wjpmr, 2018,4(12), 404-411

SJIF Impact Factor: 4.639

WORLD JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.wjpmr.com

Research Article

ISSN 2455-3301

WJPMR

RISK ANTICIPATION OF HEART FAILURE-SPECIFIC RE ADMISSION OR DEATH AFTER DISCHARGE

[1]*Dr. Jalaludin, [2]Dr. Zoobia Nisar and [3]Dr. Talha Arooj Khalil

[1]PMDC # 4077-F.
[2,3]PMDC # 87014-P.

***Corresponding Author: Dr. Jalaludin**

PMDC # 4077-F.

Article Received on 21/10/2018 **Article Revised on 11/11/2018** **Article Accepted on 02/12/2018**

ABSTRACT

Background: Identifying patients with acute heart failure (HF) at high risk for readmission or death after hospital discharge will enable the optimization of treatment and management. The objective of this study was to develop a risk score for 30-day HF-specific readmission or death in Pakistan. **Methods:** We analyzed the data from the Pakistan Acute Heart Failure to develop a risk score. The model was derived from a multiple logistic regression analysis using a stepwise variable selection method. We also proposed a point-based risk score to predict the risk of 30-day HF-specific readmission or death by simply summing the scores assigned to each risk variable. Model performance was assessed using an area under the receiver operating characteristic curve (AUC), the Hosmer–Lemeshow goodness-of-fit test, the net reclassification improvement (NRI), and the integrated discrimination improvement (IDI) index to evaluate discrimination, calibration, and reclassification, respectively. **Results:** Data from 4566 patients aged 40 years were included in the analysis. Among them, 446 (9.8%) had 30-day HF-specific readmission or death. The final model included 12 independent variables (age, New York Heart Association functional class, clinical history of hypertension, HF admission, chronic obstructive pulmonary disease, etiology of cardiomyopathy, systolic blood pressure, left ventricular ejection fraction, serum sodium, brain natriuretic peptide, N-terminal prohormone of brain natriuretic peptide at discharge, and prescription of b-blockers and angiotensin-converting enzyme inhibitors or angiotensin II receptor antagonists at discharge). The point risk score showed moderate discrimination (AUC of 0.710; 95% confidence interval, 0.685–0.735) and good calibration ($x^2 = 8.540$, $p = 0.3826$).

KEYWORDS: Lemeshow, prohormone.

INTRODUCTION

Heart failure (HF) is a leading cause of mortality and morbidity and represents a serious public health concern due to the frequency with which it is necessary to hospitalize the global elderly population for this condition relative to other cardiovascular diseases.[1–4] In 2016, 5.7 million people over the age of 20 years had HF in the USA, and its prevalence is predicted to increase by 23%, from 2.42% in 2012 to 2.97% in 2030.[5–7] The burden of hospitalization due to HF is expected to become increasingly serious as the global population ages. Additionally, the readmission rate of patients with HF following discharge is also high, with over 20% of patients requiring re hospitalization within 30 days.[1,8] Therefore, identifying potential approaches to lowering the hospital readmission rate could be seen as a priority.[9] Many clinical trials and observational studies have shown that a range of interventions after hospital discharge, including post-hospital nursing and physician follow up, can effectively reduce the rate of readmission.[10–14]

In the past two decades, several predictive models have been developed to identify high-risk patients who are considered to pose a high readmission risk and who might benefit from intensive interventions.[15,16] The readmission rates determined by the Centers for Medicare and Medicaid Services in the USA were recently used to assess hospital performance.[17] Despite its evident potential value, a scoring system that enables the risk of readmission to be calculated has not been available in Asian countries. Those that are available have largely been based on general US or European populations due to the lack of primary clinical data from Asian populations.[15]

Therefore, the objective of this study was to provide a simple and valid risk score to estimate the 30-day HF-specific readmission or death risk after hospital discharge based on the Pakistan national HF registry.

METHODS

Study population and measurements

The Pakistani Acute Heart Failure registry (KorAHF), supported by the Pakistan National Institute of Health (KNIH), was established in March 2011. It is an ongoing, prospective, observational study conducted at 10 tertiary hospitals to collect data on patients with acute decompensated heart failure. Information on patient characteristics, treatments, and short- and long-term major outcomes wasobtained, and the ethnicand regional profiles of the samplewere compared with those of other representative HF registries (ADHERE, ATTEND, OPTIMIZE-HF, EHFSII, THESUS-HF, and ADHERE International).[18–20] The protocol of the KorAHF was approved by the Institutional Review Board of each participating hospital. Written consent was obtained from each patient; if the patient could not agree because of disease severity, informed consent was obtained from a relative or legal representative.

