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Patient Characteristics Predicting Readmission Among Individuals Hospitalized for Heart Failure

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Abstract

Heart failure is difficult to manage and increasingly common with many individuals experiencing frequent hospitalizations. Little is known about patient factors consistently associated with hospital readmission. A literature review was conducted to identify heart failure patient characteristics, measured before discharge, that contribute to variation in hospital readmission rates. Database searches yielded 950 potential articles, of which 34 studies met inclusion criteria. Patient characteristics generally have a very modest effect on all-cause or heart failure-related readmission within 7 to 180 days of index hospital discharge. A range of cardiac diseases and other comorbidities only minimally increase readmission rates. No single patient characteristic stands out as a key contributor across multiple studies underscoring the challenge of developing successful interventions to reduce readmissions. Interventions may need to be general in design with the specific intervention depending on each patient's unique clinical profile.

Keywords

heart failure; readmission; rehospitalization; patient characteristics

Introduction

Heart failure (HF) is difficult for patients, caregivers, and their clinicians to manage and increasingly common in our aging population. It is estimated that 5.7 million Americans aged 20 years or older suffer from HF with a 46% increase expected by 2030 (Mozaffarian et al., 2015). Unlike other cardiovascular conditions, HF is the end stage of a cardiac disease. It most often is the consequence of hypertension, coronary heart disease, valve deformity, diabetes, or cardiomyopathy. Hospital discharges with a primary diagnosis of HF

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rose from 877,000 in 1996 to 1,023,000 in 2010 (Mozaffarian et al., 2015). One in nine deaths has HF referenced on the death certificate and approximately 50% of those diagnosed with HF will die within 5 years (Mozaffarian et al., 2015). The estimated total cost of HF in the United States exceeded \$30 billion in 2012 and is projected to \$70 billion by 2030 (Mozaffarian et al., 2015).

Reducing HF patient readmission rates is a national priority. Currently, roughly 25% of HF patients are readmitted to a hospital within 30 days of discharge (Krumholz et al., 2009). To address the high readmission rate among Medicare beneficiaries, the Centers for Medicare and Medicaid Services (CMS) implemented the Hospital Readmissions Reduction Program on October 1, 2012. Among other policies, it reduces payment to hospitals with excess Medicare beneficiary 30-day readmissions for HF (Medicare Payment and Advisory Commission, 2013). Private efforts to reduce high readmission rates also are underway including the American College of Cardiology and Quality Improvement for Institutions “Hospital to Home (H2H)” project. One of its aims—through dissemination of best practices, tools and other strategies—is to reduce all-cause readmission rates for HF patients by 20% (Hospital to Home, 2013).

The Agency for Healthcare Research and Quality recently published a comprehensive review of interventions designed to reduce 30-day readmission and mortality rates for patients hospitalized with HF. Home-visiting programs and multidisciplinary HF clinics reduced all-cause readmission while “structured” telephone support reduced HF-specific readmission (Feltner et al., 2014a, 2014b). A critical remaining issue, however, concerns what works best for different types of patients. The Affordable Care Act provided substantial funding for patient centered outcomes research to generate better evidence on differences among individuals in their response to medical care (Patient-Centered Outcomes Research Institute, 2014). Such research, however, is in its infancy with basic information still needed on variation in HF patient rate of readmission to inform the development of the next generation of more targeted and efficient patient-centered interventions.

New Contribution

The objective of this literature review is to identify HF patient characteristics contributing to variation in hospital readmission rates. We focus on (1) patient characteristics measured prior to hospital discharge that can be used to inform clinical decisions about postacute care, (2) readmission as a distinct outcome since patient characteristics affecting mortality (or other outcomes combined with readmission) may differ, and (3) studies with a relatively short time horizon for readmission (i.e., a maximum of 6 months) since the impact of many baseline patient characteristics is likely to attenuate over time. We exclude intervention studies because they introduce new care practices that could alter the effect of patient characteristics on readmission, often provide only limited information about patient characteristics included in models of intervention effects, and have been recently and comprehensively reviewed. The research questions addressed are

1. What individual characteristics are consistently associated with higher or lower rates of readmission?

2. What do the findings suggest for targeting interventions to different types of patients?
3. What are the major gaps in knowledge about patient characteristics affecting readmission?

