REVIEW ARTICLE

Statistical Models and Patient Predictors of Readmission for Heart Failure

A Systematic Review

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Background: Readmission after heart failure (HF) hospitalization is an increasing focus for physicians and policy makers, but statistical models are needed to assess patient risk and to compare hospital performance. We performed a systematic review to describe models designed to compare hospital rates of readmission or to predict patients' risk of readmission, as well as to identify studies evaluating patient characteristics associated with hospital readmission, all among patients admitted for HF.

Methods: We identified relevant studies published between January 1, 1950, and November 19, 2007, by searching MEDLINE, Scopus, PsycINFO, and all 4 Ovid Evidence-Based Medicine Reviews. Eligible English-language publications reported on readmission after HF hospitalization among adult patients. We excluded experimental studies and publications without original data or quantitative outcomes.

Results: From 941 potentially relevant articles, 117 met inclusion criteria: none contained models to compare readmission rates among hospitals, 5 (4.3%) presented models to predict patients' risk of readmission, and 112 (95.7%) examined patient characteristics associated with readmission. Studies varied in case identification, used multiple types of data sources, found few patient characteristics consistently associated with readmission, and examined differing outcomes, often either readmission alone or a combined outcome of readmission or death, measured across varying periods (from 14 days to 4 years). Two articles reported model discriminations of patient readmission risk, both of which were modest (C statistic, 0.60 for both).

Conclusions: Our systematic review identified no model designed to compare hospital rates of readmission, while models designed to predict patients' readmission risk used heterogeneous approaches and found substantial inconsistencies regarding which patient characteristics were predictive. Clinically, patient risk stratification is challenging. From a policy perspective, a validated risk-standardized statistical model to accurately profile hospitals using readmission rates is unavailable in the published English-language literature to date.

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READMISSION AFTER HOSPITAL discharge is attracting considerable attention from the Institute of Medicine,[1] the Centers for Medicare & Medicaid Services,[2] and the Medicare Payment Advisory Commission[3] as an indicator of the quality and efficiency of care. Readmission after heart failure (HF) hospitalization is being given particular attention because HF is one of the most common principal discharge diagnoses among Medicare beneficiaries[4] and because there is wide variation among hospital HF readmission rates,[3] with some studies reporting rates approaching 45% at 6 months.[5] Moreover, improved hospital[6,7] and postdischarge[8-12] care, including predischarge planning,[13,14] home-based follow-up,[15] and patient education,[13,16,17] lowers HF readmission rates, suggesting that HF readmission rates might be reduced if proved interventions were more fully instituted.

There are several issues to consider in using readmission as a measure of hospital performance. Any effort to compare readmission rates across institutions must consider differences in the spectrum of patients, with particular attention to HF disease severity and comorbid disease. Numerous publications have investigated patient factors associated with readmission risk after HF hospitalization.[5,18-26] Information from these studies and others may inform efforts to compare readmission rates among hospitals after accounting for differences across hospital populations, providing some perspective on the potential performance of a statistical model developed for such use. Moreover, this information may identify patient character istics associated with readmission that may be considered for inclusion in any developed model and assist clinicians in stratifying patients' risk for readmission. Accordingly, 3 distinct but related objectives of this systematic review are as follows: (1) to describe statistical models designed to compare hospital rates of readmission among patients admitted for HF and to determine their performance (using model operating characteristics such as C statistic or area under the receiver operating characteristic curve) and which patient characteristics were included, (2) to describe statistical models designed to predict patients' risk of readmission among patients admitted for HF and to determine their performance and which patient characteristics were included, and (3) to identify patient characteristics associated with hospital readmission among patients admitted for HF.

METHODS

Relevant studies were identified by searching the following databases: (1) Ovid MEDLINE (January 1, 1950, to November 19, 2007); (2) PubMed (January 1, 1950, to November 19, 2007); (3) Scopus, an Elsevier Science Publishers abstract and citation database (January 1, 1996, to November 19, 2007); (4) Ovid PsycINFO (January 1, 1967, to November 19, 2007); and (5) all Evidence-Based Medicine Reviews on Ovid, including *ACP Journal Club* (January 1, 1991, to September-October 2007), Cochrane Database of Systematic Reviews, Database of Abstracts and Reviews of Effects, and Cochrane Central Register of Controlled Trials (third quarter of 2007). We searched these databases using the following strategy. First, we performed a search that included the Medical Subject Headings (MeSH) term *patient readmission* (exploded) and the key words *readmi$* and *rehosp$* (using "$" for truncation), identifying 11 240 publications using our readmission terms. Second, we performed a search that included the MeSH term *risk* (exploded) and the key words *model$*, *predict$*, *use$*, *util$*, and *risk$*, identifying 4 462 843 publications using our risk/model/prediction terms. Third, we performed a search that included the MeSH term *heart failure, congestive* (exploded), identifying 106 487 publications using our HF term. Fourth, we combined our patient readmission, risk/model/prediction, and HF terms. This search identified 941 articles.

We applied several inclusion and exclusion criteria that were defined a priori to these 941 articles (article selection form available as an appendix from the author). Publications eligible for inclusion reported on readmission among individual patients hospitalized for HF as a primary outcome, secondary outcome, or part of a composite outcome. We excluded abstracts, pediatric studies, non–English language studies, and publications without original data (reviews, letters, and editorials). We also excluded studies that reported results from a case series or case report and studies without quantitative outcomes. Finally, we excluded publications from experimental studies, often randomized clinical trials, that reported on the effect of an intervention at readmission (eg, discharge planning, case management programs, or pharmaceutical treatment). Because our review is focused on identifying patient characteristics that are associated with hospital readmission, publications reporting on an intervention's effect are less relevant because they rarely report on the effect of participants' (patients') characteristics on readmission. However, we included publications that used data collected from a randomized clinical trial to examine the effect of participants' (patients') characteristics on readmission (independent of the effect of the intervention).

Two of us (J.S.R. and B.S.) independently reviewed the titles and abstracts of retrieved publications and selected relevant articles for possible inclusion in our review. Based on this review, we excluded 795 publications that did not report on readmission among patients hospitalized at baseline for HF or that met at least 1 of our exclusion criteria.

The remaining 146 potentially eligible publications were retrieved. On detailed review of the full-text publications, we excluded 29 additional articles that met our predefined exclusion criteria. The most common reasons for exclusion included the following: patients were not hospitalized at baseline (n=13), patients did not have HF (n=4), there were no original data (n=4), and readmission was not examined as an outcome (n=4).

We developed a standardized instrument (available as an appendix from the author) to perform a detailed abstraction of the remaining 117 publications by consulting with experts in cardiology and systematic review methods, preparing an instrument for their review, piloting the instrument, and making modifications as necessary. The following variables were extracted: data source; readmission type and period; study purpose, design, and period; sample sizes (hospitals and patients); analytic strategy, including methods used to handle deaths and transfers; and candidate variables examined as predictors of hospital readmission, categorized as laboratory variables, comorbid conditions, HF severity variables, and sociodemographic variables. All extractions were confirmed by a second author, and disagreements regarding assessment and data extraction were resolved by consensus among all authors.

