Journal of Clinical and Nursing Research, 2022, Volume 6, Issue 2
http://ojs.bbwpublisher.com/index.php/JCNR
ISSN Online: 2208-3693
ISSN Print: 2208-3685

A Readmission Risk Prediction Model for Elderly Patients with Coronary Heart Disease

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Abstract: *Objective:* To analyze the independent risk factors and establish a risk prediction model by investigating the readmission of elderly patients with coronary heart disease (CHD) within 1 year after discharge. *Methods:* A total of 480 CHD patients, who were hospitalized in the Affiliated Hospital of Hebei University from October 2019 to December 2020, were included in this study. A general data scale, mental health status scale, the Clinical Frailty Scale, Pittsburgh Sleep Quality Index, as well as the Family Adaptability and Cohesion Evaluation Scale were used to collect data. According to the number of readmissions due to CHD within 1 year after discharge, the patients were divided into two groups: the readmission group (n = 212) and the no readmission group (n = 268). General data, laboratory examination indicators, frailty, mental health status, sleep status, as well as family intimacy and adaptability were compared between the two groups. Logistic regression was used to analyze the independent risk factors for the readmission of these patients, and R software was used to construct a line diagram model for predicting readmission of elderly patients with CHD. *Results:* Five factors including body mass index (OR = 1.045), low density lipoprotein (OR = 1.123), frailty (OR = 1.946), mental health (OR = 1.099), as well as family intimacy and adaptability (OR = 0.928) were included to construct the risk prediction model for the readmission of elderly patients with CHD within 1 year after discharge. The ROC curve showed that the area under the curve for predicting readmission of elderly patients with CHD was 0.816; Hosmer-Lemeshow goodness of fit test showed $X^2 = 1.456$ and P = 0.989; the maximum Youden index corresponding to the predicted value of risk was 0.526. The results showed that the model could accurately predict the risk of readmission in elderly patients with CHD within 1 year after discharge. *Conclusion:* This study constructed a line diagram model based on five independent risk factors of the readmission of elderly patients with CHD: body mass index, low density lipoprotein, frailty, mental health status, as well as family intimacy and adaptability. This model has good discrimination, accuracy, and predictive efficiency, providing reference for the early prevention and intervention of readmission in elderly patients with CHD recurrence.

Keywords: Elderly patients; Coronary heart disease (CHD); Readmission; Risk prediction model

Online publication: March 23, 2022

1. Introduction

Coronary heart disease (CHD) is a common chronic and persistent disease among the elderly population with high recurrence. Based on China's *Mid - and Long-Term Plan on the Prevention and Treatment of*

Chronic Diseases (2017-2025), CHD is the leading cause of hospitalization and death among adults with CHD in China, posing a serious threat to people's health. Surveys have shown that the readmission rate of CHD patients within 1 year is as high as 41.22%, and that of CHD patients who are 65 years old or older is higher [1].

Readmission, also known as repeated hospitalization, refers to the unplanned and unpredictable hospitalization of a patient for the same disease or related disease after being discharge from the hospital after the last hospitalization. Readmission after discharge is a cause of increasing burden of patients, waste of health resources, and the "difficulty in seeing a doctor" in current society [2].

Therefore, the prevention and control of readmission of CHD patients is of great significance in alleviating the burden of families and the society, reducing the occupation of medical resources, and improving the quality of life of patients.

This study investigated the readmission status of elderly patients with CHD within 1 year after discharge based on the physiological-psychological-social theoretical framework and analyzed the independent risk factors for readmission. Screening the risk factors of readmission and establishing a readmission prediction model suitable for this population are the objectives of this study. The purpose of this survey is to identify the risk factors of readmission in a multidimensional manner, strengthen the attention and management of high-risk factors accurately and in a timely manner, as well as provide basis for the implementation of personalized intervention.

2. Methods

2.1. Setting and samples

A total of 480 elderly patients with CHD, who were hospitalized for the first time in the Department of Cardiology, Affiliated Hospital of Hebei University, were selected as subjects in this study. Patients who met the following criteria were included in the study: (1) age more than 60; (2) diagnosed with coronary heart disease; (3) normal communication skills without cognitive impairment; (4) informed consent given. Patients with severe infection, serious liver or kidney diseases, tumor history, systemic immune system diseases, or connective tissue diseases were excluded from this study. This research has been approved by the ethics committee of the work unit.

In terms of the structured equation model, it is understood that in a study, the sample size needs to be at least 10-15 times the number of observed variables of the model [3]. A total of 26 observed variables were included in the model of this study, so the sample size should be at least 260-390. However, considering 20% loss of follow-up, the sample size should be 324-468. Initially, 530 cases were included in the original sample, and after the exclusion of missing data and loss of follow-up, the final data encompassed 480 cases.

