Prognostic value of patient-reported outcomes in predicting 30 day all-cause readmission among older patients with heart failure

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Abstract

Aims  Previous prediction studies for 30 day readmission in patients with heart failure were built mainly based on electronic medical records and rarely involved patient-reported outcomes. This study aims to develop and validate a nomogram including patient-reported outcomes to predict the possibility of 30 day all-cause readmission in older patients with heart failure and to explore the value of patient-reported outcomes in prediction model.

Methods and results  This was a prospective cohort study. The nomogram was developed and internally validated by Logistic regression analysis based on 381 patients in training group from March to December 2019. The nomogram was externally validated based on 170 patients from July to October 2020. Receiver operating characteristic curves, calibration plots and decision-curve analysis were used to evaluate the performance of the nomogram. A total of 381 patients’ complete data were analysed in the training group and 170 patients were enrolled in the external validation group. In the training group, 14.4% (n = 55) patients were readmitted to hospitals within 30 days of discharge and 15.9% (n = 27) patients were readmitted in the external validation group. The nomogram included six factors: history of surgery, changing the type of medicine by oneself, information acquisition ability, subjective support, depression level, quality of life, all of which were significantly associated with 30 day readmission in older patients with heart failure. The areas under the receiver operating characteristic curves of nomogram were 0.949 (95% CI: 0.925, 0.973, sensitivity: 0.873, specificity: 0.883) and 0.804 (95% CI: 0.691, 0.917, sensitivity: 0.778, specificity: 0.832) respectively in the training and external validation groups, which indicated that the nomogram had better discrimination ability. The calibration plots demonstrated favourable coordination between predictive probability of 30 day readmission and observed probability. Decision-curve analysis showed that the net benefit of the nomogram was better between threshold probabilities of 0–85%.

Conclusions  A novel and easy-to-use nomogram is constructed and demonstrated which emphasizes the important role of patient-reported outcomes in predicting studies. The performance of the nomogram drops in the external validation cohort and the nomogram must be validated in a wide prospective cohort of HF patients before its clinical relevance can be demonstrated. All these findings in this study can assist professionals in identifying the needs of HF patients so as to reduce 30 day readmission.

Keywords  Nomogram; Patient-reported outcomes; Readmission; Heart failure; older adult

Introduction

With the speedy increase of the aged population in the world, heart failure (HF) became a leading and increasing cause of morbidity and mortality. A report from Lancet showed that there were 64.3 million HF patients worldwide in 2017. An estimated 4 million people were living with HF according to the Report on Cardiovascular Health and...
Diseases in 2019 of China. Due to common cardiovascular conditions in older adults in conjunction with age-associated changes in cardiovascular structure and function, HF became the quintessential cardiovascular syndrome of aging and the numbers of older patients with HF were growing. Patient’s age at first presentation of HF increased from 76.5 years in 2002 to 77.0 years in 2014.

In any diagnosis, HF was associated with the highest 30 day readmission rate. Nearly 25% of HF patients were readmitted within 30 days following the first hospitalization due to HF, and 50% were readmitted within 6 months. Each readmission increased mortality at 6 months and 1 year. Older patients with HF were more prone to experience the frequent readmission and higher cost than those in younger patients. Nearly 9290 dollars were needed in monthly total direct healthcare cost per patient. Considering the worse prognosis and higher cost in older HF patients, it is important to identify high-risk readmission group. Accurate prediction models of readmission are helpful for older patients to counsel regarding their prognosis as well as involving them in the process of decision-making regarding further management. Prediction models might draw more attention of older HF patients with higher readmission risk, and lower 30 day readmission rate, reduce the economic burden.

In recent years, prediction models for readmission in HF patients were constructed using Logistic regression analysis, Cox proportional hazards model or Machine learning in some countries, like the USA, the Netherlands, and Australia. However, previous prediction models lacked a holistic view. Most prediction models were based on electronic medical records and rarely involved patient-reported outcomes (PROs). PROs are measures of patients’ physical, mental and emotional well-being obtained by patients’ self-report. Krumholz conducted a study to explore the value of PROs in the prediction model and found that incorporated PROs could improve risk prediction compared with a model that incorporated only clinical and demographic factors. However, the sample in Krumholz’s study was derived from a clinical trial population in the USA which limited its clinical ease of use in general HF patients and generalizability in other countries. PROs provided a methodologically robust strategy to bring patients’ voice to the clinical encounter and enable interpretation of treatment efficacy from patients’ perspective. As patient-centred care is coming to the forefront of high value healthcare delivery, incorporation of PROs into clinical practice and research is critical. Integrating objective variables with more PROs may provide greater insight into readmission reasons in older HF patients.