RESULTS

There were 117 publications included in our review. As per our research objectives, (1) we identified no studies that presented statistical models that were derived or designed explicitly to compare hospital rates of readmission among patients with HF, (2) we identified 5 studies (4.3%) that presented statistical models that were derived or designed explicitly to predict risk of readmission among patients with HF, and (3) we identified 112 studies (95.7%) that examined patient characteristics associated with readmission among patients with HF but did not derive a statistical model to predict patient readmission risk. In other words, none of the articles reported the development or application of a statistical model for the purpose of comparing hospitals or other health care organizations, the first objective of our systematic review.

MODELS AND RISK SCORES TO PREDICT PATIENT RISK OF READMISSION

Table 1 gives characteristics of 5 studies[20,23,27-29] that presented statistical models or risk scores derived to predict patient risk of readmission after HF hospitalization, the second objective of our systematic review. All studies examined patients within the United States, but none used national data. Two studies predicted all-cause readmission, 1 study predicted HF-specific readmission, and the remaining 2 studies predicted death or all-cause readmission; the period studied ranged from 60 days to 1 year. Three studies de-

Table 1. Characteristics of Identified Publications Developing Models or Risk Scores to Predict Patient Readmission Risk After Heart Failure (HF) Hospitalization (Second Objective of Our Systematic Review)

Source	Study Type	Data Source (Study Period)	Study Location	No. of Hospitals/No. of Patients	Study Outcome	Follow-up Period	Analytic Model	Derivation or Validation	C Statistic
Chin and Goldman,[27] 1997	Prospective cohort	Medical record review (1993-1994)	Boston, Massachusetts	1/257	All-cause readmission or death	60 d	Cox proportional hazards regression	Derivation only	Not provided
Philbin and DiSalvo,[23] 1999	Retrospective cohort	SPARCS, from the New York State Department of Health (1995)	New York State	236/42 731[a]	HF-specific readmission	1 y	Multivariate logistic regression	Derivation and validation	0.60
Krumholz et al,[20] 2000	Retrospective cohort	MEDPAR file from HCFA and medical record review (1994-1995)	Connecticut	18/1129 in derivation cohort and 1047 in validation cohort	All-cause readmission	6 mo	Cox proportional hazards regression	Derivation and validation	Not provided
Felker et al,[28] 2004	RCT cohort	Collected during RCT (1997-1999)	United States	78/949	All-cause readmission or death	60 d	Multivariate logistic regression	Derivation only	0.69
Yamokoski et al,[29] 2007	RCT cohort	Collected during RCT (study period given)	United States and Canada	26/373	All-cause readmission	6 mo	Multivariate logistic regression	Derivation only	0.60

Abbreviations: HCFA, Health Care Financing Administration; MEDPAR, Medicare Provider Analysis and Review; RCT, randomized controlled trial; SPARCS, Statewide Planning and Research Cooperative System.
[a] Patients were randomly assigned to the derivation and validation cohorts; exact numbers in each cohort were not presented.

rived a model risk score, whereas the other 2 studies derived and validated a model risk score to predict hospital readmission.

Chin and Goldman[27] used prospectively collected medical record review data from a single academic hospital in Boston, Massachusetts, of 257 patients to derive a risk score for death or all-cause readmission to any hospital within 60 days among patients with HF. Patients were identified using the admitting diagnosis in combination with clinical characteristics. The authors examined 25 candidate variables for inclusion in their risk score (**Table 2**), including access to care, laboratory measures, comorbid conditions, clinical characteristics, and sociodemographic characteristics. Using Cox proportional hazards regression modeling, they developed an 11-point scoring system to stratify patient risk for death or all-cause readmission within 1 year (with 0-1 indicating lowest risk and 8-11 indicating highest risk), wherein each patient is assigned 2 points for single marital status, 1 point per Charlson Comorbidity Index (to a maximum of 4), 3 points for an initial systolic blood pressure of 100 mm Hg or less, and 2 points for new ST-T wave changes on an admission electrocardiogram (no C statistic was presented).

Philbin and DiSalvo[23] used registry data collected from hospitals by the New York State Department of Health as part of the Statewide Planning and Research Cooperative System of 42 731 patients in 236 hospitals to derive and validate a risk score for HF-specific readmission to any New York State hospital within 1 year among patients with HF. Patients were identified using *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) codes. The authors examined 60 candidate variables for inclusion in their risk score, including patient dispositions, hospital characteristics, hospital course measures, sociodemographic characteristics, and comorbid conditions and the Charlson Comorbidity Index. Using multivariate logistic regression analysis, they developed a 15-point scoring system to stratify patient risk for HF readmission within 1 year (with 0-3 indicating lowest risk and 11-15 indicating highest risk), wherein each patient is assigned 4 points at baseline and 1 point is added for each of the following 11 variables: (1) black race/ethnicity; (2) primary insurance of Medicare or Medicaid; medical history of (3) ischemic heart disease, (4) valvular heart disease, (5) diabetes mellitus, (6) renal disease, (7) chronic lung disease, (8) idiopathic cardiomyopathy, or (9) cardiac surgery; (10) the use of telemetry during the index hospitalization; and (11) home health care services after hospital discharge. One point is subtracted for each of the following 4 variables: (1) treatment at a rural hospital; (2) echocardiogram or (3) cardiac catheterization performed during the index hospitalization; and (4) discharge to a skilled nursing facility (C statistic, 0.60).

Krumholz et al[20] used Connecticut Medicare Provider Analysis and Review file data from the Health Care Financing Administration, supplemented with medical record review of 2176 patients in 18 hospitals, to derive and validate a statistical model to predict risk of all-cause readmission to any Connecticut hospital within 6 months among older patients admitted for HF. Patients were identified using *ICD-9-CM* codes. The authors examined 32 candidate variables for their statistical model, including mobility, HF disease severity, comorbid conditions, clinical characteristics, discharge medications, sociodemographic characteristics, and hospital course and laboratory measures.