2.2. Indicators and follow-up

All the case data were derived from the hospital information management system. According to the inclusion criteria, 480 cases were included at the end of the follow-up. Based on relevant literatures, the factors that affect the readmission of patients involve six domains.

(1) Social demographic information: age, gender, height, weight, educational background, marital status, living status, manner of payment for medical expenses, etc.
(2) Clinical data: past medical history, physiological and biochemical indicators, including heart rate, blood pressure, blood glucose level, glycosylated hemoglobin, total cholesterol, triglyceride, high-density lipoprotein, low-density lipoprotein, troponin I, brain natriuretic peptide, high-sensitivity C-reactive protein, and other indicators.
(3) Clinical Frailty Scale (CFS): The Canadian Study of Health and Aging Clinical Frailty Scale of 7 points was used to assess frailty. Frailty is defined as ≥ 5.

(4) Mental health status: A simplified version of the General Health Questionnaire (GHQ) with 12 items was used, and the 4-Point Likert Scale was used for each item (0-3 points). The total score reflects the mental health status of the subjects. The higher the score, the worse the psychological condition.
(5) Pittsburgh Sleep Quality Index (PSQI): A total of 18 items were covered under seven domains, such as sleep quality and sleep time. The range of the score is from 0 to 21, in which the higher the score, the worse the sleep quality.
(6) Family Adaptability and Cohesion Evaluation Scale, Second Edition (FACESII-CV): The Chinese version was adapted and revised by a local scholar, Fei Lipeng [4]. This scale is a self-rating scale with a total of 20 questions. It is divided into two domains: closeness, which is the emotional connection between family-members, and adaptability; that is, the ability of the family system to deal with problems. For each domain, there were 10 questions, with odd numbers measuring closeness and even numbers measuring adaptability. Using a standard 5-point evaluation, the higher the grade, the higher the frequency of occurrence. The scale has high reliability and validity, in which the internal consistency coefficients of the two domains were 0.85 and 0.73, respectively.

2.3. Data collection

The blood indexes of all the patients were drawn and submitted for examination within 24 hours after admission, and data were completed within 48 hours after admission. Follow-up records were established for all patients when they were discharged, and regular outpatient as well as telephone follow-ups were followed through. The end point of the follow-up was considered as the time of rehospitalization to the Affiliated Hospital of Hebei University or other hospitals for CHD or related complications within 1 year or a year from previous hospitalization. Based on the number of readmissions within 1 year, the patients were divided into two groups: (1) no readmission group, in which the number of readmissions within 1 year = 0; (2) readmission group, in which the number of readmissions within 1 year ≥ 1.

2.4. Establishment and verification of the line graph model

Univariate analysis was carried out to determine the influencing factors for the readmission of elderly patients with CHD within 1 year after discharge, and logistic regression analysis was used to screen the independent risk factors for readmission. Based on the aforementioned independent risk factors, a line diagram model was constructed to predict the risk of readmission in elderly patients with CHD within 1 year after discharge.

2.5. Data analysis

SPSS 24.0 was used for statistical analysis, and general descriptive analysis was used for the general data, clinical data, as well as the scores of each scale. T test, chi-square (X^2) test, and ANOVA were used to analyze the influencing factors of readmission. The logistic regression equation was used to perform multifactor analysis and construct a risk prediction model. R software was used to achieve competitive risk model analysis. $P < 0.05$ was considered statistically significant.

3. Results

3.1. Readmission of elderly patients with CHD within 1 year after discharge

All 480 patients improved significantly after treatment in terms of their symptoms and were discharged. However, 212 patients were hospitalized again for CHD at different times within 1 year after discharge, accounting for 44.17%.

3.2. Univariate analysis of the readmission of elderly patients with CHD within 1 year after discharge

Univariate analysis showed that the risk factors for the readmission of patients with CHD within 1 year were BMI, living status, manner of payment for medical expenses, high-sensitivity C-reactive protein, low-density lipoprotein, frailty status, GHQ score, PSQI score, and FACESII- CV score ($P < 0.05$). The results are shown in **Table 1**.