Accordingly, this study aims to construct a risk prediction model including both objective variables and PROs to predict 30 day readmission in older HF patients and to explore the value of PROs in the prediction model. To further the aim and better understand the risk factors of readmission in older HF patients, Andersen’s Behavioural Model in phase 4 was adapted as the conceptual model. Andersen’s Behavioural Model groups factors associated with health service utilization into four categories: environment, population characteristics (predisposing, enabling, need), health behaviour, and outcomes. This model provided a holistic view for understanding how individual and environmental factors impact health outcomes and had been used extensively in exploring the influencing factors. Therefore, Andersen’s Behavioural Model can be an effective framework for exploring the comprehensive risk factors of readmission in older HF patients.

Methods

Population

Participants were enrolled from March 2019 to October 2020 at three tertiary hospitals in Tianjin, China. The inclusion criteria were (i) diagnosed with HF on admission; (ii) aged over 60 years; and (iii) able to understand and write Chinese. Participants with following co-morbidities would be excluded: dementia, hemiplegia, solid tumour, leukaemia, lymphoma, and AIDS, which could seriously affect patients’ prognosis.

Data collection

Data were collected at three stages: 24 h before discharge, the 7th and 30th day after discharge, which were normally the HF patients’ clinic visit in these hospitals. The outcome was 30 day all-cause readmission which was defined as any unplanned hospital readmission. Patient’s information at three stages were collected by three researchers separately to keep blind to other data in other stages for every researcher. Objective variables were gathered through the medical record. If older patients could not see the question clearly, researchers would read it literally.

Assessment tool

All the risk factors that might affect the 30 day readmission of older HF patients were summarized from four aspects (environment, population characteristics, health behaviour, and outcomes) based on Andersen’s Behavioural Model through review of literature and clinical practice. The following 38 characteristics including PROs and objective variables were obtained from the participants and their medical records: (i) Environment: hospital and residence. (ii) Population characteristics: gender, age, BMI, educational level, career, marital status, living conditions, caregivers, social support, health literacy, per capita income, payment of medical
expenses, anxiety level, depression level, history of surgery (including any type of surgery), history of heart failure, co-morbidities, vital signs on the day of admission, heart function grade of NYHA, BNP, orthopoea, and quality of life. (iii) Health behaviour: smoke, drink, cardiac stimulant, medication adherence, HF clinical visit on time, self-care behaviour, changing the type of medicine by oneself, low sodium diet, regular exercise, admission from the emergency department, number of hospitalizations in the past year, number of hospitalizations due to HF in the past year and Length of stay. (iv) Outcome: 30 day readmission.

Among these indexes, seven indexes of quality of life, medication adherence, hf clinical visit on time, self-care behaviour, changing the type of medicine by oneself, low sodium diet, regular exercise were collected in the second stage and the outcome was collected in the third stage.

Some indexes were evaluated using the following measures:

1. Social Support Rating Scale (SSRS) was adopted to measure participants’ social support level. SSRS was designed by Xiao and included three subscales: subjective support (emotional support provided by relatives or friends), objective support (connection with others or participation in social groups and networks) and use of social support (resources provided by others and the utilization of both objective support and subjective support). Total score ranged from 12 to 66, with a higher score indicating better social support level. The test–retest reliability coefficient for SSRS was 0.92 and for each item between 0.89 and 0.94.

2. Health Literacy Management Scale (HeLMS) was used to measure health literacy level. The scale was made by Jordan and translated into Chinese version by Sun. HeLMS was composed of 24 items covering 4 dimensions: information acquisition ability, communicative interaction ability, health improvement willingness, economic support willingness. Each item was rated from 5 (no difficulty) to 1 (totally unable), with a higher score reflecting higher health literacy level. Cronbach’s α was 0.894 and the test–retest reliability was 0.683.

3. Hospital Anxiety and Depression Scale (HADS) was adopted to evaluate participants’ anxiety and depression level. The scale included 14 items and two subscales: The anxiety subscale and depression subscale (seven items in each subscale). A psychiatric score of 7 or less is for non-cases (remarked as 1 in this study), scores of 8–10 for doubtful cases (remarked as 2 in this study) and scores of 11 or more for definite cases (remarked as 3 in this study) in two subscales. The Cronbach’s α for total scale, anxiety subscale and depression subscale were 0.879, 0.806, 0.806 and the test–retest reliability were 0.945, 0.921, 0.932 (P < 0.001), respectively.