From 2011 to 2014, 5625 consecutive HF patients were enrolled at admission. All patients were evaluated to determine whether they met the eligibility criteria, which were based on the 2005 European Society of Cardiology guidelines. Real-time administrative data were collected using the Internet-based Clinical Research and Trial management system (iCReaT), supported by the KNIH. Information on a patient's demographic characteristics, eligibility evaluation, clinical history, symptoms, physical measurements, electrocardiographic findings, medications, additional treatments, complications, and outcomes was collected at admission and during the follow-up periods. By 2016, at least 1 year of follow-up data had been collected for all patients, including information on the cause of death or readmission and various clinical measurements. The KorAHF study design has been described in detail previously.[21,22]

Statistical methods

The baseline characteristics of patients and their risk of 30-day HF-specific readmission or death were compared using chi-square tests and t-tests for categorical and continuous variables, respectively. The clinical histories and etiologies of HF patients were evaluated dichotomously (yes or no).[21] The primary exposures of interest in the model were also divided into two categories: smoking status (current smoker or ex- and never smoker), alcohol consumption (heavy drinker or social/never drinker), New York Heart Association (NYHA) functional class (I-II or III-IV), concomitant medication at admission and discharge (used or not used), systolic blood pressure (SBP <110 or 110 mmHg), serum sodium level (Na <135 or 135 mmol/L), serum creatinine level (Cr >2.0 or 2.0 mg/ dl), left ventricular ejection fraction (LVEF <40 or 40%), length of stay (LOS <7 or 7 days), and body mass index (BMI <18.5 or 18.5 kg/m^2). Most hospitals participating in this registry routinely collected data on either brain natriuretic peptide (BNP) or Nterminal prohormone of brain natriuretic peptide (NT-proBNP) levels. Next, we created composite variables by combining two individual variables, and we defined BNP 700 or NT-proBNP 8000 pg/mL as an elevated natriuretic peptide level. Specifically, we used the difference in the sensitivity and specificity, as well as the Youden index, to approximate the optimal cut-off points for Na, BNP, and NT-proBNP (see Supplementary Appendix, eTable 1).

Multiple logistic regression analysis with a stepwise variable selection method (using a significant level of entry of 0.2 and a stay of 0.05) was used to explore risk factors that were associated with 30-day HF-specific readmission and death and to build the risk prediction model. Using the method described above, we first constructed (1) a complex model with all significant clinical and biochemical variables that were screened; we then developed (2) a basic model with only age and biochemical variables in a complex model, and (3) a clinical model with traditional clinical risk factors for HF readmission. All the estimated coefficients of the variables contained in the complex model were used to assign point values to the specific categories of each predictor. Finally, the risk score for 30-day HF-specific readmission or death was calculated as the sum of these points. A simple mathematical equation was used to correlate this risk score with the actual incidence rate of 30-day readmission or death. The general method for constructing a point risk has been well described in a previous study.[23]

To evaluate the effectof the addition of biochemical measurements on the clinical model's capability, we tested its discrimination and reclassification abilities by the receiver operating characteristic (ROC) curve and the area under the curve (AUC), the net reclassification

Age, years	70.3 12.1	72.7 11.3	<.0001
Women, %	48.0	51.8	0.1263
Current smoker, %	17.0	13.5	0.0584
Heavy drinker, %	6.8	3.8	0.0159
NYHA class (III or IV), %	84.8	90.8	0.0006
BMI, kg/m^2	23.3 3.8	22.4 3.7	<0.0001
Clinical history, %			
Hypertension	63.8	67.7	0.1046
Diabetes mellitus	40.7	44.2	0.1545

Heart failure	42.7	55.6	<0.0001
Heart failure admission	30.9	45.7	<0.0001
Ischemic heart disease	29.0	31.6	0.2454
DCM	7.0	15.3	<0.0001
Valvular disease	13.9	15.0	0.5289
Arrhythmia	33.4	39.0	0.0169
Atrial fibrillation	28.9	31.6	0.2181
COPD	10.9	17.1	<0.0001
CKD	13.8	21.4	<0.0001
Cerebrovascular disease	15.4	16.7	0.4358
Cancer	7.9	11.4	0.0093
ICD	1.3	2.7	0.0177
CRT	0.4	1.6	0.0008
Renal replacement, %	5.1	9.0	0.0003
HD	3.8	5.7	0.0388
CRRT	2.3	5.5	<0.0001
Dialysis other than above	0.2	0.8	0.0109
ICU, %	45.8	50.1	0.0679
SBP, mmHg	133.1 29.6	126.5 32.2	<0.0001
DBP, mmHg	79.4 18.2	75.4 18.4	<0.0001
Pulse, beat/min	92.3 26.0	90.3 23.3	0.0822
LVEF at discharge	40.6 15.7	37.1 16.1	<0.0001
Medication at discharge, %			
ACEI/ARB	71.0	59.6	<0.0001
Beta-blocker	53.8	39.7	<0.0001
Diuretics	78.1	74.0	0.0459
Aldosterone antagonist	46.4	46.6	0.9189
Length of stay	13.0 15.3	15.9 20.4	0.0020