Table 1. Univariate analysis of the readmission in elderly patients with CHD [Number of cases (%)]

Factor	Readmission group (n = 212)	No readmission group (n = 268)	$t/F/X^2$	P
BMI			-3.675	0.034
< 18.5	49 (23.11)	18 (6.72)		
18.5-23.9	65 (30.66)	151 (56.34)		
≥ 24	143 (46.23)	99 (36.94)		
Living status			-2.779	0.000
Live alone	82 (38.68)	66 (24.63)		
Living with spouse	86 (40.57)	125 (46.64)		
Living with children	44 (20.75)	77 (28.73)		0.023
Manner of payment for medical expenses			-2.658	0.034
Self-paying	26 (12.26)	68 (25.37)		
Urban residents / NRCMS	79 (37.26)	122 (45.52)		
Medical insurance	107 (50.47)	78 (29.11)		
Frailty			16.316	0.000
Yes	156 (73.58)	128 (47.76)		
No	56 (26.42)	140 (52.24)		
High-sensitivity C-reactive protein	4.01±3.72	2.88±2.19	-2.989	0.002
LDL	3.89±0.92	2.67±0.72	-3.675	0.001
PSQI	7.85±2.39	6.79±2.27	-2.608	0.023
GHQ	5.58±2.89	4.07±2.89	-3.541	0.002
FACESII-CV	52.07±7.85	61.79±7.79	5.346	0.001
Family intimacy	55.9I±8.54	66.91±9.32	5.798	0.001
Family adaptability	48.23±7.16	56.67±6.25	4.689	0.001

Note: $P < 0.05$ is statistically significant.

3.3. Multivariate analysis of the readmission of elderly patients with CHD within 1 year after discharge

The above risk factors were included in the multivariate logistic regression analysis, and the results showed that BMI, LDL, frailty, GHQ score, and FACESII-CV score were independent risk factors for the readmission of elderly patients with CHD within 1-year after discharge ($P < 0.05$). According to the prediction model equation, P = 1 / [1 + exp(-Z)], the prediction model can be derived: Z = 1.013*BMI + 2.286*LDL + 2.067*weak – 1.218*GHQ + 1.011*FACESII-CV – 8.618. The results are shown in **Table 2**.

Table 2. Logistic regression analysis of the readmission of elderly patients with CHD (n = 480)

Factor	β	Wald	P	OR	95%CI
Constant term	-8.618	9.758	0.001	0.000	
BMI	1.013	1.449	0.002	1.045	1.003～3.051
LDL	2.286	1.834	0.012	1.123	1.003～3.051
Frailty	2.067	4.728	0.001	1.946	1.109～4.611
GHQ	-1.218	3.341	0.017	1.099	1.016～1.189
FACESII-CV	1.011	4.343	0.001	0.928	0.966～1.999

Note: Adjusted R^2 = 0.503; the regression equation explained 50.3% of the variation of the dependent variable.

3.4. Assessing the goodness of fit and the prediction effect of the risk prediction model

Hosmer-Lemeshow test and the area under the ROC curve were used to verify the goodness of fit and discrimination of the model. The result of Hosmer-Lemeshow test showed X^2 = 1.456 and P = 0.989, indicating that the model can better fit the occurrence of readmission in elderly patients with CHD. According to the prediction model equation, the area under the ROC curve was 0.816. Taking the maximum value of Youden index as the optimal critical value of the prediction model, the maximum value of Youden index was 0.526, showing that the model could more accurately predict the risk of readmission of elderly patients with CHD within 1 year after discharge. The results are shown in **Table 3**.

Table 3. Evaluation of the effect of the risk prediction model for the readmission of elderly patients with CHD within 1 year after discharge

AUC	Standard error	*P*	95% Confidence interval	
			Lower limit	Upper limit
0.816	0.054	< 0.001	0.736	0.946

4. Discussion

4.1. Significance of establishing a risk prediction model for the readmission of elderly patients with CHD

China Cardiovascular Disease Report 2018 stated that there are currently 11 million CHD patients in China, and the age distribution ranges from 55 to 79 years old [5]. As a common underlying disease among the elderly population, CHD has high recurrence. The results of this study showed that the readmission rate of CHD patients within 1 year after discharge was 44.17%, higher than that of similar studies [1,6]. In China, research reports on factors related to CHD readmission have become more common in the past two years. The following are the details of three research reports from Shandong University: by establishing a CHD follow-up cohort and using a competing risk model, a CHD incidence prediction model has been constructed; the 1-year readmission risk factors of CHD patients have been investigated and analyzed; however, a readmission predictive model has not been established; foreign studies mostly focus on the relationship between a single disease, a single factor, and its disease prognosis or the recurrence of cardiovascular events, with a lack of multidimensional studies on the readmission of elderly patients with CHD. Based on the physiological-psychological-social theoretical framework, this research investigated and analyzed the sociodemographic data, clinical data, physiological and biochemical indicators, frailty, sleep, mental health status, and family function of elderly patients with CHD. The condition and its influencing factors were analyzed, the risk factors of the readmission of elderly patients with CHD within 1 year after discharge were screened, and a suitable risk prediction model of readmission for this population

has been established, in order to identify the risk factors of readmission in a timely and multidimensional manner as well as provide a basis for the implementation of personalized intervention.