4. Age-adjusted Charlson co-morbidity index (aCCI) was adopted to assess participants’ co-morbidities. Charlson co-morbidity index (CCI) was built by Charlson to predict 10 year survival rate in patients with multiple co-morbidities. Later, age was included in CCI to form aCCI. Compared with CCI, aCCI was a better index to predict prognosis which used age, the number and severity of co-morbidities to quantify the impact of co-morbidities. The scores of each co-morbidity category were not exactly the same which range from 0 to 6. Higher total score indicated worse health condition.

5. The Chinese version of Minnesota Living with Heart Failure Questionnaire (MLHFQ) was adopted to assess the quality of life. This scale included 21 items and 3 dimensions: physical dimension (8 items), the emotional dimension (5 items) and the other dimension (8 items). Each item was rated from 5 (obvious influence) to 0 (no influence). The total score was ranged from 0 to 105 wherein a higher score reflected worse quality of life. The Cronbach’s α of Chinese version MLHFQ was 0.881.

6. Morisky Medication Adherence Scale-8 was adopted to evaluate medication adherence. The scale was built by Morisky in 2008 to evaluate the medication adherence in discharged patients. The Chinese version was translated by Si and includes 8 items. The total score ranged from 0 to 8 and the score less than 6 indicated patients with low medication adherence (remarked as 1 in this study), 6–7.75 meaning patients with moderate medication adherence (remarked as 2 in this study) and 8 meaning patients with high medication adherence (remarked as 3 in this study). The Cronbach’s α of Chinese version was 0.81 and the test–retest reliability was 0.95.

7. The European Heart Failure Self-care Behaviour Scale (EHFScBS) was used to evaluate the self-care behaviour. EHFscBS was developed by Jaarsma and translated into Chinese by Wang. The scale included 12 items and each item was rated from 5 (I completely disagree) to 1 (I completely agree). A higher score was associated with patients’ worse self-care behaviour. The Cronbach’s α of Chinese version was 0.72 and the test–retest reliability was 0.83.

Sample size was calculated based on the recommendations (at least 10–15 subjects per item) by Pett. There were 38 indexes in the Assessment tool, and thus at least 380 participants were needed in this study.

Ethical considerations

The study protocol was approved by the Research Ethics Committee of the University. The study was conducted following the tenets of the Declaration of Helsinki. Oral and written informed consents were provided at the beginning of the study and signed by each participant.
Data analysis

Data collected from March to December 2019 were used to construct the prediction model as the training group. After the prediction model was constructed, the information of predictors were collected from July to October 2020 as the external validation group to evaluate the prediction model.

Statistical analysis was performed using the SPSS 26.0 (SPSS Inc. Chicago, IL, USA) and R software (version 3.5.2). Patient characteristics were summarized as number (%) for categorical variables and mean ± SD/median, interquartile range (IQR) for continuous variables. When the continuous variable in one group was nonnormally distributed, it would be expressed as ‘median, IQR’ both in readmission group and non-readmission group to be comparable. Differences in readmission group and non-readmission group were tested in univariate analysis using the χ2 test or Fisher’s exact test for categorical variables and the t-test or the Mann–Whitney U test for continuous variables.

Variables with statistical significance in the univariate analysis were entered into the multivariate analysis. Multivariate logistic regression analysis was conducted to identify the independent predictors of 30 day readmission in the training group. Tolerance and variance inflation factor (VIF) were used for collinearity diagnosis of the covariates. The nomogram was developed based on multivariate regression coefficients and was internally and externally validated by receiver operating characteristic (ROC) curves and the calibration plots. The clinical applicability of the nomogram was evaluated by decision-curve analysis (DCA). All tests were two-sided with a statistical significance level set at P < 0.05.

Results

Baseline characteristics and univariate analysis in the training group

In the current study, 29 patients (7.07%) dropped during follow-up because of not answer the phone or not willing to participate. Finally, a total of 381 patients’ complete data were analysed in the training group. Among these patients, 14.4% (n = 55) were readmitted to hospitals within 30 days of discharge. The mean age of patients was 72.74 years, 57.5% were male and nearly 31% of patients were singles. The results of univariate analysis showed that the patients with following characteristics were more likely to be readmitted within 30 days after discharge (Table 2): lower social support level, lower health literacy level, higher anxiety and depression level, no history of surgery, lower quality of life, no HF clinical visit on time, worse self-care behaviour and changing the type of medicine by oneself.