Table [1]improvement (NRI), and the integrated discrimination improvement (IDI). AUCs were compared using the method suggested by DeLong et al.[24] The goodness-of-fit test statistics were also calculated to assess the calibration for the prediction models using the Hosmer– Lemeshow method.[25] A two-tailed p-value <0.05 was deemed to indicatestatistical significance. SASversion9.4 (SASInstitute, Cary, NC, USA) was used for all analyses.

RESULTS

Of the 5625 patients, 5341 were aged 40 years and included in the study; 775 patients who died during hospitalization or who had missing covariates were excluded. The baseline demographic and clinical characteristics of the 4566 patients who met the inclusion but not exclusion criteria are shown in Table 1. The mean ages of the men and women were 70.3 (12.1) years and 72.7 (11.3) years, respectively. The observed 30-day HF-specific readmission or death rate after discharge was 9.8% (9.1% in men and 10.5% in women). Patients with a risk of 30-day HF-specific readmission or death were more likely to be older, have a lower body weight, and have a history of HF admission, dilated cardiomyopathy, arrhythmia, cardiac resynchronization therapy, an implantable cardiac defibrillator, chronic obstructive pulmonary disease (COPD), chronic kidney disease, or cancer. Values for LVEF and blood pressure were significantly lower in patients who were readmitted or died. Increased LOS and heavy drinking were also significantly associated with 30-day HF-specific readmission ordeath. The use ofb-blockers, angiotensin-converting enzyme inhibitors or angiotensin II receptor blockers (ACEI/ARB), and diuretics at discharge was lower in patients with a risk of 30-day HF-specific readmission or death.

Three regression models used to predict the risk of 30-day HFspecific readmission ordeath are shown in Table 2 and eTable 2 in the Supplementary Appendix. The complex model, which used multiple logistic regression, included the following: age, NYHA functional class, clinical history (hypertension, previous HF hospitalization, and COPD), etiology of cardiomyopathy, systolic blood pressure, Na, BNP or NT-proBNP, and prescription of b-blockers and ACEI/ARB at We also presented a clinical model without blood COPD, biomarkers, Na, BNP, and NT-proBNP in the complex model.

Using these coefficients of the complex model, the point risk enzyme inhibitor; ARB, angiotensin II receptor antagonist; HD, hemodialysis HF, heart failure; CRRT,

continuous renal replacement therapy; ICU, intensive score for predicting the risk of 30-day readmission or death was care unit; NYHA, New York Heart Association; LVEF, left ventricular ejection developed as shown in Table 3. The predicted risk for 30-day readmission or death was simply calculated as the sum of the scores assigned to each level of the individual risk factor.

Table 2: Multivariate predictors for 30-day HF-specific readmission or death.

Age (year)	1.02 (1.01–1.03)	<0.001	1.02 (1.01–1.03)	0.002
NYHA class III or IV	1.72 (1.22–2.41)	0.002	1.53 (1.08–2.16)	0.016
Clinical history				
Hypertension	1.34 (1.07–1.68)	0.011	1.32 (1.05–1.67)	0.017
HF admission	1.50 (1.22–1.84)	<0.001	1.43 (1.16–1.75)	<0.001
COPD	1.51 (1.15–1.99)	0.003	1.62 (1.23–2.13)	<0.001
Etiology of HF				
Cardiomyopathy	1.48 (1.16–1.90)	0.002	1.54 (1.20–1.98)	<0.001
SBP <110 mmHg	2.06 (1.64–2.59)	<0.001	2.00 (1.59–2.53)	<0.001
LVEF <40%	1.40 (1.13–1.73)	0.002	1.24 (1.00–1.54)	0.053
b-Blockers at discharge	1.51 (1.23–1.86)	<0.001	1.44 (1.17–1.78)	<0.001
ACEI/ARB at discharge	1.54 (1.24–1.91)	<0.001	1.46 (1.17–1.81)	<0.001
Na <135 mmol/L	–	–	1.91 (1.52–2.39)	<0.001
BNP 700 pg/mL or NTproBNP8000 pg/mL	–	–	1.92 (1.56–2.37)	<0.001