Table 2. Sociodemographic, Comorbidity, and Medical History Variables Examined in Identified Publications Developing Models or Risk Scores to Predict Patient Readmission Risk After Heart Failure (HF) Hospitalization Considered as Candidates for Multivariate Models (Second Objective of Our Systematic Review)

Candidate Variable	Chin and Goldman[27,a]	Philbin and DiSalvo[23,b]	Krumholz et al[20,c]	Felker et al[28,d]	Yamokoski et al[29,e]
Sociodemographic Variables					
Age	Yes	Yes	Yes	Yes	Yes
Sex	Yes	Yes	Yes	Yes	Yes
Race/ethnicity	Yes	Yes[f]	Yes	Yes	Yes
Marital status	Yes[f]	No	No	No	No
Comorbidity and Medical History Variables					
Active or inactive cancer	No	Yes	No	No	No
Acute or chronic renal disease	No	Yes[f]	No[g]	No[g]	No[g]
Acute pneumonia	No	Yes	No	No	No
Admission in past year	No	No	Yes[f]	No	No
Admission (HF-specific) in past year	No	No	Yes[f]	Yes[f]	No
Anemia	No	Yes[f]	No	No[h]	No
Angina	No	No	Yes	Yes	No
Atrial fibrillation or flutter	No	Yes	Yes	Yes	No
Cerebrovascular disease or stroke	No	Yes	Yes	Yes	No
Charlson Comorbidity Index	Yes[f]	Yes	No	No	No
Chronic lung disease or chronic obstructive pulmonary disease	No	Yes	Yes	Yes	No
Diabetes mellitus	Yes	Yes[f]	Yes[f]	Yes	No
Drug or alcohol abuse	No	Yes	No	No	No
HF	Yes	No	Yes[f]	Yes	No
Hyperlipidemia	No	No	No	Yes	No
Hypertension	Yes	No	Yes	Yes	No
Hypertensive heart disease	No	Yes	No	Yes	No
Ischemic heart disease	No	Yes[f]	No	Yes	Yes
Life-threatening arrhythmia disorder	Yes	Yes	No	Yes	No
Liver disease	No	No	No	Yes	No
Myocardial infarction	Yes	Yes	Yes	Yes	No
New York Heart Association class	No	No	No	Yes[f]	Yes
Other cardiomyopathies	No	Yes[f]	No	No	No
Peripheral vascular disease	No	Yes[f]	No	No	No
Previous coronary artery bypass graft surgery	No	Yes[f]	Yes	Yes	No
Previous percutaneous transluminal coronary angioplasty	No	No	Yes	Yes[f]	No
Shock	No	Yes	No	No	No
Valvular heart disease	No	Yes	No	No	No

[a] Model comprised 25 candidate variables, including income, education, access to care, 6 clinical presentation characteristics, and 2 laboratory measures.
[b] Model comprised 60 candidate variables, including insurance plan, hospital location and type, 22 hospital course measures, and 4 disposition measures.
[c] Model comprised 32 candidate variables, including mobility, 7 clinical presentation characteristics, 4 hospital course measures, and 5 laboratory measures.
[d] Model comprised 41 candidate variables, including weight, height, 11 clinical presentation characteristics, and 6 laboratory measures.
[e] Model comprised 18 candidate variables, including 6 clinical presentation characteristics, 4 hospital course measures, and 3 laboratory measures.
[f] Independent predictor of readmission ($P \leq .05$).
[g] Model did not include medical history of acute or chronic renal disease but measured serum creatinine or blood urea nitrogen level, which was an independent predictor of readmission ($P \leq .05$).
[h] Model did not include medical history of anemia but measured hemoglobin level, which was an independent predictor of readmission ($P \leq .05$).

Using Cox proportional hazards regression modeling, their final model included the following independent predictors of readmission (no C statistic was presented): (1) hospitalization in the prior year (hazard ratio [HR], 1.25; 95% confidence interval [CI], 1.05-1.48; P=.01), (2) medical history of HF (HR, 1.23; 95% CI, 1.02-1.48; P=.03), (3) medical history of diabetes mellitus (HR, 1.17; 95% CI, 0.99-1.39; P=.07), and (4) serum creatinine level exceeding 2.5 mg/dL (to convert creatinine level to micromoles per liter, multiply by 88.4) at discharge (HR, 1.72; 95% CI, 1.35-2.18; $P < .001$).

Felker et al[28] used data from 949 patients in 78 hospitals enrolled in the Outcomes of a Prospective Trial of Intravenous Milrinone for Exacerbations of Chronic Heart Failure Study to derive a statistical model to predict risk of death or all-cause readmission to any hospital within 60 days among patients with HF. Patients were identified by their clinical presentation on admission. The authors examined 41 candidate variables for their statistical model, including height, weight, laboratory measures, comorbid conditions, clinical characteristics, admission medications, and sociodemographic characteristics. Using multivariate logistic regression, their final model included the following independent predictors of death or readmission (C statistic, 0.69): (1) HF hospitalization in the prior year (odds ratio [OR], 1.14; 95% CI, 1.06-1.23; $P < .001$), (2) prior percutaneous coronary intervention (OR, 1.46; 95% CI, 1.00-2.12; P=.05), (3) systolic blood pressure (OR, 0.82; 95% CI, 0.75-0.89;

Table 3. Characteristics of Identified Publications Examining the Association Between Specific Patient Characteristics and Readmission After Heart Failure (HF) Hospitalization (Third Objective of Our Systematic Review)

Source	Study Type	Data Source (Study Period)	Study Location	No. of Hospitals/No. of Patients	Study Outcome	Follow-up Period	Analytic Model
Rich and Freedland,[30] 1988	Retrospective cohort	Hospital administrative (1983-1986)	St Louis, Missouri	1/410	All-cause readmission	3 mo	Descriptive
Vinson et al,[31] 1990	Prospective cohort	Medical record review (1987)	St Louis, Missouri	1/140	All-cause readmission	3 mo	χ^2 Test
Brophy et al,[32] 1993	Prospective cohort	Medical record review (1988)	Canada	2/153	All-cause readmission or death	6 mo	Multivariate logistic regression
Krumholz et al,[5] 1997	Retrospective cohort	MEDPAR file from HCFA (1991-1994)	Connecticut	Multiple, No. not presented/17 448	All-cause readmission	6 mo	Multivariate logistic regression
McDermott et al,[33] 1997	Retrospective cohort	Medical record review (1992-1993)	Chicago, Illinois	1/412	All-cause readmission or death	3 mo	χ^2 Test
Pernenkil et al,[34] 1997	Prospective cohort	Hospital administrative and medical record review (study period not presented)	St Louis, Missouri	1/399	All-cause readmission	3 mo	Multivariate logistic regression
Philbin and Roerden,[35] 1997	Prospective cohort	Medical record review (1995)	New York State	10/1402	All-cause readmission	6 mo	χ^2 Test
Lowe et al,[36] 1998	Prospective cohort	Medical record review (1993)	Australia	2/409	All-cause readmission	28 d	Multivariate logistic regression
Ni et al,[37] 1998	Retrospective cohort	Oregon State hospital discharge index dataset (1995)	Oregon	Multiple, No. not presented/5821	HF-specific readmission	3 mo	Multivariate logistic regression
Philbin and DiSalvo,[38] 1998	Retrospective cohort	SPARCS, from the New York State Department of Health (1995)	New York State	243/43 157	All-cause readmission	6 mo	Multivariate logistic regression
Philbin and DiSalvo,[22] 1998	Retrospective cohort	SPARCS, from the New York State Department of Health (1995)	New York State	236/42 731	All-cause readmission	1 y	Multivariate logistic regression
Afzal et al,[39] 1999	Prospective cohort	Medical record review and patient self-report (1996)	Detroit, Michigan	1/163	All-cause readmission	6 mo	Multivariate logistic regression
Alexander et al,[40] 1999	Retrospective cohort	California hospital discharge data (1991-1992)	California	Multiple, No. not presented/90 316	All-cause readmission	1 y	Cox proportional hazards regression
Harjai et al,[41] 1999	Retrospective cohort	Hospital administrative, medical record review, and patient self-report (1994-1995)	New Orleans, Louisiana	1/326	All-cause readmission or death	30 d	Multivariate logistic regression
Ofili et al,[42] 1999	Retrospective cohort	Hospital administrative and medical record review (1995)	Atlanta, Georgia	1/1200	All-cause readmission	1 y	Multivariate logistic regression
Vaccarino et al,[26] 1999	Retrospective cohort	MEDPAR file from HCFA and medical record review (1994-1995)	Connecticut	18/2445	All-cause readmission	6 mo	Cox proportional hazards regression