Development of the nomogram

Multivariate Logistic regression was performed in the training group including the variables with statistical significance in univariate analysis. The results showed that the six factors of history of surgery, changing the type of medicine by oneself, information acquisition ability, subjective support, depression level, quality of life were independent predictors of 30 day readmission in older HF patients (Table 2). All VIFs of those variables were less than 5, indicating that no multicollinearity was detected among these factors. A nomogram was built on the basis of these six predictors (Figure 2).

Scoring technique

Using this nomogram to predict 30 day readmission risk of HF patients was as follows: the points of the above predictors could be obtained by a vertical line drawn to the points axis at the top of nomogram, and these points were added up to obtain a total score at the bottom of nomogram, then the risk of 30 day readmission in HF patients could be predicted. For example, having history of surgery = 0 point, changing the type of medicine by oneself = 20 points, information acquisition ability = 15 = 30 points, subjective support = 14 = 30 points, depression level = 12 = 40 points, quality of life = 60 = 54.5 points. The total score was 0 + 20 + 30 + 30 + 40 + 54.5 = 174.5 and the corresponding risk of 30 day readmission was 0.65 (65%).

Validation of the nomogram

In internal validation, the discrimination ability of the nomogram was evaluated by ROC curve. The area under the ROC curve (AUC) was 0.949 (95% CI: 0.925, 0.973, sensitivity: 0.873, specificity: 0.883) (Figure 2A) which indicated great internal discrimination ability. Calibration plot was utilized to visualize the performance of the nomogram demonstrating favourable coordination between predictive probability of 30 day readmission and observed probability in internal validation (Figure 3A). Moreover, the result of DCA suggested that the nomogram had the superior clinical applicability at threshold probabilities of 0–85% (Figure 4).

The external validation of the nomogram was performed. A total of 170 patients were enrolled in the external validation group. The criteria of participants and the data collection were the same as that in the training group. Only the information of six predictors in nomogram were collected which were showed in Table 3. In the external validation group, 27(15.9%) patients were readmitted within 30 days after discharge. The discrimination ability of the nomogram was evaluated by AUC which was 0.804 (95% CI: 0.691, 0.917, sensitivity: 0.778, specificity: 0.832) (Figure 2B). The predictive
# Table 1 Participants’ information in the training group

