the research cohort, and the scholars such as Derrick Y constructed the Clinical Risk Scoring Tool based on Canadian population data, but the C-statistic of both models are less than 0.7[9–10]. Some Chinese scholars have studied the application value of foreign risk prediction models in the Chinese population[12], due to various factors such as ethnicity and national conditions, the application effect was poor.

The prediction model constructed in this study includes 6 indicators: gender (female), age ≥ 65 years, insurance type （private）, diabetes, hypertension （level 2,3）and congenital heart disease. It can be noted that these 6 variables are all preoperative variables, which implied that patient's own physical condition, lifestyle and economic status may determine to a greater extent whether the patient will be admitted to the hospital again. Moreover, basic diseases, poor diet and exercise habits, lack of health awareness and knowledge would not only lead to the occurrence of diseases, but also affect the prognosis of patients. Research by Bates and Lin showed that health education and interventions can reduce the rate of postoperative readmission and improve the quality of life in CABG patients[19–20]. Therefore, it is necessary to educate patients on health and intervene according to their respective conditions. The CABG readmission risk prediction model can help medical staff identify the high-risk population who will be readmitted after CABG, and provide a basis for stratified management and intervention of patients with different degrees of risk, which will help to maximize the effectiveness of treatment and reduce medical costs. The scoring system constructed in this study can quickly measure the patients' score before the first discharge, assess the patients' risk of readmission, and guide medical workers to complete individualized nursing and medical interventions.

Although the risk prediction model can predict the patients' readmission risk to a certain extent, it does not mean that the prediction result can be absolutely matched with each clinical patient. This study also

included inevitable limitations of the single-center retrospective research, since China has only started to develop electronic medical record systems in recent years, there is currently no database like Nationwide Readmissions Database[18], which makes the data we collected incomplete, so there are some predictive factors that have not been included in the study. And for a patient who has undergone surgical treatment in our hospital, if he/she went to another hospital for treatment for the second time, it means that the patient has not been readmitted. Therefore, the readmission rate in this study may be lower than the actual readmission rate. Despite the limitations, the discrimination and calibration of our risk prediction model were excellent with the available variables.

5. Conclusion

In summary, we constructed and validated the risk prediction model for CABG patient readmission, which has great discrimination and calibration capabilities, based on the data set of patients who have undergone CABG at Wuhan Asian Heart Hospital. The model is a simple, convenient, and objective scoring system that can predict the readmission risk of CABG patients and make therapeutic interventions for their prevention. The model will still need to use a large amount of multiple centre data for verification and optimization in the future.

We declare that we don't have any commercial or associative interest that represents a conflicts of interest in connection with the work submitted.

Abbreviations

CABG
coronary artery bypass grafting
AUC
the area under the ROC curve
ROC
the receiver operating characteristic
H- L test
I- Hosmer-Lemeshow test

Declarations

- Consent for publication:

Not applicable

- Competing interests:

We declare that we have no competing interests.

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- Authors' contributions:

LGZ analyzed the data of CABG patients with statistical software and was a major contributor in writing the manuscript, ZYH helps revise the paper, ZW, HL help collect data, LT, CH, HYH help collect literature, HJ provides funding, All authors read and approved the final manuscript.

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- Availability of data and materials section:

The data that support the findings of this study are available from Wuhan Asian Heart Hospital but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Wuhan Asian Heart Hospital.

- Ethics approval and consent to participate:

Wuhan University of Science and Technology Medical Ethics Committee

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Figures

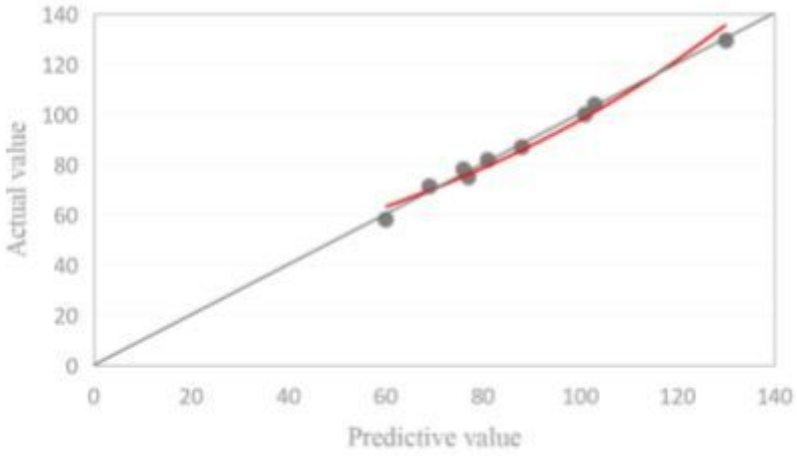

Figure 1

Calibration curve of predicted probability and actual probability of readmission after CABG The gray line is the best curve, and the red line is the actual curve

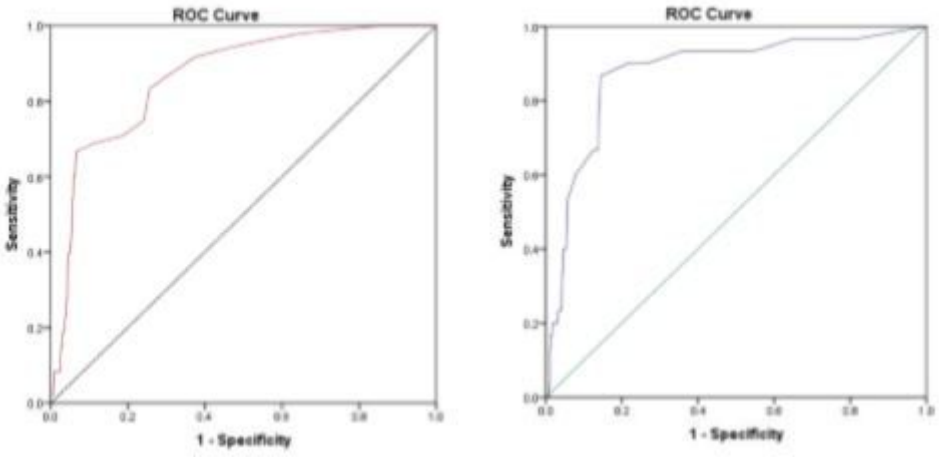

Figure 2

ROC curve obtained by applying the model to the modeling group and the verification group （red is the modeling group, and blue is the verification group）