(continued)

$P<.001$), (4) serum urea nitrogen level (OR, 1.26; 95% CI, 1.14-1.41; $P<.001$), and (5) serum hemoglobin level (OR, 0.89; 95% CI, 0.82-0.97; $P=.006$).

Yamokoski et al[29] used data from 373 patients in 26 hospitals enrolled in the Evaluation Study of Congestive Heart Failure and Pulmonary Artery Catheterization Effectiveness trial to derive a statistical model to predict risk of all-cause readmission to any hospital within 6 months among patients with HF. Their objective was to compare the accuracy of the model with physician and nurse estimates of the same outcome for patients. Patients were identified by their clinical presentation on admission. The authors examined 18 candidate variables for their statistical model, including clinical characteristics, discharge medications, sociodemographic characteristics, New York Heart Association class, and hospital course and laboratory measures. Using multivariate logistic regression analysis, their final model included the following independent predictors of readmission (C statistic, 0.60): (1) serum urea nitrogen level and (2) high-dose diuretics at discharge.

PATIENT CHARACTERISTICS ASSOCIATED WITH READMISSION

Table 3 summarizes 112 studies* that examined the association of specific patient characteristics with readmission among patients hospitalized for HF, the third objective of our systematic review. These studies often described a multivariate model used to adjust for the effect of patient characteristics on readmission when examining a specific

**References 5, 18, 19, 21, 22, 24-26, 30-133.*

Table 3. Characteristics of Identified Publications Examining the Association Between Specific Patient Characteristics and Readmission After Heart Failure (HF) Hospitalization (Third Objective of Our Systematic Review) (cont)

Source	Study Type	Data Source (Study Period)	Study Location	No. of Hospitals/No. of Patients	Study Outcome	Follow-up Period	Analytic Model
Evangelista et al,[43] 2000	Retrospective cohort	VA hospital administrative and medical record review (1997-1998)	Los Angeles, California	1/753	All-cause readmission	1 y	Multivariate logistic regression
Heller et al,[44] 2000	Retrospective cohort	Hospital administrative	Australia	22/877	All-cause readmission	1 y	Multivariate logistic regression
Kossovsky et al,[45] 2000	Case-control	Medical record review (1993-1998)	Switzerland	1/91	All-cause readmission	30 d	Multivariate logistic regression
Smith et al,[46] 2000	RCT cohort	Collected during RCT (within VA hospitals) (1992-1994)	United States	9/1378	All-cause readmission	3 mo	Cox proportional hazards regression
Armola and Topp,[47] 2001	Retrospective cohort	Medical record review (1997-1998)	Toledo, Ohio	1/187	HF-specific readmission	30 d	χ^2 Test
Cheng et al,[48] 2001	Prospective cohort	VA hospital administrative and medical record review (1999)	San Diego, California	1/72	HF-specific readmission	30 d	Multivariate logistic regression
Dauterman et al,[49] 2001	Retrospective cohort	Hospital administrative and medical record review (1993-1996)	California	Multiple, No. not presented/ 782	All-cause readmission	1 y	χ^2 Test
Harjai et al,[50] 2001	Retrospective cohort	Hospital administrative and medical record review (1994-1995)	New Orleans, Louisiana	1/434	All-cause readmission	30 d	Multivariate logistic regression
Jiang et al,[51] 2001	Prospective cohort	Medical record review and patient self-report (1997-1998)	Durham, North Carolina	1/357	All-cause readmission or death	30 d	Multivariate logistic regression
Philbin et al,[21] 2001	Retrospective cohort	SPARCS, from the New York State Department of Health (1995)	New York State	236/41 776	All-cause readmission	1 y	Multivariate logistic regression
Shah et al,[52] 2001	RCT cohort	Collected during RCT (study period not presented)	United States and Europe	No. not presented/ 440	All-cause readmission	1 y	Other time to event
Tsuchihashi et al,[53] 2001	Retrospective cohort	Hospital administrative and medical record review (1997-1999)	Japan	5/230	HF-specific readmission	1 y	Multivariate logistic regression
Tsutsui et al,[54] 2001	Retrospective cohort	Hospital administrative and medical record review (1997-1999)	Japan	5/172	HF-specific readmission	2.4 y (Mean)	Other time to event
Ahmed et al,[55] 2002	Retrospective cohort	MEDPAR file from HCFA and medical record review (1994)	Alabama	11/438	HF-specific readmission	6 mo	Cox proportional hazards regression
Alonso-Martínez et al,[56] 2002	Prospective cohort	Hospital administrative and medical record review (study period not presented)	Spain	1/76	HF-specific readmission or death	18 mo	Multivariate logistic regression
Bettencourt et al,[57] 2002	Prospective cohort	Medical record review and patient self-report (2001)	Portugal	1/50	All-cause readmission or death	6 mo	Cox proportional hazards regression
Dai et al,[58] 2002	Prospective cohort	Patient self-report (2000-2001)	Taiwan	5/334	All-cause readmission	2 mo	Multivariate logistic regression
Evangelista et al,[59] 2002	Retrospective cohort	VA hospital administrative and medical record review (1997-1998)	Los Angeles, California	1/753	All-cause readmission	2 y	Multivariate logistic regression
Faris et al,[60] 2002	Retrospective cohort	Medical record review (1994-1998)	United Kingdom	1/396	All-cause readmission	4 y	Cox proportional hazards regression
Gronda et al,[61] 2002	Retrospective cohort	Hospital administrative (1996-1997)	Italy	Multiple, No. not presented/ 32 093	HF-specific readmission	30 d	Multivariate logistic regression
Ishii et al,[62] 2002	Prospective cohort	Medical record review (1997-1998)	Japan	1/98	HF-specific readmission or death	1 y	Cox proportional hazards regression
Malki et al,[63] 2002	Prospective cohort	Medical record review and patient self-report (study period not presented)	Detroit, Michigan	1/187	All-cause readmission	6 mo	χ^2 Test
Babayan et al,[64] 2003	Retrospective cohort	Medical record review (1996-1997)	Baltimore, Maryland	1/493	All-cause readmission	16.5 mo (Mean)	Cox proportional hazards regression