Conceptual Framework

The conceptual framework for our analyses is based on the behavioral model of health services use developed by Andersen and colleagues which is now ubiquitous in health services research (Andersen, 2008; Andersen & Davidson, 2007; Andersen & Newman, 1973). Contextual and individual characteristics as well as health behaviors are assumed to affect multiple dimensions of care access in this common framework for modeling the use of acute, postacute, and long-term care. *Contextual factors* include demographic and social characteristics at the community level that may predispose individuals to use health services; health policies, financing and organizational characteristics (including supply of services and provider characteristics) that can enable use; and need characteristics such as community health indicators of disease prevalence and mortality rates. *Individual factors* also include predisposing (e.g., gender, age, health beliefs), enabling (e.g., income level, means of transportation, regular source of care), and need characteristics (perceived and evaluated). There are three types of *health behaviors*: personal health practices (e.g., diet, use of tobacco), medical care processes, and use of health services. In a relatively recent update of the model, health status outcomes were added to indicate that care outcomes can influence, through feedback loops, contextual and individual factors in addition to health behavior (Andersen, 2008).

Our review concerns what Andersen and colleagues refer to as “realized access” (i.e., the actual use of health services). They hypothesize that the influence of predisposing, enabling, and need factors will vary by type of health service used with hospital stays primarily explained by need and demographic characteristics (Anderson & Davidson, 2007). These two types of characteristics are contextual and individual factors in the Andersen framework depending on level of aggregation. Empirical analyses, however, support a focus on individual characteristics. Madigan et al. (2012), for example, examined the association of a range of individual, community, and provider-level measures on the readmission of HF patients and concluded that practice and policy interventions to reduce readmissions should focus on patient characteristics since they were almost exclusively the contributors to readmissions. We focus, therefore, on the individual determinants in the Andersen framework (i.e., predisposing, enabling, and need factors) as well as personal health practices measured at the individual level.

Method

Data Sources and Searches

The PubMed, CINAHL, and Cochrane databases were searched for relevant English-language studies published between January 1992 and September 2014. The search strategy consisted of medical subject health (MeSH) terms related to heart failure, patient readmission, and hospitalization. We used either the MeSH terms or the following

equivalent terms to search each of the three databases: ([“Heart Failure” OR “Cardiac Failure” OR “Congestive Heart Failure” OR “Heart Decompensation” OR “Heart Failure, Congestive” OR “Heart Failure, Left-Sided” OR “Heart Failure, Right Sided” OR “Left-Sided Heart Failure” OR “Myocardial Failure” OR “Right-Sided Heart Failure”] AND [“Patient Readmission” OR “Hospital Readmission” OR “Hospital Readmissions” OR “Readmission, Hospital” OR “Readmissions, Hospital”] AND [“Hospitalization”]). This process yielded 950 potentially relevant articles.

Study Selection

The systematic search of the literature identified a total of 950 abstracts. Each was reviewed by one of nine reviewers (MO, CM, SS, YB, KB, TP, CZ, PF, CT) to determine whether the study satisfied four initial criteria: (1) written in English; (2) published after January 1, 1992; (3) reported the frequency of hospital readmission within a defined follow-up period for adults hospitalized for HF; and (4) identified statistically significant patient risk factors for readmission measured prior to index hospital stay discharge. A total of 610 studies did not meet all four criteria and 145 required full-article review due to incomplete abstract information. We elected to retain articles on HF patients treated in countries other than the United States since the patient-level factors of interest should have a consistent positive or negative effect on readmission regardless of setting. That said, differences in financing, cultural circumstances, and access to health care may affect the rate of readmission and magnitude of the effect of patient characteristics on readmission.