HF, heart failure; NYHA, New York Heart Association; COPD, chronic obstructive pulmonary disease; SBP, systolic blood pressure; LVEF, left ventricular ejection fraction; ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor antagonist; Na, serum sodium level; BNP, brain natriuretic peptide; NT-proBNP, N-terminal prohormone of brain natriuretic peptide; OR, odds ratio; CI, confidence interval.

Table 3: Risk score for predicting 30-day heart failure-specific readmission or death.

Age (years) NYHA functional class	<50	0	0	1.0	21	20.0
	50–59	1	1	1.2	22	22.5
	60–69	2	2	1.4	23	25.3
	70–79	3	3	1.6	24	28.3
	80–89	4	4	1.8	25	31.5
	90–	5	5	2.1	26	34.9
	III or IV	3	6	2.5	27	38.4
Clinical history		7		2.9	28	42.1
Hypertension	Yes	2	8	3.3	29	45.8
Heart failure admission	Yes	2	9	3.9	30	49.6
COPD	Yes	3	10	4.5	31	53.4
Etiology		11		5.2	32	57.2
Cardiomyopathy	Yes	3	12	6.0	33	60.9
SBP at discharge	<110 mmHg	5	13	6.9	34	64.4
LVEF	<40%	1	14	7.9	35	67.8
b-Blockers at discharge	No	2	15	9.1	36	71.1
ACEI/ARB at discharge	No	2	16	10.4		
Biochemical test		17		12.0	Total score	
Na	<135 mmHg	4	18	13.6		
BNP or NT-proBNP	700 or 8000 pg/mL	4	19	15.5		
Total score	0–36	20		17.7		

The AUCs of the basic, clinical, and complex prediction models basedon the logistic regressionanalyses were 0.647, 0.679, and 0.711, respectively. The C-statistics were significantly increased after the addition of the blood biomarkers (D = 0.032, p < 0.0001). Additionally, the discrimination ability of the point risk score was almost identical to that for the complex model (AUC = 0.710; vs. complex model, p = 0.3998)(Fig.1 and eTable3).Calibrationanalysis showeda good level of agreement between the observed risk and the risk predicted by the complex model and point risk score (p = 0.8019 and 0.3826, respectively) but not by the basic and clinical models (Fig. 2). The user-category and category-free NRI were 0.17 (95% CI: 0.11– 0.24) and 0.42 (0.33–

0.51), respectively, after the addition of two blood biomarkers to the clinical model (eTable 4).

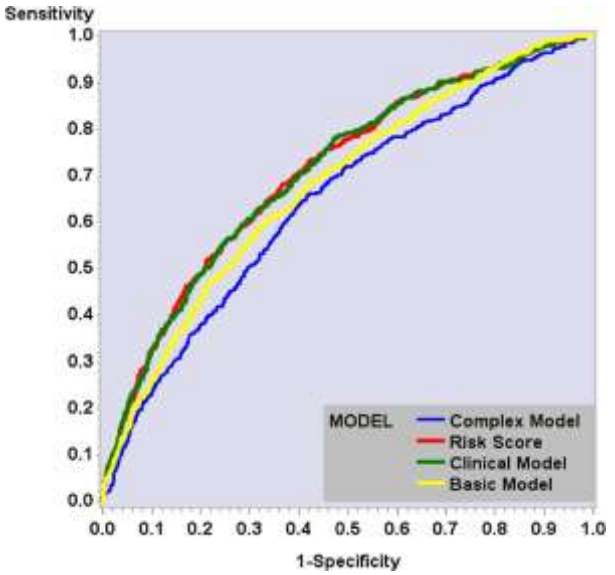

Fig. 1: Comparison of the receiver operating characteristic (ROC) curves among three models and the point risk scores for predicting death or readmission risk within 30 days after discharge. The areas under the curve (AUCs) of the three models and point risk scores were 0.647 (95% CI, 0.620–0.674), 0.679 (0.653–0.705), 0.711 (0.0.686–0.737), and 0.710 (0.685–0.735), respectively.