| Variables                        | Readmission group | Non-readmission group | P      |
|----------------------------------|-------------------|------------------------|--------|
|                                  | n (%)/mean ± SD/median, IQR |                       |        |
|                                  |                   |                        |        |
| **Hospital**                     |                   |                        |        |
| **A**                            | 19 (34.5)         | 87 (26.7)              | 0.559  |
| **B**                            | 25 (45.5)         | 154 (47.2)             |        |
| **C**                            | 11 (20.0)         | 85 (26.1)              |        |
| **Residence**                    |                   |                        |        |
| **City**                         | 48 (87.3)         | 266 (81.6)             | 0.306  |
| **Country**                      | 7 (12.7)          | 60 (18.4)              |        |
| **Gender**                       |                   |                        |        |
| **Male**                         | 32 (58.2)         | 187 (57.4)             | 0.909  |
| **Female**                       | 23 (41.8)         | 139 (42.6)             |        |
| **Age (year)**                   | 73.35 ± 12.60     | 72.67 ± 12.58          | 0.900  |
| **BMI**                          |                   |                        |        |
| **Underweight**                  | 11 (20.0)         | 28 (8.6)               | 0.100  |
| **Normal**                       | 18 (32.7)         | 118 (36.2)             |        |
| **Overweight**                   | 26 (47.3)         | 180 (55.2)             |        |
| **Educational level**            |                   |                        |        |
| **Primary school or lower**      | 18 (32.7)         | 108 (32.5)             | 0.981  |
| **Middle school**                | 16 (29.1)         | 88 (27.0)              |        |
| **High school**                  | 8 (14.5)          | 63 (19.3)              |        |
| **Junior college or higher**     | 13 (23.7)         | 69 (21.2)              |        |
| **Career**                       |                   |                        |        |
| **Physical labour**              | 35 (63.6)         | 184 (56.4)             | 0.318  |
| **Mental work**                  | 20 (36.4)         | 143 (43.6)             |        |
| **Marital status**               |                   |                        |        |
| **Singles**                      | 16 (29.1)         | 101 (31.0)             | 0.779  |
| **Married**                      | 39 (70.9)         | 225 (69.0)             |        |
| **Living conditions**            |                   |                        |        |
| **Spouse and/or children**       | 53 (96.4)         | 295 (90.5)             | 0.335  |
| **Others**                       | 0 (0.0)           | 4 (1.2)                |        |
| **Caregivers**                   |                   |                        |        |
| **Spouse/children**              | 50 (90.9)         | 295 (90.5)             | 0.973  |
| **Nurse’s aide**                 | 1 (1.8)           | 5 (1.5)                |        |
| **Others or none**               | 4 (7.3)           | 26 (8.0)               |        |
| **Social support**               |                   |                        |        |
| **Total**                        | 28.70 ± 5.31      | 33.14 ± 7.05           | <0.001**|
| **Objective support**            | 7.13 ± 1.50       | 8.13 ± 2.09            | <0.001**|
| **Subjective support**           | 14.19 ± 2.72      | 16.93 ± 4.39           | 0.000**|
| **Support utilization degree**   | 7.51 ± 2.56       | 8.07 ± 2.52            | 0.049*  |
| **Health literacy**              |                   |                        |        |
| **Total**                        | 77.95 ± 23.33     | 99.33 ± 17.10          | <0.001**|
| **Information acquisition ability** | 25.00, 22        | 40.00, 12.00           | <0.001**|
| **Communicative interaction ability** | 29.22 ± 7.69     | 36.73 ± 6.99           | <0.001**|
| **Health improvement willingness** | 16.00, 12        | 20.00, 4.00            | 0.001**|
| **Economic support willingness** | 6.84 ± 1.74       | 8.18 ± 1.88            | <0.001**|
| **Per capita income (yuan/month)** | -                | -                      |        |
| **<3000**                        | 2 (3.6)           | 20 (6.1)               | 0.693  |
| **2000–2999**                    | 12 (21.8)         | 79 (24.2)              |        |
| **3000–3999**                    | 20 (36.4)         | 101 (31.0)             |        |
| **≥4000**                        | 21 (38.2)         | 126 (38.7)             |        |
| **Payment of medical expenses**  |                   |                        |        |
| **Medical insurance**            | 49 (89.1)         | 263 (80.7)             | 0.260  |
| **New rural cooperative medical care** | 5 (9.1)         | 42 (12.9)              |        |
| **Uninsured**                    | 1 (1.8)           | 21 (6.4)               |        |
| **Anxiety level**                | 9.00, 2.00        | 6.00, 6.00             | <0.001**|
| **Depression level**             | 13.00, 7.00       | 7.00, 8.00             | <0.001**|
| **History of surgery**           | 15 (27.3)         | 171 (52.5)             | 0.001**|
| **The type of surgery**          |                   |                        |        |
| **Gastrointestinal surgery**      | 6 (37.5)          | 43 (20.7)              | 0.874  |
| **Orthopaedic surgery**          | 1 (6.3)           | 15 (7.2)               |        |
| **Cardiovascular surgery**        | 6 (37.5)          | 83 (39.9)              |        |
| **Gynaecology**                  | 2 (12.5)          | 14 (6.7)               |        |
| **Neurosurgery**                 | 0                 | 3 (1.4)                |        |
| **Ophthalmology**                | 1 (6.2)           | 21 (10.1)              |        |
| **Oral and maxillofacial surgery** | 0                 | 1 (0.5)                |        |
| **Otolaryngology**               | 0                 | 7 (3.4)                |        |
| **Thoracic**                     | 0                 | 12 (5.8)               |        |
| **Urology**                      | 0                 | 9 (4.3)                |        |
| **History of heart failure**     | 24 (43.6)         | 128 (39.3)             | 0.540  |
| **aCCI**                         | 31 (56.4)         | 198 (60.7)             |        |
| **Body temperature**             |                   |                        |        |
| **Normal**                       | 54 (98.2)         | 321 (98.5)             | 1.000  |
| **Fever**                        | 1 (1.8)           | 5 (1.5)                |        |
| **Heart rate**                   |                   |                        |        |
| **Sinus bradycardia**            | 1 (1.8)           | 26 (8.0)               | 0.812  |
| **Normal**                       | 48 (87.3)         | 251 (77.0)             |        |
| **Sinus tachycardia**            | 6 (10.9)          | 49 (15.0)              |        |
| **Respiratory rate**             | 50 (90.9)         | 288 (88.4)             | 0.576  |

(Continues)
probability of 30 day readmission in nomogram was highly consistent with the observed probability in the calibration plot (Figure 3B).