(continued)

Table 3. Characteristics of Identified Publications Examining the Association Between Specific Patient Characteristics and Readmission After Heart Failure (HF) Hospitalization (Third Objective of Our Systematic Review) (cont)

Source	Study Type	Data Source (Study Period)	Study Location	No. of Hospitals/No. of Patients	Study Outcome	Follow-up Period	Analytic Model
Blackledge et al,[65] 2003	Retrospective cohort	Hospital administrative and patient self-report (1998-2001)	United Kingdom	Multiple, No. not presented/5789	HF-specific readmission or death	6 mo	Cox proportional hazards regression
Felker et al,[66] 2003	RCT cohort	Collected during RCT (1997-1999)	United States	78/906	All-cause readmission or death	6 mo	Cox proportional hazards regression
Fisher et al,[67] 2003	RCT cohort	Collected during RCT (1997-1999)	United Kingdom	1/87	HF-specific readmission or death	1 y	Multivariate logistic regression
Ishii et al,[68] 2003	Prospective cohort	Medical record review (1999-2001)	Japan	1/100	HF-specific readmission or death	1 y	Cox proportional hazards regression
Kosiborod et al,[19] 2003	Retrospective cohort	MEDPAR file from HCFA and medical record review (1994-1995)	Connecticut	18/2281	All-cause readmission	1 y	Cox proportional hazards regression
Rathore et al,[24] 2003	Retrospective cohort	MEDPAR file from CMS and medical record review (1998-1999)	United States	Multiple, No. not presented/29 732	All-cause readmission	1 y	Hierarchical logistic regression
Schwarz and Elman,[69] 2003	Prospective cohort	Medical record review and patient self-report (study period not presented)	Northeastern Ohio (rural)	2/149	All-cause readmission	3 mo	Cox proportional hazards regression
Smith et al,[70] 2003	Prospective cohort	Medical record review and patient self-report (1996-1998)	New Haven, Connecticut	1/316	All-cause readmission	6 mo	Cox proportional hazards regression
Smith et al,[71] 2003	Prospective cohort	Medical record review (1996-1998)	New Haven, Connecticut	1/412	All-cause readmission	6 mo	Cox proportional hazards regression
Agoston et al,[72] 2004	Retrospective cohort	VA medical record review (1998-2001)	Houston, Texas	1/448	HF-specific readmission	6 mo	Cox proportional hazards regression
Ahmed et al,[73] 2004	Retrospective cohort	MEDPAR file from HCFA and medical record review (1994)	Alabama	11/944	HF-specific readmission	30 d	Cox proportional hazards regression
Akhter et al,[74] 2004	RCT cohort	Collected during RCT (study period not presented)	United States	55/481	All-cause readmission	30 d	χ^2 Test
Baker et al,[75] 2004	Retrospective cohort	MEDPAR file from HCFA and CHCQ, Cleveland-area hospital administrative (1991-1997)	Cleveland, Ohio	30/22 203	All-cause readmission	30 d	Multivariate logistic regression
Bettencourt et al,[76] 2004	Prospective cohort	Medical record review and patient self-report (2002-2003)	Portugal	1/182	All-cause readmission or death	6 mo	Cox proportional hazards regression
Del Carlo et al,[77] 2004	Prospective cohort	Medical record review and patient self-report (1999)	Brazil	1/62	All-cause readmission or death	1 y	Multivariate logistic regression
Deswal et al,[78] 2004	Retrospective cohort	VA hospital administrative and medical record review (1997-1999)	United States	153/21 003	All-cause readmission	1 y	Hierarchical logistic regression
Gackowski et al,[79] 2004	Prospective cohort	Medical record review (2001-2002)	France	1/95	HF-specific readmission or death	60 d	Cox proportional hazards regression
Hadase et al,[80] 2004	Prospective cohort	Medical record review (2000-2003)	Japan	1/54	HF-specific readmission or death	19.7 mo (Mean)	Multivariate logistic regression
Lee et al,[81] 2004	Retrospective cohort	Kaiser-Permanente hospital administrative and medical record review (1999-2000)	Oakland, California	16/1591	All-cause readmission or death	Followed up for ≤2 y	Cox proportional hazards regression
Logeart et al,[82] 2004	Prospective cohort	Hospital administrative and medical record review (study period not presented)	France	2/223	HF-specific readmission or death	6 mo	Cox proportional hazards regression

(continued)

patient characteristic (eg, race/ethnicity) but did not derive a statistical model to predict patient readmission risk.

These 112 studies were evenly divided between patients within (57 studies) and outside (55 studies) the United States (Table 3). One study used a case-control design, 14 studies used a cohort of patients drawn from a randomized controlled trial, 42 studies were retrospective cohort studies, and 55 studies were prospective cohort studies. Most studies (n = 62) were conducted at a single hospital. Of 57 studies that examined patients within the United States, various data sources were used: 16 studies used hospital administrative data (including data from Veteran Affairs medical centers

Table 3. Characteristics of Identified Publications Examining the Association Between Specific Patient Characteristics and Readmission After Heart Failure (HF) Hospitalization (Third Objective of Our Systematic Review) (cont)