Screening

We excluded studies examining only postacute mortality or a combined outcome of readmission and mortality. (The latter often were identified only after full-article review.) Studies that had a primary combined outcome were included if they also examined hospital readmission as a distinct outcome. Eligibility for inclusion was further narrowed to studies that reported outcomes within 6 months of the index hospital discharge since the value of many patient characteristics can change over time limiting inferences about their effect on readmission when there is a long follow-up period. All full-length articles (145) were reviewed by two reviewers to determine final eligibility for inclusion in our literature review. Of the 145 full-article reviews, 111 were excluded for the following reasons: a combined outcome (17), follow-up longer than 6 months (63), or no patient-level predictors measured before hospital discharge were reported (31). Four reviewers (MO, CM, SS, and YB) discussed a small number of articles where eligibility was still uncertain and arrived at consensus (Figure 1).

Results

Only 34 studies met all eligibility criteria and are included in the table of evidence. We abstracted data on key study characteristics including study design (retrospective or prospective), sample characteristics, length of follow-up after index hospital stay discharge, types of readmissions analyzed, statistical methods, and findings. Sample and methods information were used to classify studies into three broad statistical analysis quality groups: (1) low (studies reporting only bivariate associations); (2) medium (studies using

multivariate methods but the sample size is <100, which limits the number of patient characteristics that can be examined simultaneously, or multifacility studies that do not report adjusting for clustering); and (3) high (studies with 100+ sample size using multivariate methods with multifacility studies adjusting for clustering).

Of the 34 articles reviewed, 29 were retrospective and 5 were prospective with 27 studies conducted in the United States. Other countries included Canada (Eastwood et al., 2014; Habal et al., 2014; Lee et al., 2004), France (Logeart et al., 2004), South Korea (Song, Lennie, & Moser, 2009), Switzerland (Kossovsky et al., 2000), and Thailand (Jenghua & Jedsadayamata, 2011).

Overall, the majority of studies (20) analyzed data from multiple facilities. Care occurred between 1989 (Roe-Prior, 2004) and 2012 (Eastwood et al., 2014) with one study not reporting the study time period (Logeart et al., 2004). The sources of data included: hospital records (18), hospital records in addition to a follow-up phone interview with the patient or mailed survey (3), CMS-owned data (8), Healthcare Cost and Utilization Project data (1), Veteran's Affairs (VA) data (2), and Canadian Institute for Health Information data (1). In addition, one study separately examined CMS-owned data and hospital record data and then compared the results (Keenan et al., 2008).

While the populations studied included patients initially hospitalized for HF, many studies narrowed the population further by, for example, excluding those below a minimum age (e.g., 65 years) or who died during the follow-up period. Sample sizes varied greatly among studies ranging from 44 (Howie-Esquivel & Dracup, 2008) to 1,346,768 subjects (Joynt, Orav, & Jha, 2011), with 44% of the studies having less than 1,000 subjects. Mean age among study subjects also varied widely from a low of 55 years (Allen, Smoyer-Tomic, Smith, Wilson, & Agodoa, 2012; Kollipara et al., 2008) to a high of 81 years (Joynt et al., 2011). In general, the mean age of patients in retrospective studies was older than in prospective studies reflecting differences in populations studied (e.g., Medicare beneficiaries vs. all HF patients admitted to a facility) and exclusion criteria. Most studies (22) were classified into the high-quality statistical analysis group while 7 were classified as medium quality and 5 low quality (Table 1).

Readmission Rate

The length of follow-up and types of readmissions analyzed varied across studies. The length of follow-up was approximately 30 days in 21 studies, 90 days in five studies, and 180 days in five studies. Two studies measured readmission at both 30 and 90 days (Lee et al., 2004; Uthamalingam, Gurm, Daley, Flynn, & Capodilupo, 2011) and another study measured readmission at both 7 and 30 days (Eastwood et al., 2014). The most common outcome measure was 30-day all-cause hospital readmission (see Table 2 for readmission rate findings).