**Discussion**

In the present study, a practical and reliable nomogram including objective outcomes and PROs was constructed and demonstrated to predict 30 day readmission risk of older HF patients in China. Data were generated from 381 older HF patients in the training group and the sample included a diverse range of patients which had good representation of different individual characteristics, such as age, gender and socioeconomic status in China. The nomogram exhibited good practicality and reliability. The values of AUC were 0.949 and 0.804 in the internal validation and the external validation group which showed better discriminatory ability. Favourable predictive accuracy in predicting 30 day

### Table 1 (continued)

| Variables                                      | n (%) | mean ± SD/median, IQR |
|------------------------------------------------|-------|-----------------------|
| **Blood pressure**                             |       |                       |
| Hypotension                                    | 2 (3.6) | 16 (4.9)             |
| Normal                                         | 33 (60.0) | 142 (43.6)       |
| Hypertension                                   | 19 (34.5) | 159 (48.7)       |
| **Heart function grade of NYHA**               |       |                       |
| 2                                              | 6 (10.9) | 35 (10.7)          |
| 3                                              | 22 (40.0) | 155 (47.6)        |
| 4                                              | 27 (49.1) | 136 (41.7)        |
| **Heart function grade of NYHA**               |       |                       |
| 1                                              | 0 (0.0)  | 5 (1.5)             |
| 2                                              | 6 (10.9)  | 48 (14.7)          |
| 3                                              | 21 (38.2) | 140 (42.9)        |
| 4                                              | 28 (50.9) | 133 (40.9)        |
| **BNP**                                        |       |                       |
| Yes                                            | 17 (30.9) | 127 (39.0)       |
| No                                             | 38 (69.1) | 199 (61.0)       |
| **Orthopnoea**                                 |       |                       |
| Total score                                    | 71.46 ± 22.87 | 38.09 ± 19.40 |
| Physical dimension                             | 28.65 ± 10.35 | 15.67 ± 8.65 |
| Emotional dimension                            | 18.00, 12.00 | 5.00, 6.00       |
| Other dimension                                | 29.00, 8.00 | 15.00, 11.00    |
| **Smoke**                                      |       |                       |
| Yes                                            | 17 (30.9) | 127 (39.0)       |
| No                                             | 38 (69.1) | 199 (61.0)       |
| **Drink**                                      |       |                       |
| Yes                                            | 5 (9.1)   | 59 (18.1)          |
| No                                             | 50 (90.9) | 267 (81.9)        |
| **Cardiac stimulant**                          |       |                       |
| Yes                                            | 29 (52.7) | 151 (46.3)       |
| No                                             | 26 (47.3) | 175 (53.7)       |
| **Medication adherence**                       |       |                       |
| Total score                                    | 8, 0   | 8, 0                |
| 1                                              | 4 (7.3)   | 23 (7.1)           |
| 2                                              | 2 (3.6)   | 33 (10.1)          |
| 3                                              | 49 (89.1) | 270 (82.8)        |
| **HF clinical visit on time**                  |       |                       |
| Yes                                            | 18 (32.7) | 157 (48.2)       |
| No                                             | 37 (67.3) | 169 (51.8)       |
| **Self-care behaviour**                        |       |                       |
| Yes                                            | 7 (12.7)  | 14 (4.3)           |
| No                                             | 48 (87.3) | 312 (95.7)        |
| **Low sodium diet**                            |       |                       |
| Yes                                            | 49 (89.1) | 281 (86.2)       |
| No                                             | 6 (10.9)  | 45 (13.8)          |
| **Regular exercise**                           |       |                       |
| Yes                                            | 10 (18.2) | 97 (29.8)         |
| No                                             | 45 (81.8) | 229 (70.2)       |
| **Admission from the emergency department**    |       |                       |
| Yes                                            | 34 (61.8) | 201 (61.7)       |
| No                                             | 21 (38.2) | 125 (38.3)       |
| **Number of hospitalizations in the past year**|       |                       |
| Yes                                            | 2, 2   | 2, 2                |
| No                                             | 1, 2   | 1, 1                |
| **Number of hospitalizations due to HF in the past year** | 1, 2   | 1, 1                |
| **Length of stay**                             | 12, 9 | 10, 7               |

CCI, Charlson co-morbidity index.