Source	Study Type	Data Source (Study Period)	Study Location	No. of Hospitals/No. of Patients	Study Outcome	Follow-up Period	Analytic Model
McClellan et al,[83] 2004	Prospective cohort	Hospital administrative and medical record review (1998)	Georgia	120/662	All-cause readmission	30 d	Multivariate logistic regression
Opasich et al,[84] 2004	Prospective cohort	Medical record review (2000)	Italy	417/2127	All-cause readmission	6 mo	χ^2 Test
Roe-Prior,[85] 2004	RCT cohort	Collected during RCT (1992-1996)	Philadelphia, Pennsylvania	2/103	All-cause readmission	3 mo	Multivariate logistic regression
Arimoto et al,[86] 2005	Prospective cohort	Medical record review (study period not presented)	Japan	1/179	HF-specific readmission or death	20 mo (Mean)	Cox proportional hazards regression
Arimoto et al,[87] 2005	Prospective cohort	Medical record review (study period not presented)	Japan	1/140	HF-specific readmission or death	480 d (Median)	Cox proportional hazards regression
Berry et al,[88] 2005	Retrospective cohort	Medical record review (2000)	United Kingdom	1/445	All-cause readmission	814 d (Median)	Cox proportional hazards regression
Brand et al,[89] 2005	Retrospective cohort	Hospital administrative (1998)	Australia	1/902	All-cause readmission	30 d	Multivariate logistic regression
Cho et al,[90] 2005	Prospective cohort	Medical record review (2000-2003)	South Korea	1/106	HF-specific readmission or death	30 d	Cox proportional hazards regression
Hamada et al,[91] 2005	Prospective cohort	Medical record review (study period not presented)	Japan	1/52	HF-specific readmission or death	1 y	Cox proportional hazards regression
Hamner and Ellison,[92] 2005	Retrospective cohort	Hospital administrative and medical record review (2000-2002)	Southeastern United States	1/557	All-cause readmission	6 mo	Multivariate logistic regression
Klein et al,[93] 2005	RCT cohort	Collected during RCT (1997-1999)	United States	78/949	HF-specific readmission	60 d	Cox proportional hazards regression
Koitabashi et al,[94] 2005	Retrospective cohort	Medical record review (1996-2002)	Japan	1/427	HF-specific readmission or death	34 mo (Mean)	Cox proportional hazards regression
Kosiborod et al,[18] 2005	Retrospective cohort	MEDPAR file from CMS and medical record review (1998-2001)	United States	Multiple, No. not presented/ 44 441	HF-specific readmission	1 y	Multivariate logistic regression
Niizeki et al,[95] 2005	Prospective cohort	Medical record review (1996-2004)	Japan	1/90	HF-specific readmission or death	421 d (Mean)	Cox proportional hazards regression
Niizeki et al,[96] 2005	Prospective cohort	Medical record review (1996-2004)	Japan	1/186	HF-specific readmission or death	534 d (Mean)	Cox proportional hazards regression
O'Connor et al,[97] 2005	Prospective cohort	IMPACT-HF registry (2001-2002)	United States	30/567	All-cause readmission or death	60 d	Multivariate logistic regression
Perna et al,[98] 2005	Prospective cohort	Medical record review and patient self-report (1997-1999)	Argentina	1/184	HF-specific readmission	9.7 mo (Mean)	Cox proportional hazards regression
Rodríguez-Artalejo et al,[99] 2005	Prospective cohort	Hospital administrative, medical record review, and patient self-report (2000-2001)	Spain	4/433	All-cause readmission	1 y	Cox proportional hazards regression
Sheppard et al,[100] 2005	Retrospective cohort	Quebec Province hospital administrative (1998-2002)	Quebec Province, Canada	Multiple, No. not presented/ 32 639	All-cause readmission	1 y	Cox proportional hazards regression
Berry et al,[101] 2006	Retrospective cohort	Hospital administrative and medical record review (2000)	United Kingdom	1/519	HF-specific readmission or death	814 d (Median)	Cox proportional hazards regression
Danciu et al,[102] 2006	Retrospective cohort	Hospital administrative (2003)	Chicago, Illinois	1/217	All-cause readmission or death	6 mo	χ^2 Test
Dokainish et al,[103] 2006	Prospective cohort	Medical record review (study period not presented)	Houston, Texas	1/110	All-cause readmission or death	527 d (Mean)	χ^2 Test

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and the Kaiser-Permanente Health System) alone or in combination with medical record review; 15 studies used medical record review, often in combination with patient self-report; 14 studies used government administrative data (ie, Medicare Provider Analysis and Review files) alone or in combination with

Table 3. Characteristics of Identified Publications Examining the Association Between Specific Patient Characteristics and Readmission After Heart Failure (HF) Hospitalization (Third Objective of Our Systematic Review) (cont)

Source	Study Type	Data Source (Study Period)	Study Location	No. of Hospitals/No. of Patients	Study Outcome	Follow-up Period	Analytic Model
Echols et al,[104] 2006	RCT cohort	Collected during RCT (1997-1999)	United States	78/949	HF-specific readmission or death	60 d	Cox proportional hazards regression
Formiga et al,[105] 2006	Prospective cohort	Medical record review and patient self-report (2001-2002)	Spain	1/88	HF-specific readmission	30 d	χ^2 Test
Kubler et al,[106] 2006	Prospective cohort	Medical record review (study period not presented)	Poland	1/54	HF-specific readmission or death	1 y	Cox proportional hazards regression
Luthi et al,[107] 2006	Retrospective cohort	Hospital administrative and medical record review (1999)	Switzerland	2/955	All-cause readmission	30 d	Multivariate logistic regression
Luttik et al,[108] 2006	Retrospective cohort	Patient self-report (1994-1997)	the Netherlands	1/179	All-cause readmission or death	30 d	Multivariate logistic regression
Mejhert et al,[109] 2006	RCT cohort	Collected during RCT (1996-1999)	Sweden	1/208	All-cause readmission or death	1122 d (Mean)	Cox proportional hazards regression
Niizeki et al,[110] 2006	Prospective cohort	Medical record review (1996-2005)	Japan	1/247	HF-specific readmission or death	451 d (Mean)	Cox proportional hazards regression
Rathore et al,[25] 2006	Retrospective cohort	MEDPAR file from CMS and medical record review (1998-2000)	United States	Multiple, No. not presented/ 25 086	All-cause readmission	1 y	Hierarchical logistic regression
Rodríguez-Artalejo et al,[111] 2006	Prospective cohort	Hospital administrative, medical record review, and patient self-report (2000-2001)	Spain	4/433	All-cause readmission	1 y	Cox proportional hazards regression
Siswanto et al,[112] 2006	Prospective cohort	Medical record review (2005)	Indonesia	1/97	All-cause readmission or death	6 mo	Cox proportional hazards regression
Tavazzi et al,[113] 2006	Prospective cohort	Medical record review (2004)	Italy	204/1406	All-cause readmission	6 mo	χ^2 Test
Wojtkowska et al,[114] 2006	Prospective cohort	Medical record review (study period not presented)	Poland	1/120	All-cause readmission	3 y	χ^2 Test
Xue et al,[115] 2006	Prospective cohort	Medical record review (2002-2004)	China	1/128	HF-specific readmission or death	378 d (Mean)	Cox proportional hazards regression
Bettencourt et al,[116] 2007	Prospective cohort	Medical record review and patient self-report (2002-2004)	Portugal	1/224	All-cause readmission or death	6 mo	Cox proportional hazards regression
Cournot et al,[117] 2007	Prospective cohort	Medical record review (2004)	France	1/61	HF-specific readmission or death	7 mo (Median)	Cox proportional hazards regression
Darze et al,[118] 2007	Prospective cohort	Medical record review and patient self-report (2001-2003)	Brazil	1/198	All-cause readmission or death	3 mo	Multivariate logistic regression
Dokainish et al,[119] 2007	Prospective cohort	Medical record review (study period not presented)	Houston, Texas	1/100	All-cause readmission or death	527 d (Mean)	Cox proportional hazards regression
Ferreira et al,[120] 2007	Prospective cohort	Medical record review and patient self-report (2002-2004)	Portugal	1/304	All-cause readmission or death	6 mo	Cox proportional hazards regression
Filippatos et al,[121] 2007	RCT cohort	Collected during RCT (study period not presented)	United States	Multiple, No. not presented/ 319	All-cause readmission or death	60 d	Cox proportional hazards regression
Fonarow et al,[122] 2007	RCT cohort	Collected during RCT (2003-2004)	United States	256/48 612	All-cause readmission	60 d	Cox proportional hazards regression

(continued)

medical record review; and 12 studies used data collected during a randomized controlled trial.