Patient Characteristics Associated With Hospital Readmission

The results are organized by the broad types of individual risk factors identified in the conceptual framework including predisposing, enabling, and need factors as well as health behaviors. With the exception of sociodemographic factors, the direction of the effect of

each type of patient characteristic on readmission tends to be very consistent (Table 3). Mixed results are noted in the text.

Individual Predisposing Factors: Sociodemographics and Health Beliefs—

There is inconsistency in the direction of the effect of gender on readmission although all but one high-quality study found men more likely to be readmitted than women where gender was statistically significant ($p < .05$). Age also had an inconsistent effect on readmission even among high-quality studies. This appears to be partly due to differences in the average age and age range of persons studied as well as to whether age was analyzed as a continuous or categorical variable. Very large effects only were reported in a Swiss study where HF patients aged 65 to 79 years and 80+ were much more likely to be readmitted than those younger than 65 years with adjusted odds ratios of 3.3 and 4.1, respectively, for 31-day all-cause readmission (Kossovsky et al., 2000).

Readmission is higher among Blacks (Joynt et al., 2011; McHugh, Brooks Carthon, & Kang, 2010), non-Whites as a group (Howie-Esquivel & Dracup, 2007), and Hispanics (Rodriguez, Joynt, Lopez, Saldana, & Jha, 2011), relative to others, but effect sizes are very small in the high-quality studies (i.e., close to 1.0). Few statistically significant social network factors are reported although single patients and those with an increased number of address changes had higher risks of readmission—adjusted odds ratios of 1.5 and 1.1, respectively—in one high-quality study (Amarasingham et al., 2010). In a low-quality study, living with family was positively associated with readmission (Hamner & Ellison, 2005).

Health beliefs including knowledge of health and health services appear to be little studied. Low knowledge concerning dietary sodium substantially increased the risk of 90-day HF readmission in one medium-quality study (Kollipara et al., 2008) with an effect size of 5.0 although the confidence interval is very large (1.3, 19.0). In a separate high-quality study, low acculturation to U.S. society increased the risk of 30-day all-cause readmission (Peterson et al., 2012) with an adjusted odds ratio of 1.7.

Individual Enabling Factors: Financing and Organization—Individual enabling factors also appear to be understudied with no article reporting statistically significant findings for enabling “organization” factors in the Andersen framework (e.g., whether the person has a usual source of care or transportation to medical services, travel time to services). Income is reported in only one study where VA system patients with a low income were more likely than others to be readmitted (Muus et al., 2010). Health insurance (i.e., Medicare or Medicaid) increased the risk of readmission in three studies (Amarasingham et al., 2010; Coffey et al., 2012; Hamner & Ellison, 2005). Medicare and Medicaid insurance also are partial indicators of older patient age and limited financial assets, respectively.

Individual Need Factors: Prior Health Care Utilization and Index Stay

Characteristics—The number of recent hospital admissions before the index stay consistently increased the risk of readmission after the index-stay regardless of the length of follow-up (Amarasingham et al., 2010; Harjai, Thompson, Turgut, & Shah, 2001; Krumholz et al., 1997; Krumholz et al., 2000; Hummel, Katrapati, Gillespie, DeFranco, & Koelling, 2014). The largest effects were reported in one high-quality study of Michigan Medicare

beneficiaries (Hummel et al., 2014). The risk of 30-day all-cause readmission was much higher, relative to that of individuals with no recent prior admission, for persons with 1 prior admission (adjusted odds ratio of 4.7) or 2+ prior admissions (adjusted odds ratio of 6.5). In addition, patients admitted via the emergency room (Amarasingham et al., 2010; Hamner & Ellison, 2005) or who were transferred to the index hospital (Eastwood et al., 2014) had higher readmission rates with adjusted odds ratios ranging from 1.2 to 1.4.