*P < 0.050.

**P < 0.010.

†The variable was tested on the day of admission.

‡The variable was tested on the day of discharge.

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readmission risk was found in the calibration plots. The nomogram had the superior clinical applicability at threshold probabilities of 0–85% in DCA.

The factors associated with increased 30 day readmission risk of older HF patients were history of surgery, changing the type of medicine by oneself, information acquisition ability, subjective support, depression level, and quality of life. Aside from the history of surgery, other five factors were PROs. Considerable differences were found between the importance assigned by patients and professionals to clinical

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**Table 2 Multivariate logistic analysis of 30 day readmission in older HF patients**

| Variables                                      | Coefficient | Adjusted OR (95% CI) | P   | Collinearity statistics |
|------------------------------------------------|-------------|----------------------|-----|-------------------------|
| History of surgery                             |             |                      |     |                         |
| No                                             | -1.520      | 0.219 (0.088, 0.547) | 0.001 | 0.988 | 1.012 | Tolerance | VIF |
| Yes                                            | 1.465       | 4.329 (1.099, 17.052) | 0.036 | 0.981 | 1.019 |
| Changing the type of medicine by oneself       |             |                      |     |                         |
| No                                             | 0.073       | 0.930 (0.889, 0.972) | 0.001 | 0.779 | 1.283 |
| Yes                                            | 0.120       | 0.887 (0.792, 0.993) | 0.038 | 0.855 | 1.170 |
| Information acquisition ability                |             |                      |     |                         |
| No                                             | 0.243       | 1.275 (1.144, 1.422) | <0.001 | 0.734 | 1.362 |
| Yes                                            | 0.065       | 1.067 (1.045, 1.091) | <0.001 | 0.854 | 1.172 |
| Subjective support                             |             |                      |     |                         |
| No                                             | -3.314      | 0.036                | 0.014 |                     |
| Yes                                            | 1.00        |                      |     |                         |

CI, confidence interval; OR, odds ratio.

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**Figure 1** Nomogram predicting risk of 30-day readmission in older HF patients.

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**Figure 2** Receiver operating characteristic (ROC) curves in the internal and external validation groups. (A) ROC curve in the internal validation group. (B) ROC curve in the external validation group.
and functional outcomes. PROs provided more reliable information on the patients’ experience than that reported by clinicians, and the routine collection and inclusion of PROs in patient care improved the quality of care and clinical outcomes for patients.

In this study, HF patients with history of any surgery had lower 30 day readmission rate which was consistent with that in Kheiri’s study. Kheiri found that comparing with medical therapy, patients with transcatheter leaflet repair, reshaping, annuloplasty, or mitral valvular surgery had improvements in long-term clinical outcomes, such as lower 12-month HF hospitalization rate and 24-month mortality rate. Patients with history of surgery had better heart function and higher HF-related knowledge level, which helped them reduce avoidable readmission. However, Saito’s study found that post coronary bypass was related to 90 day

Figure 3 Calibration plots of the nomogram in the internal validation group and the external validation group. (A) Calibration plot in the internal validation group. (B) Calibration plot in the external validation group.

Figure 4 Decision-curve analysis for 30 day readmission in older HF patients.
all-cause readmission or death (OR = 1.23). In this study, there was no significant difference of surgery types between readmission group and non-readmission group because of the small sample size of different surgery types in two groups. The effect of different surgeries on patients’ short-term and long-term clinical outcomes was worthwhile to be explored with a large sample size.

Patients who changed the type of medicine by themselves after discharge had higher risk of 30 day readmission in this study. Evidence-based pharmacotherapy could improve HF patients’ prognosis, and thus adherence to prescribed drugs was very important for patients. However, medication non-adherence among HF patients was common, and non-adherence in these patients might possibly have contributed to worse prognosis. About 74.7% HF patients with poor medication adherence were found in Pallangyo’s study and displayed a 70% increased risk for readmission compared to others with good adherence.32 Patients’ individual medication knowledge decreased significantly and only 18% knew the correct number of their drugs 3 months after discharge13 which resulted in poor medication adherence easily. Medication knowledge inversely related to N-terminal prohormone of brain natriuretic peptide levels33 which revealed an urgent need for better strategies to improve and promote the medication adherence in patients with high risk of readmission.