Studies from the United States used all-cause readmission (46 studies) far more often than HF-specific readmission (11 studies) as an outcome, whereas non-US studies used all-cause readmission (29 studies) and HF-specific readmission (26 studies) almost equally as often as outcomes (Table 3). Follow-up periods ranged from 14 days to 4 years, with 1 year (23 studies), 6 months (22 studies), and 1 month (19 studies) being most common.

The studies also varied in methods for identifying and excluding patients hospitalized at baseline for HF. For identification, 52 studies used clinical presentations on admission, 29 studies used *ICD-9-CM* codes at discharge, 19 studies used admitting diagnoses, and 12 studies

Table 3. Characteristics of Identified Publications Examining the Association Between Specific Patient Characteristics and Readmission After Heart Failure (HF) Hospitalization (Third Objective of Our Systematic Review) (cont)

Source	Study Type	Data Source (Study Period)	Study Location	No. of Hospitals/No. of Patients	Study Outcome	Follow-up Period	Analytic Model
Gheorghiade et al,[123] 2007	RCT cohort	Collected during RCT (2003-2004)	United States	256/48 612	All-cause readmission	60 d	Cox proportional hazards regression
Greenberg et al,[124] 2007	RCT cohort	Collected during RCT (2003-2004)	United States	256/48 612	All-cause readmission	60 d	Cox proportional hazards regression
Howie-Esquivel and Dracup,[125] 2007	Prospective cohort	Medical record review and patient self-report (2004-2005)	Northern California	1/72	HF-specific readmission	3 mo	Cox proportional hazards regression
Koyama et al,[126] 2007	Prospective cohort	Medical record review (study period not presented)	Japan	1/141	HF-specific readmission or death	479 d (Mean)	Cox proportional hazards regression
Nishio et al,[127] 2007	Prospective cohort	Medical record review (2004-2005)	Japan	1/145	All-cause readmission or death	379 d (Mean)	Cox proportional hazards regression
Pascual-Figal et al,[128] 2007	Prospective cohort	Medical record review (2002)	Spain	1/212	HF-specific readmission	20.4 mo (Median)	Cox proportional hazards regression
Pimenta et al,[129] 2007	Prospective cohort	Medical record review (2002-2004)	Portugal	1/283	All-cause readmission or death	6 mo	Cox proportional hazards regression
Ruiz-Ruiz et al,[130] 2007	Prospective cohort	Medical record review (2000-2003)	Spain	1/111	HF-specific readmission	21 mo (Mean)	Cox proportional hazards regression
Ruiz-Ruiz et al,[131] 2007	Prospective cohort	Medical record review (2000-2003)	Spain	1/111	HF-specific readmission	21 mo (Mean)	Cox proportional hazards regression
Shah et al,[132] 2007	RCT cohort	Collected during RCT (study period not presented)	United States and Canada	Multiple, No. not presented/ 141	All-cause readmission	6 mo	Cox proportional hazards regression
Shenkman et al,[133] 2007	Prospective cohort	Hospital administrative and medical record review (2005)	Rochester, New York	1/257	All-cause readmission or death	30 d	Multivariate logistic regression

Abbreviations: CHCQ, Cleveland Health Quality Choice program; CMS, Centers for Medicare & Medicaid Services; HCFA, Health Care Financing Administration; IMPACT-HF, Initiation Management Pre-discharge Assessment of Carvedilol Heart Failure; MEDPAR, Medicare Provider Analysis and Review; RCT, Randomized Controlled Trial; SPARCS, Statewide Planning and Research Cooperative System; VA, Veteran Affairs.

used diagnosis-related group codes. Forty-four studies included patients who died during the follow-up period in their main outcome analyses (ie, death or readmission), 43 studies examined death during the follow-up period as a separate outcome, 14 studies excluded these patients from analyses, and 11 studies did not discuss their analytic plan for patients who died during follow-up. Only 29 studies (25.9%) discussed their analytic plan for patients who were transferred during their baseline hospitalization; 19 studies excluded these patients from analyses, 9 studies "assigned" the hospitalization to the transferring (index) hospital, and 1 study assigned the hospitalization to the receiving hospital.

Many studies were explicitly designed to examine the association between readmission and a specific patient-level characteristic such as sex (n=6), race/ethnicity (n=8), socioeconomic status (n=2), systolic ejection fraction (n=10), duration of index hospital admission (n=3), medical history of renal disease (n=3) or anemia (n=4), and serum markers, including hematocrit and levels of sodium, creatinine, C-reactive protein, serum urea nitrogen, cardiac troponin T, and B-type natriuretic peptide, while adjusting for multiple other variables. However, approximately one-third of studies reported the significance test only for the primary independent variable of interest and not for other covariates included in their analyses.

There was some consistency across studies as to which variables were included in the multivariate analyses examining the association between readmission and a specific patient-level characteristic. Among sociodemographic variables, age (81.3% of studies) and sex (71.4%) were most frequently included in analyses (**Table 4**), although none were consistently associated with readmission. Among comorbid conditions, diabetes mellitus (46.4%) and hypertension (41.1%) were most frequently included in analyses, although again none were consistently associated with readmission. Among HF severity variables, systolic ejection fraction (56.3%) and New York Heart Association class (34.8%) were frequently included in analyses, although neither was consistently associated with readmission. Finally, among serum markers, creatinine or serum urea nitrogen level (44.6%), sodium level (25.0%), and B-type natriuretic peptide level (21.4%) were frequently included in analyses, although only elevated B-type natriuretic peptide was consistently associated with readmission (77.3%).

Table 4. Sociodemographic Variables, Comorbid Conditions, Markers of Heart Failure (HF) Severity, and Serum Markers Included in Identified Publications Examining the Association Between Specific Patient Characteristics and Readmission After HF Hospitalization (Third Objective of Our Systematic Review)