4.2. Risk factors for the readmission of elderly patients with CHD

4.2.1. BMI

This study showed that BMI is associated with readmission. Many studies have validated that being overweight and obese are risk factors for developing cardiovascular diseases. Among overweight and obese people, there are 32.0% of CHD events. Several studies have shown that BMI is positively correlated with the risk of CHD events [6].

4.2.2. LDL

This study showed that LDL is associated with readmission. The main role of LDL is to transport lipids to vascular endothelial cells. High LDL can lead to excessive lipid deposition and aggravate atherosclerosis. Lipid metabolism is one of the most important pathological links in coronary atherosclerosis. As an objective physiological measurement index, LDL is not affected by subjective factors. In addition to improving lipid metabolism and hypercoagulable state through the use of certain drugs, patients should be educated in terms of diet, exercise, and lifestyle to reduce the risk factors for the recurrence of CHD [7].

4.2.3. Frailty

This study showed that frailty is associated with readmission. A meta-analysis that included more than 2,000 CHD patients found that frailty is an important prognostic indicator in patients with coronary heart disease. The assessment of frailty can be used to predict risk in patients with acute coronary syndromes, who are prone to recurrent myocardial infarction and an increased risk of hospitalization. It is believed that frailty can increase the readmission rate of patients with cardiovascular disease [8]. The Asia-Pacific Clinical Practice Guidelines for the Management of Frailty stated that exercise and nutritional supplements can improve or reverse frailty [9]. It is of great significance to strengthen the assessment of frailty in elderly patients through various assessment tools in addition to early detection and timely intervention, in order to prevent the occurrence of adverse outcomes [10].

4.2.4. GHQ score

This study showed that GHQ score is associated with readmission. With the vigorous development of psychosomatic medicine and the in-depth study of cardiovascular disease, the psychological factors of cardiovascular disease have attracted the attention of scholars. Most scholars believe that psychological factors affect the mental health status of patients, alleviate or aggravate disease symptoms, and thus affect the occurrence, development, recovery, and prognosis of CHD. A study showed that the incidence of cardiovascular events and the rate of readmission of CHD patients with depression were significantly high, indicating that depression seriously affects the outcome and prognosis of CHD patients [11]. From a survey [12], it showed that CHD patients have serious mental health problems; in addition, their total score and the score for each dimension in SCL-90 were significantly higher than the national norm. Psychological factors are involved in the occurrence and development of cardiovascular diseases as predisposing factors. Medical staffs should fully understand the psychological state of CHD patients, provide adequate care and love to these patients, listen patiently, psychologically help them to relieve negative emotions, such as anxiety and depression, as well as assist them in maintaining a positive mental state.

4.2.5. FAC2ESII-CV score

This study showed that FACESII-CV score is associated with readmission. CHD patients are usually those

in the elderly age group. Good family functions can provide financial support, life care, and spiritual comfort for the elderly, relieve or adjust environmental pressure, as well as maintain physical and mental health. Several studies have shown that poor family functions will lead to serious disease behaviors among elderly patients with CHD. Compared with young people, elderly people have much less opportunities to be in contact with the outside world, and suffering from CHD, they are even more disconnected from the society. They will rely too much on the care, communication, and integration from the family. For example, when a family encounters a situation that requires a major decision to be made, if they seek and listen to the opinions of the elderly, the elderly will feel that they are still valuable. Encouraging family members to face up to and accept the patient's disease, reduce family conflicts, provide support and understanding, build on mutual intimacy and adaptability, as well as cultivate close emotional connections helps to reduce the psychological burden of patients while maintaining good mental health, thus reducing disease recurrence. On the other hand, medical staffs should be encouraged to systematically help patients and their family members to establish good family environment and family functions as well as increase the support and intervention for family intimacy and adaptability, so as to reduce complaints against patients by their family members in addition to providing appropriate care and attention to these patients [13].

5. Conclusion

A readmission risk prediction model for elderly patients with CHD was established in this paper. The study showed that the model has good predictive performance, which can provide a basis for early screening of high-risk groups among elderly patients with CHD for readmission. However, due to manpower and time constraints, the reasons for readmission (CHD recurrence, related complications, or sequelae) were not taken into account in this study. Moreover, this study was a single-center study with convenient sampling and limited sample representation. The model should be further revised in clinical practice.

Funding

S&T Program of Hebei (192777102D).

Disclosure statement

The authors declare no conflict of interest.

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