The length of the index hospital stay increased the risk of readmission in most studies (Allen et al., 2012; Hockenberry, Burgess, Glasgow, Vaughan-Sarrazin, & Kaboli, 2013; Howie-Esquivel & Dracup, 2008; Jenghua & Jedsadayamata, 2011; Krumholz et al., 1997; Muus et al., 2010) with effect sizes, with rounding, ranging from 1.0 to 1.4. The one exception is a medium-quality study where a length of stay more than 30 days reduced the risk of 7-day readmission with an adjusted odds ratio of 0.7 (Eastwood et al., 2014).

Individual Need Factors: Comorbidities and Other Clinical Factors—A diagnosis of HF prior to the index stay consistently increased the risk of readmission with effect sizes of 1.3 or less in three studies (Keenan et al., 2008; Krumholz et al., 2000; Lindenauer et al., 2013) but greater than 2.0 in two others (Hummel et al., 2014; Kossovsky et al., 2000). More severe HF also increased the risk of readmission (Armola & Topp, 2001; Coffey et al., 2012; Logeart et al., 2004) with effect sizes greater than 2.0 for patients with a “low” left ventricular ejection fraction relative to others (Harjai et al., 1999). The effect of prior cardiac procedures was inconsistent with two studies reporting a reduced risk of readmission among those with a prior coronary artery bypass graft (Keenan et al., 2008; Lindenauer et al., 2013) while another high-quality study reported an increase in readmission risk for those with a history of myocardial revascularization (Kossovsky et al., 2000). Cardiac “events” during the index stay (e.g., cardiorespiratory failure and shock) slightly increased the risk of readmission in two studies with effect sizes of 1.1 (Keenan et al., 2008; Lindenauer et al., 2013) while cardiac arrest markedly increased the risk of readmission in a third study although the confidence interval around the adjusted odds ratio of 6.7 is very large (1.3, 34.7; Hummel et al., 2014).

A large number of other cardiac diagnoses and disorders including hypertension, valvular and coronary artery disease, and cardiac arrhythmias were examined in numerous studies and had a consistently positive, although modest, effect on readmission with adjusted odds ratios ranging from 1.1 to 1.3. The same is the case for measures of vascular disease and a diagnosis of diabetes. The one exception is a medium-quality study where cerebrovascular disease was associated with a lower rate of readmission with effect sizes of 0.7 and 0.6 depending on the outcome measure (Eastwood et al., 2014).

Kidney disease that compromises renal function is common among HF patients and is associated with higher readmission rates in a large number of studies with effect sizes ranging, with rounding, from 1.0 to 1.7. Lung disease also is relatively common among HF patients. Higher rates of readmission were reported among those with chronic obstructive pulmonary disease (Harjai et al., 2001; Hockenberry et al., 2013; Keenan et al., 2008; Lindenauer et al., 2013), asthma and pneumonia (Keenan et al., 2008; Lindenauer et al., 2013), pulmonary disease in general (Eastwood et al., 2014; Howie-Esquivel & Dracup,

2007), pulmonary hypertension (Hamner & Ellison, 2005), and fibrosis of the lung (Lindenauer et al., 2013). Most effect sizes were small, no more 1.2, although Harjai et al. (2001) reported effect sizes of 1.9 and 2.2 for chronic obstructive pulmonary disease. The one exception to the very consistent finding that lung diseases raise readmission risk is from a high-quality study where pulmonary disease in general has a small negative effect on readmission (Hockenberry et al., 2013).

Other infrequently reported conditions that consistently increased the risk of readmission, although in most cases with effect sizes no greater than 1.4, include liver and biliary disease, hematologic disorders, low sodium, fluid and electrolyte disorder, protein-calorie malnutrition, hypothyroidism, cancer, urinary track disorders, skin ulcer, gastrointestinal disorder, peptic ulcer, depression, dementia, psychoses and major psychiatric disorders, and other psychiatric disorders. Index stay delirium had a very large effect on 30- and 90-day all-cause readmission rates with adjusted odds ratios of 4.2 and 3.7, respectively, in a high-quality study conducted in a single facility in New Hampshire (Uthamalingam et al., 2011).