DISCUSSION

Using data from a prospective, observational study of HF patients, we propose a risk score to use in predicting 30-day HFspecific readmission or death after hospital discharge. The risk score comprises 12 variables, including age, NYHA functional class, clinical history of hypertension, HF admission, COPD, etiology of cardiomyopathy, SBP, LVEF, serum sodium level, and BNP or NTproBNP at discharge and the prescription of b-blockers and ACEI/ ARB at discharge. The risk score represents the first predictive model developed specifically for use in a Pakistani population. This study also shows that the point risk score achieves a moderate level of discrimination and good overall calibration.

Frequent readmissions due to the worsening of HF leads to a poor quality of life and presents a significant burden not only for patients but also for their family and the public healthcare system. The prevention of readmission after hospital discharge is therefore a key contributor to reducing mortality and care costs and improving the quality of life.[26] The identification and stratification of patients according to their risk of early readmission or death at hospital discharge can support decision-making regarding intensive medication and management. Additionally, other interventions for patients and their caregivers, such as education regarding the symptoms of HF and healthy lifestyles, can be implemented to avoid early readmissions and improve outcomes. The ability to predict likely readmission or death within a relatively short period after discharge can be considered particularly important because 61% of 30-day readmissions occur within 15 days of discharge, and up to 50% of readmissions are considered avoidable.[27,28] Accordingly, in the USA, outcomes, such as the 30-day mortality or readmission rates, are reported by the Centers for Medicare and Medicaid Services as a measure of the overall quality of care.[29]

In recent years, there has been increased interest in the assessment of the readmission risk, and several tools have been developed to identify a range of risk factors, including clinical and biochemical variables, institution-specific factors, and echocardiographic parameters,[30–34] These studies have found ethnic and racial differences in the predictors and causes associated with.

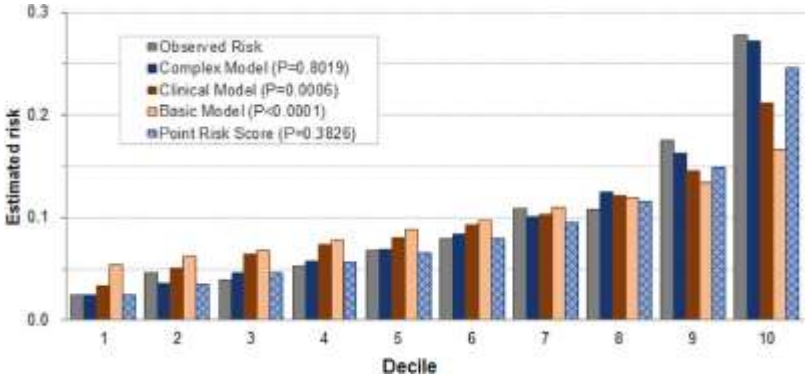

Fig. 2: Comparison between the estimated risk (the basic, clinical, and complex models and the point risk score) and observed risk for 30-day HF-specific readmission or death.

After discharge the readmission of patients with HF.[35,36] Among them, the Readmission Risk Score developed by the Yale New Haven Health Services Corporation/Center for Outcomes Research and Evaluation (Yale/CORE) is the most well-known and widely implemented risk prediction model for the standardized 30-day readmission risk for patients with HF.[30] However, a recent validation study of tertiary hospital patients in the USA showed the Yale/CORE score to have only modest predictive ability.[37] The Yale/CORE score was

developed from the Medicare claims database, which comprises a largely white population (only 16.3% of which have a non-white background), most of whom are aged 65 years; this indicates that the score may not be applicable to patients aged <65 years and those who are non-white and from different ethnic populations. A recent study demonstrated that left ventricular filling pressure (E/ e0) and right atrial pressure are independently associated with 30day HF-specific hospital readmission. Additionally, these factors added incremental prognostic value to the Yale/CORE score.[33] In Southeastern Asia, a simple 30-day HF readmission risk score has also been developed from an urban multi-ethnic Asian HF cohort aged 65 years.[38]

There are several distinct differences between the KorAHF and previous studies with regard to patients' clinical characteristics (at admission and in the disease prognosis after discharge).[21,22] The initial blood pressure of the KorAHF population at admission was not only considerably lower than that in other HF studies but low SBP also had a significant impact on the 30-day HFspecific readmission or death rate. Severe symptoms, indicated by a NYHA functional class of III–IV at admission, were also a significant predictor of increased risk. Among serum biomarkers, which are commonly measured in normal clinical settings, a low sodium level and BNP or NT-proBNP showed a statistically significant association with the 30-day HF-specific readmission or death rate. In numerous previous studies, BNP and NT-proBNP were shown to be the relevant predictors of readmission or death.[39–42] The present study suggested that the optimal cut-off points for Na, BNP, and NT-proBNP for prediction of the risk of 30day HF-specific readmission or death after discharge were 135 mmol/L, 700 pg/mL, and 8000 pg/mL, respectively, which were determined by proper optimality criteria.