	No. (%)		
Candidate Variable	Studies Examining the Candidate Variable	Studies Reporting a Statistical Association Between the Candidate Variable and Readmission[a]	Studies for Which the Statistical Association Between the Candidate Variable and Readmission Was Significant
Sociodemographic Variables			
Age	91 (81.3)	60 (65.9)	11 (18.3)[b]
Sex	80 (71.4)	55 (68.8)	9 (16.4)[c]
Race/ethnicity	39 (34.8)	23 (59.0)	6 (26.1)[d]
Living status	13 (11.6)	9 (69.2)	3 (33.3)[e]
Married	8 (7.1)	7 (87.5)	0
Insurance	7 (6.3)	4 (57.1)	2 (50.0)
Education	6 (5.4)	5 (83.3)	0
Income	5 (4.5)	4 (80.0)	1 (25.0)
Comorbid Conditions			
Diabetes mellitus	52 (46.4)	37 (71.2)	6 (16.2)
Hypertension	46 (41.1)	32 (69.6)	4 (12.5)
Coronary artery disease	38 (33.9)	23 (60.5)	1 (4.3)
HF	30 (26.8)	18 (60.0)	7 (38.9)
Atrial fibrillation or flutter	30 (26.8)	18 (60.0)	3 (16.7)
Chronic obstructive pulmonary disease	28 (25.0)	17 (60.7)	5 (29.4)
Myocardial infarction	25 (22.3)	16 (64.0)	2 (12.5)
Renal disease	16 (14.3)	12 (75.0)	4 (33.3)
Cerebrovascular disease or stroke	16 (14.3)	9 (56.3)	4 (44.4)
Previous coronary artery bypass graft surgery	16 (14.4)	10 (62.5)	2 (20.0)
Previous percutaneous transluminal coronary angioplasty	11 (9.8)	8 (72.7)	3 (37.5)
Markers of HF Severity			
Left ventricular ejection fraction	63 (56.3)	55 (87.3)	9 (16.4)
New York Heart Association class	39 (34.8)	34 (87.2)	6 (17.6)
Serum Markers			
Blood urea nitrogen or creatinine	50 (44.6)	33 (66.0)	13 (39.4)
Sodium	28 (25.0)	20 (71.4)	7 (35.0)
B-type natriuretic peptide	24 (21.4)	22 (91.7)	17 (77.3)
Hematocrit or hemoglobin	21 (18.8)	17 (80.9)	6 (35.3)
Troponin	7 (6.3)	6 (85.7)	6 (100.0)

[a] Reporting the statistical association includes reporting the *P* value from the test of the association between the candidate variable and readmission, reporting the effect size with 95% confidence interval, or reporting that the candidate variable was not significantly associated with readmission.
[b] Older age was significantly associated with readmission in 9 studies; younger age, in 2 studies.
[c] Male sex was significantly associated with readmission in 8 studies; female sex, in 1 study.
[d] Nonwhite race/ethnicity was significantly associated with readmission in 5 studies; white race/ethnicity, in 1 study.
[e] Living alone was significantly associated with readmission in 2 studies; living with family, in 1 study.

COMMENT

Our systematic review reveals several important considerations for efforts to compare hospital-specific rates of readmission after HF hospitalization and to stratify patient risk of readmission. Among 117 studies[20,23,27-29] included in our review, we did not identify a model designed to compare readmission rates, the first objective of our systematic review. Five studies developed models to predict patient risk of readmission, the second objective of our systematic review, but none found that patient characteristics strongly predict readmission. In fact, the 117 studies examined a large number of diverse patient characteristics to determine the associated readmission risk, and no consistent predictors emerged from our review, although not all studies reported the prognostic importance of all candidate variables. In addition, there was considerable methodological heterogeneity among research examining HF readmission risk. Studies varied in analytic approach, outcome examined, follow-up period, case identification, and handling of patient deaths and transfers, demonstrating that there is little consensus on approaches to compare institutions or to stratify risk for individual patients and making the literature difficult to synthesize. Nevertheless, it is clear that the risk of readmission is high after HF hospitalization among studies with shorter and longer follow-up periods, reinforcing the importance of focusing on HF readmissions to improve quality and efficiency in health care.

The 5 studies[20,23,27-29] we identified that developed models to predict patient risk of readmission demonstrate the challenge of stratifying patient risk based on clinical and demographic characteristics. Collectively, these models considered a large number of patient characteristics, yet few were consistently associated with risk of readmission across studies. Given the differing methodological approaches used, perhaps these inconsistencies are not surprising. Among 2 statistical models that specifically examined risk of readmission (as opposed to the combined outcome of readmission or death),[23,29] patient characteristics provide only modest information about readmission risk, with discriminations (as measured by C statistic) of 0.60. In contrast, statistical models used to predict mortality after HF hospitalization demonstrate better discrimination,[134-137] with C-statistic discriminations ranging from 0.67 to 0.81.

The discrimination differences between the readmission and mortality models may be a reflection of the challenges in predicting patient risk of readmission based on clinical and demographic characteristics. Each readmission model included many variables that are also found in the mortality models, which have higher predictive ability, suggesting that the lower discrimination of the readmission models is unlikely to be because a critical patient characteristic was omitted. A possible explanation is that other nonpatient factors may have a larger role in readmission risk, although this was not the focus of our systematic review. For instance, readmission risk may be more responsive to improved hospital[6,7] and postdischarge[8-17] care than mortality risk, and it may depend more on health care system characteristics such as acute care hospital capacity or physician supply.[138]

There are some key differences between models that we identified to stratify patient risk of readmission and models that might be used to profile hospitals. First, all of the patient risk models relied on clinical information (eg, admission physical examination findings) and laboratory test results, whereas profiling models would likely need to use administrative data, particularly for national comparisons. Second, most patient risk models accounted for patient characteristics that may be inappropriate for profiling models such as length of stay, discharge disposition, inhospital events and complications, and patient income, education, and race/ethnicity.[139] Accounting for such characteristics could inappropriately risk-standardize hospital performance for the differences in quality and efficiency that profiling efforts attempt to measure, including inhospital complications, excessively long or short lengths of stay, and premature discharges to skilled nursing facilities rather than to home. Third, patient risk models would be expected to include patient characteristics present on discharge (including comorbidities and complications) for optimal risk stratification, whereas profiling models should only consider patient characteristics present on admission so that hospitalization complications are not used to adjust risk. Fourth, none of the patient risk models accounted for the clustering of patients within hospitals, whereas profiling models should account for the nonindependence of readmissions to each hospital.

The Medicare Payment Advisory Commission recently recommended that Medicare should publicly report short-term readmission rates and use these rates to adjust payments for HF and other conditions, including pneumonia, acute myocardial infarction, coronary artery bypass graft surgery, and chronic obstructive pulmonary disease, emphasizing that Medicare's hospital payment system provides no explicit encouragement or reward for hospitals that reduce readmissions, although readmissions may be indicative of poor care or missed opportunities to better coordinate care.[3] Despite a large literature examining HF readmissions, our review demonstrates that the evidence to support such an HF measure is insufficient. Further research focused on deriving and validating a risk-standardized statistical model that accounts for important patient characteristics associated with readmission and for clustering of patients within hospitals is critical if hospitals are to be profiled on readmission rates.

Despite growing interest among physicians and policy makers in hospital readmissions as an indicator of quality and efficiency of care,[1-3] our systematic review highlights several methodological issues that need to be resolved before hospitals are compared and profiled based on readmission rates after HF hospitalization. No such hospital-level comparative measure yet exists (to our knowledge), and the collection of evidence that we identified to inform profiling efforts found inconsistent results, varied in the inclusion of patient characteristics for risk standardization, and used heterogeneous approaches to case identification, outcomes, and follow-up periods. Readmissions after HF admission are common, and from a clinical perspective it seems difficult to stratify patient risk. From a policy perspective, a validated risk-standardized statistical model that accounts for important patient characteristics associated with readmission is necessary if hospitals are to be profiled on their readmission rates, with the caveat that patient characteristics are likely to account for only a small amount of the variation among hospitals.

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