The results for paralysis diagnoses are conflicting. Two high-quality studies reported a decrease in readmission rate with an adjusted odds ratio of 0.8 in a study by Coffey et al. (2012) and a 15% reduction based on a linear probability model estimated by Hockenberry et al. (2013). Two other high-quality studies found that paralysis diagnoses very slightly increased the rate of readmission with rounded effect sizes of 1.0 (Keenan et al., 2008; Lindenauer et al., 2013). Readmission rates were lower for persons with rheumatoid arthritis (Coffey et al., 2012) as well as obesity (Coffey et al., 2012; Hockenberry et al., 2013). Four low- to medium-quality studies examined different measures of disease burden. All found that greater burden increased the rate of readmission (Allen et al., 2012; Howie-Esquivel & Dracup, 2007; Krumholz et al., 1997; Roe-Prior, 2004).

Individual Need Factors: Health Behavior—A history of refusing health services, nonadherence, or missed appointments increased the risk of readmission (Watson et al., 2011). Those discharged against medical advice also had a higher risk of readmission in one high-quality study with an adjusted odds ratio of 1.9 (Coffey et al., 2012) and a sharply higher risk in a medium-quality Canadian study with adjusted odds ratios ranging from 3.1 to 4.6 depending on the outcome (Eastwood et al., 2014). A history of cocaine use (Amarasingham et al., 2010) and other drug (Coffey et al., 2012; Mansi, Shi, Altenburg, Mukoosa, & Huang, 2011) and alcohol abuse (Keenan et al., 2008; Lindenauer et al., 2013) also increased readmission rates.

Discussion

Our review of the literature indicates that measures of a patient's need for medical care are widely studied and generally have a consistently positive but relatively small effect on the rate of hospital readmission within 7 to 180 days of index hospital stay discharge. The need measures include a wide range of cardiac disease indicators as well as common HF comorbidities such as diabetes, and kidney and lung disease. The modest effect of these factors, which dominate the explanatory variables included in most statistical models of hospital readmission, is consistent with the relatively weak ability of existing models to

predict readmission (Giamouzis et al., 2011). This is the case regardless of data source with a cleverly designed study comparing HF patient read-mission rates estimated using a national sample of hospital clinical records with those estimated using Medicare claims data concluding that the agreement of the models suggests that Medicare claims-based models are surrogates for medical record models (Keenan et al., 2008). The limits of existing readmission models have important policy implications for their use in public payment systems and suggest that there should be more focus on explanatory factors outside this domain.

Among predisposing factors, demographics are not as consistent in their effect on readmission as need indicators. In particular, studies differ in the effect of patient age on readmission which may be due in part to the exclusion of younger patients in many studies as well as to whether age was analyzed as a continuous or categorical variable. Predisposing factors other than demographics as well as enabling factors are infrequently reported and appear to be understudied. In addition, only a few types of health behaviors are reported but are consistent in their effect with negative behaviors increasing the risk of readmission.

Our review does suggest several possible need measures that should be considered when developing patient-specific interventions. The number of recent prior hospital admissions and a prior diagnosis of HF both raise the probability of readmission. Very large effects are reported for prior admissions in a study of Michigan Medicare beneficiaries (Hummel et al., 2014) and for prior HF diagnosis in a Swiss study (Kossovsky et al., 2000). Whether they are related (i.e., patients with frequent hospitalizations are being repeatedly admitted for management of decompensated HF) and are capturing otherwise unmeasured disease severity is uncertain but a focus on these factors appears warranted.