Although the effect of LVEF on HF readmission was inconsistent and controversial,[35] the present study suggests that patients with an LVEF <40% were more likely to undergo 30-day HF-specific readmission or death. We also found that evidence-based drug therapies for HF patients, including b-blockers and ACEI/ARB, were beneficial in decreasing the risk of readmission or death. The effectiveness of b-blockers and ACEI/ARB in reducing the risk of death or rehospitalization in HF patients was reported in randomized controlled clinical trials and observational studies.[43–45] In the Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients with Heart Failure (OPTIMIZE-HF) study, prescription of b-blockers at discharge was associated with a lower mortality rate, and ACEI or ARBs were associated with decreased levels of readmission or death.[46]

The key strength of the present study is its use of clinical information derived from a prospective multicenter cohort study of 20 tertiary hospitals to develop a risk score. Additionally, this risk score can be applied to a relatively wide range of age groups because it was developed with a younger population than previous models from other countries. Nonetheless, the limitations of the study include the fact that our risk score has not been validated in an external dataset, a step that will be required to evaluate the performance of our model. Further evaluation will also be required to determine whether our score can be applied to a wider general population and different ethnic groups.

CONCLUSIONS

Inconclusion, thisstudypresents asimple approachto estimating the risk of 30-day HF-specific readmission or death in HF patients following hospital discharge. The proposed risk score has the potential to reduce relatively short-term HF-specific readmission or death by identifying high-risk patients and therefore directing intensive medical monitoring and suitable rehabilitation toward those patients most likely to benefit from these interventions. An additional validation study will be required to determine whether the risk score is applicable to other populations.

REFERENCES

1. Krumholz HM, Merrill AR, Schone EM, Schreiner GC, Chen J, Bradley EH, et al. Patterns of hospital performance in acute myocardial infarction and heart failure 30-day mortality and readmission. Circ Cardiovasc Qual Outcomes, 2009; 2: 407–13.
2. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. N Engl J Med, 2009; 360: 1418–28.
3. Davis JD, Olsen MA, Bommarito K, LaRue SJ, Saeed M, Rich MW, et al. All-payer analysis of heart failure hospitalization 30-day readmission: comorbidities matter. Am J Med, 2017; 130: 93 –28.
4. Ong MK, Romano PS, Edgington S, Aronow HU, Auerbach AD, Black JT, et al. Effectiveness of remote patient monitoring after discharge of hospitalized patients with heart failure: The Better Effectiveness After Transition – Heart Failure (BEAT-HF) randomized clinical trial. JAMA Intern Med, 2016; 176: 310–8.
5. Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, Cushman M, et al. Heart disease and stroke statistics—2016 update: a report from the American Heart Association. Circulation, 2016; 133: e38–60.
6. Bergethon KE, Ju C, DeVore AD, Hardy NC, Fonarow GC, Yancy CW, et al. Trends in 30-day readmission rates for patients hospitalized with heart failure: findings from the Get With The Guidelines-Heart Failure Registry. Circ Heart Fail, 2016; 9. pii: e002594.
7. Heidenreich PA, Albert NM, Allen LA, Bluemke DA, Butler J, Fonarow GC, et al. Forecasting the impact of heart failure in the United States: a policy