In the current study, the mean score of information acquisition ability was 25.00 in readmission group and was 40.00 in non-readmission group which was significantly different between two groups. Information acquisition ability refers to the ability that individuals recognize their health needs and then obtain, understand and judge information independently.32 HF patients with higher information acquisition ability had lower 30 day readmission risk in this study which was consistent with Fabbri’s study.34 Fabbri34 found that the hazard ratio for hospitalizations was 1.30 in patients with low health literacy, compared with patients with adequate health literacy. Patients’ information acquisition ability was influenced by socioeconomic factors, educational level, and so on. All these factors could lead patients with limited information acquisition ability to have less effective interaction with physicians and lower self-care level after discharge which played an important role in the higher risk of readmission.34 Some interventions focusing on patients with low information acquisition ability are needed to improve health behaviours and clinical outcomes.

Subjective support, the emotional support provided by relatives or friends, was the predictor for 30 day readmission in HF patients in this study. Compared to patients in non-readmission group, patients in readmission group had significantly lower subjective support level in univariate analysis. The important role of relatives’ support in patients’ outcomes has been previously reported.35,36 Defective support network was stressed by many HF patients that increased hospital readmission.36 The mechanisms whereby higher subjective support lead to better outcomes likely involved self-care behaviours and nutritional status. Adequate families’ support might provide a network that reinforced motivation of self-care behaviours and ensure that patients were well nourished. Companionship itself might improve prognosis, giving patients ‘something to live for’.35 Interventions aiming to improve patients’ outcomes could involve the caregivers and explore their important role in patients’ outcomes.

Depression caused most serious impact in readmission rate in this model (OR = 38.67, 37.64). In patient with HF, depression disorder was common and associated with adverse development and progression of HF, including reduced adherence to prescribed medicine, poor heart function and increased hospitalizations and mortality rates, likely mediated through both physiologic and behavioural mechanisms.19 Sevilla-Cazes37 found that after discharge, HF patients easily experienced a cycle of despair which characterized by decreased medicine adherence, worsening symptoms, and intensification of negative emotions. Patients experienced worsening symptoms despite perceived good adherence which resulted in profound psychological distress characterized by feelings of hopelessness and frustration.37 These findings help to explain why these measures and interventions, targeted to reduce readmission, need to involve not only patients’ physical challenges, but also their psychological needs.
Quality of life was the predictor of 30 day readmission in HF patients in this study. Patients’ quality of life in our study was better than that reported in Chen’s study (44.4)\(^{38}\) and worse than that in Paz’s study (34.3).\(^{20}\) Only patients with a reduced ejection fraction (HFrEF) were included in Chen’s study and we enrolled patients with reduced ejection fraction (HFrEF), preserved ejection fraction (HFpEF) or mid-range ejection fraction (HfmrEF) in this study. The reason that quality of life was better than that reported in Chen’s study may be that when ejection ability of left ventricle decreased, patients’ physical symptoms would exacerbate, resulting in poor quality of life. Additionally, patients’ quality of life significantly related to age that explained the lower quality of life in this study (patients’ mean age = 72.74 years) than that in Paz’s study (mean age = 60.23 years).\(^{20}\) Higher quality of life was associated with better clinical outcomes which was reported previously.\(^{39}\) As a prognosis indicator of readmission and mortality, the concern with the individuals’ quality of life has been highlighted in the Health Sciences area. More interventions were needed to improve patients’ quality of life.

**Limitations**

Although the sample size was 10 subjects per item recommended by Pett,\(^ {28}\) it might influence the effects of objective variables in 30 day readmission prediction model. In addition, sample was based on a single data source from one city. Multicentre larger sample study is needed to verify the impact of PROs and objective variables on prognosis and to demonstrate the nomogram.

**Conclusions**

In this study, a novel and easy-to-use nomogram integrating objective variables with PROs is constructed and demonstrated, including history of surgery, changing the type of medicine by oneself, information acquisition ability, subjective support, depression level, and quality of life. Internal validation shows that the nomogram has favourable discriminatory ability and predictive accuracy in predicting 30 day readmission based on the ROC curve and calibration plot. DCA curve indicates good clinical applicability. The performance of the nomogram drops in the external validation cohort and the nomogram must be validated in a wide prospective cohort of HF patients before its clinical relevance can be demonstrated. This nomogram emphasizes the important role of the PROs which deserve more attention in predicting studies. All these findings in this study can assist professionals in identifying the needs of HF patients so as to reduce 30 day readmission.

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**Conflict of interest**

The authors have no conflicts of interest to disclose.

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