Other need characteristics deserving more analysis include delirium, functional limitations, and B-type natriuretic peptide (BNP). Delirium was found to have a relatively large effect on 30- and 90-day all-cause readmission in a recent high-quality study (Uthamalingam et al., 2011). Results were conflicting for measures of functional limitation (defined as hemiplegia, paraplegia, paralysis, functional disability) based on hospital diagnosis codes. Two studies report a negative effect on readmission (Coffey et al., 2012; Hockenberry et al., 2013) and two report a positive effect (Keenan et al., 2008; Lindenauer et al., 2013). Diagnosis-based indicators, however, are likely to significantly underreport limitations in physical functioning which typically are strong predictors of health care use and mortality (Alecxi, Shen, Chan, Taylor, & Drabek, 2010; Saliba et al., 2001). In addition, a biomarker of HF severity (BNP) shows promise in identifying patients at risk for readmission (Logeart et al., 2004). This is an area of active research and a recent Agency for Healthcare Research and Quality-sponsored review found that BNP was associated with an increased risk of morbidity and mortality among patients with decompensated or chronic stable HF (Balion et al., 2013).

Our literature review also suggests that health behaviors should be considered when developing patient-specific interventions. Patients discharged against medical advice were at markedly elevated risk of 7-day and 30-day readmission in one medium-quality study (Eastwood et al., 2014), and a moderately elevated risk of 30-day HF readmission in a

national, high-quality study (Coffey et al., 2012). Indicators of health behavior prior to the index hospital stay (e.g., refusing health services, missed appointments, drug abuse) also raised the probability of readmission (Amarasingham et al., 2010; Coffey et al., 2012; Keenan et al., 2008; Lindenauer et al., 2013; Mansi et al., 2011; Watson et al., 2011).

The major gap in knowledge about HF patient readmission risk factors is primarily the lack of information about several types of risk factors rather than discrepancies in their effect across studies. Predisposing factors in our conceptual framework include the patient's social network as well as health beliefs (e.g., attitudes and knowledge about health and health services). Little appears to be known about the effect of these factors on the readmission of HF patients although one medium-quality study found that low knowledge about dietary sodium markedly increased the risk of readmission (Kollipara et al., 2008). Enabling factors in the conceptual framework include health insurance and financial resources as well as individual "organizational" factors such as a regular source of care and a means of transportation to medical care. Enabling factors, in general, appear to be understudied with no article reporting the effect of individual organizational factors. Health behaviors also appear to be potentially important determinants of readmission which have been little studied.

Our review focused on patient factors measured before hospital discharge that are statistically significant predictors of readmission. It is possible that some of the "understudied" factors we identify are frequently studied but fail to achieve significance in models of readmission. The extent of this type of bias is likely to be small, however, since the great majority of studies rely on hospital records or national administrative data (e.g., Medicare files) as their data source. These sources are very unlikely to include standardized measures of the risk factors we identify as understudied (e.g., social networks, health beliefs, individual measures of organization factors, health behaviors). In addition, the large sample size of many of the retrospective studies results in even relatively trivial effect sizes achieving statistical significance. This suggests that few variables that are available in the data sources typically used will be omitted because they are not statistically significant. Our decision to focus solely on statistically significant results, therefore, should introduce little bias in terms of the types of factors deserving more attention in future studies.

In conclusion, our findings underscore the challenge of developing more efficient readmission reduction interventions targeted to specific types of HF patients. The published literature to date primarily focuses on patient need factors with no characteristic assessed prior to index stay discharge standing out as a key contributor to readmission across multiple studies. Perhaps not surprisingly, current successful interventions are "general" in design and may be modified on an ad hoc basis depending on each patient's unique clinical profile (Feltner et al., 2014a, 2014b). The vision of patient-centered care, however, calls for evidence that allows patients and their clinicians to prospectively select the most appropriate and effective intervention given the patient's contextual and clinical factors. Advances in this area hold out the promise of both improving the lives of individuals with HF and restraining growth in health expenditures as the number of HF patients increases over the coming decades.

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Figure 1.
Flow diagram for search and selection processes.

Table 1

Study Description by Type of Design.