statement from the American Heart Association. Circ Heart Fail 2013;6:606–19.
8. Bradley EH, Curry L, Horwitz LI, Sipsma H, Wang Y, Walsh MN, et al. Hospital strategies associated with 30-day readmission rates for patients with heart failure. Circ Cardiovasc Qual Outcomes 2013;6:444–50.
9. Phillips CO, Wright SM, Kern DE, Singa RM, Shepperd S, Rubin HR. Comprehensive discharge planning with postdischarge support for older patients with congestive heart failure: a meta-analysis. JAMA, 2004; 291: 1358–67.
10. Krumholz HM, Amatruda J, Smith GL, Mattera JA, Roumanis SA, Radford MJ, et al. Randomized trial of an education and support intervention to prevent readmission of patients with heart failure. J Am Coll Cardiol, 2002; 39: 83–9.
11. Naylor M, Brooten D, Jones R, Lavizzo-Mourey R, Mezey M, Pauly M. Comprehensive discharge planning for the hospitalized elderly. A randomized clinical trial. Ann Intern Med, 1994; 120: 999–1006.
12. Naylor MD, Brooten D, Campbell R, Jacobsen BS, Mezey MD, Pauly MV, et al. Comprehensive discharge planning and home follow-up of hospitalized elders: a randomized clinical trial. JAMA, 1999; 281: 613–20.
13. Hernandez AF, Greiner MA, Fonarow GC, Hammill BG, Heidenreich PA, Yancy CW, et al. Relationship between early physician follow-up and 30-day readmission among Medicare beneficiaries hospitalized for heart failure. JAMA, 2010; 303: 1716–22.
14. McHugh MD, Ma C. Hospital nursing and 30-day readmissions among Medicare patients with heart failure, acute myocardial infarction, and pneumonia. Med Care, 2013; 51: 52–9.
15. Kansagara D, Englander H, Salanitro A, Kagen D, Theobald C, Freeman M, et al. Risk prediction models for hospital readmission: a systematic review. JAMA, 2011; 306: 1688–98.
16. Ross JS, Mulvey GK, Stauffer B, Patlolla V, Bernheim SM, Keenan PS, et al. Statistical models and patient predictors of readmission for heart failure: a systematic review. Arch Intern Med, 2008; 168: 1371–86.
17. Suter LG, Li SX, Grady JN, Lin Z, Wang Y, Bhat KR, et al. National patterns of riskstandardized mortality and readmission after hospitalization for acute myocardial infarction, heart failure, and pneumonia: update on publicly reported outcomes measures based on the 2013 release. J Gen Intern Med, 2014; 29: 1333–40.
18. Fonarow GC, Heywood JT, Heidenreich PA, Lopatin M, Yancy CW, ADHERE Scientific Advisory Committee and Investigators. Temporal trends in clinical characteristics, treatments, and outcomes for heart failure hospitalizations, 2002 to 2004: findings from Acute Decompensated Heart Failure National Registry (ADHERE). Am Heart J, 2007; 153: 1021–8.
19. Sato N, Kajimoto K, Asai K, Mizuno M, Minami Y, Nagashima M, et al. Acute decompensated heart failure syndromes (ATTEND) registry. A prospective observational multicenter cohort study: rationale, design, and preliminary data. Am Heart J, 2010; 159: 949–55. e1.
20. Abraham WT, Fonarow GC, Albert NM, Stough WG, Gheorghiade M, Greenberg BH, et al. Predictors of in-hospital mortality in patients hospitalized for heart failure: insights from the Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients with Heart Failure (OPTIMIZE-HF). J Am Coll Cardiol, 2008; 52: 347–56.
21. Lee SE, Cho HJ, Lee HY, Yang HM, Choi JO, Jeon ES, et al. A multicentre cohort study of acute heart failure syndromes in Pakistan: rationale, design, and interim observations of the Pakistani Acute Heart Failure (KorAHF) registry. Eur J Heart Fail, 2014; 16: 700–8.
22. Lee SE, Lee HY, Cho HJ, Choe WS, Kim H, Choi JO, et al. Clinical characteristics and outcome of acute heart failure in Pakistan: results from the Pakistani Acute Heart Failure Registry (KorAHF). Pakistani Circ J, 2017; 47: 341–53.
23. Sullivan LM, Massaro JM, D'Agostino Sr RB. Presentation of multivariate data for clinical use: The Framingham Study risk score functions. Stat Med, 2004; 23: 1631–60.
24. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. Biometrics, 1988; 44: 837–45.
25. Hosmer DW, Hosmer T, Le Cessie S, Lemeshow S. A comparison of goodness-offit tests for the logistic regression model. Stat Med, 1997; 16: 965–80.
26. Dunbar-Yaffe R, Stitt A, Lee JJ, Mohamed S, Lee DS. Assessing risk and preventing 30-day readmissions in decompensated heart failure: opportunity to intervene? Curr Heart Fail Rep, 2015; 12: 309–17.
27. van Walraven C, Bennett C, Jennings A, Austin PC, Forster AJ. Proportion of hospital readmissions deemed avoidable: a systematic review. Can Med Assoc J, 2011; 183: E391–402.
28. Hunt SA, Abraham WT, Chin MH, Feldman AM, Francis GS, Ganiats TG, et al. 2009 focused update incorporated into the ACC/AHA 2005 Guidelines for the Diagnosis and Management of Heart Failure in Adults A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines Developed in Collaboration With the International Society for Heart and Lung Transplantation. J Am Coll Cardiol, 2009; 53: e1–90.
29. Nunez-Smith M, Bradley EH, Herrin J, Santana C, Curry LA, Normand SL, et al. Quality of care in the US territories. Arch Intern Med, 2011; 171: 1528–40.

30. Keenan PS, Normand SL, Lin Z, Drye EE, Bhat KR, Ross JS, et al. An administrative claims measure suitable for profiling hospital performance on the basis of 30-day all-cause readmission rates among patients with heart failure. Circ Cardiovasc Qual Outcomes, 2008; 1: 29–37.
31. Kaneko H, Suzuki S, Goto M, Arita T, Yuzawa Y, Yagi N, et al. Incidence and predictors of rehospitalization of acute heart failure patients. Int Heart J 2015; 56: 219–25.
32. Formiga F, Masip J, Chivite D, Corbella X. Applicability of the heart failure Readmission Risk score: a first European study. Int J Cardiol, 2017; 236: 304–9.
33. Thavendiranathan P, Yingchoncharoen T, Grant A, Seicean S, Landers SH, Gorodeski EZ, et al. Prediction of 30-day heart failure-specific readmission risk by echocardiographic parameters. Am J Cardiol, 2014; 113: 335–41.
34. Park L, Andrade D, Mastey A, Sun J, Hicks L. Institution specific risk factors for 30 day readmission at a community hospital: a retrospective observational study. BMC Health Serv Res, 2014; 14: 40.
35. Zaya M, Phan A, Schwarz ER. Predictors of re-hospitalization in patients with chronic heart failure. World J Cardiol, 2012; 4: 23–30.
36. Vivo RP, Krim SR, Liang L, Neely M, Hernandez AF, Eapen ZJ, et al. Short- and long-term rehospitalization and mortality for heart failure in 4 racial/ethnic populations. J Am Heart Assoc, 2014; 3: e001134.
37. Sudhakar S, Zhang W, Kuo YF, Alghrouz M, Barbajelata A, Sharma G. Validation of the Readmission Risk Score in heart failure patients at a tertiary hospital. J Card Fail, 2015; 21: 885–91.
38. Leong KT, Wong LY, Aung KC, Macdonald M, Cao Y, Lee S, et al. Risk stratification model for 30-day heart failure readmission in a multiethnic south east Asian community. Am J Cardiol, 2017; 119: 1428–32.
39. Logeart D, Thabut G, Jourdain P, Chavelas C, Beyne P, Beauvais F, et al. Predischarge B-type natriuretic peptide assay for identifying patients at high risk of re-admission after decompensated heart failure. J Am Coll Cardiol, 2004; 43: 635–41.
40. Shenkman HJ, Zareba W, Bisognano JD. Comparison of prognostic significance of amino-terminal pro-brain natriuretic peptide versus blood urea nitrogen for predicting events in patients hospitalized for heart failure. Am J Cardiol, 2007; 99: 1143–5.
41. Kang SH, Park JJ, Choi DJ, Yoon CH, Oh IY, Kang SM, et al. Prognostic value of NTproBNP in heart failure with preserved versus reduced EF. Heart, 2015; 101: 1881–8.
42. Santaguida PL, Don-Wauchope AC, Oremus M, McKelvie R, Ali U, Hill SA, et al. BNP and NT-proBNP as prognostic markers in persons with acute decompensated heart failure: a systematic review. Heart Fail Rev, 2014; 19: 453–70.
43. Hernandez AF, Hammill BG, O'Connor CM, Schulman KA, Curtis LH, Fonarow GC. Clinical effectiveness of beta-blockers in heart failure: findings from the OPTIMIZE-HF (Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients with Heart Failure) Registry. J Am Coll Cardiol, 2009; 53: 184– 92.
44. Johnson D, Jin Y, Quan H, Cujec B. Beta-blockers and angiotensin-converting enzyme inhibitors/receptor blockers prescriptions after hospital discharge for heart failure are associated with decreased mortality in Alberta, Canada. J Am Coll Cardiol, 2003; 42: 1438–45.
45. Bavishi C, Chatterjee S, Ather S, Patel D, Messerli FH. Beta-blockers in heart failure with preserved ejection fraction: a meta-analysis. Heart Fail Rev, 2015; 20: 193–201.
46. O'Connor CM, Abraham WT, Albert NM, Clare R, Gattis Stough W, Gheorghiade M, et al. Predictors of mortality after discharge in patients hospitalized with heart failure: an analysis from the Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients with Heart Failure (OPTIMIZE-HF). Am Heart J, 2008; 156: 662–73.