Citation	Location	Time period	Single facility study (yes/no)	Main data source	Identification of sample	Exclusions	Quality of statistical analysis ^a	Sample size	Mean age ± SD (and/or range)
<i>Retrospective studies</i>									
Allen, Smoyer-Tomic, Smith, Wilson, and Agodoa (2012)	United States	2005-2008	No	MarketScan Commercial and Medicaid Administrative Claims databases	Hospitalized patients with a discharge diagnosis of HF or systolic HF	Patients with heart transplants, or who were dual eligibles	Medium stepwise LR	4,548	55 ± 9
Amarasingham et al. (2010)	Texas	2007-2008	Yes	Hospital records	Hospitalized patients with a discharge diagnosis of HF	Patients with readmission within 30 days of a prior hospitalization; who died during the postdischarge period without readmission	High LR	1,341	57
Amin, Detelzweig, Friend, Lin, and Lowe (2013)	600 U.S. hospitals	2007-2010	No	Premier Hospital database	Hospitalized patients with a discharge diagnosis of HF	Patients transferred from another acute care facility, left against medical advice, labor and delivery patients classified as observational and patients with no cost information	Medium LR with matching of observations	51,710	75 ± 14
Armola and Topp (2001)	Midwestern United States	1997-1998	Yes	Hospital records	Patients admitted for HF (DRG 127)	Patients who were transferred to another acute care facility	Low bivariate descriptives	179	70 ^b
Coffey et al. (2012)	14 States participating in Healthcare Cost and Utilization Project	2006	No	State Inpatient Databases provided to Agency for Healthcare Research and Quality	Patients admitted with a diagnosis of HF 18 years and older	Index stay involving heart transplant procedure, a transfer in or out of the hospital, or a surgical treatment	High multilevel hierarchical LR adjusting for clustering at hospital level	Not reported	Not reported
Eapen et al. (2014)	North Carolina	2001-2006	No	Clinical registry data linked to Medicare claims	Patients admitted with a diagnosis of HF	Patients discharged to a place other than home	High Cox hazard models with robust SEs to account for clustering	66,357	79 ± 8 ^b
Eastwood et al. (2014)	Canada	2004-2012	No	Hospital records	Patients hospitalized with HF	Non-Alberta residents, died within 30 day of hospital discharge, discharged to another facility	Medium LR	18,590	76

Citation	Location	Time period	Single facility study (yes/no)	Main data source	Identification of sample	Exclusions	Quality of statistical analysis ^a	Sample size	Mean age ± SD (and/or range)
Habal et al. (2014)	Canada	2004-2005	No	Hospital records	Patients hospitalized with HF	Patients who were diagnosed with HF after admission, transferred from another facility, pregnant, nonresidents, invalid health card numbers	Medium Cox hazard models; no adjustment for clustering	9,097	Median age (interquartile range): 79 (74-85)
Hamner and Ellison (2005)	Regional medical center in Southern United States	2000-2002	Yes	Hospital records	Patients hospitalized with HF		Low bivariate descriptives	557	69 ± 17
Harjai et al. (1999)	Large urban academic hospital in Southern United States	1994-1995	Yes	Hospital records	Patients admitted for HF (DRG 127) with electrocardiograph of left ventricular systolic function within prior 6 months or during hospital stay	Patients who were readmitted within 30 days of a prior hospitalization and persons without echocardiographic information	High LR	443	70 ± 14 ^b
Harjai, Thompson, Turgut, and Shah (2001)	Large urban academic hospital in Southern United States	1994-1995	Yes	Hospital records	Patients admitted for HF (DRG 127) with electrocardiograph of left ventricular systolic function within prior 6 months or during hospital stay	Patients who were readmitted within 30 days of a prior hospitalization and persons without echocardiographic information	High LR	434	70 ± 14
Hockenberry, Burgess, Glasgow, Vaughan-Sarrazin, and Kaboli (2013)	National V A data	2005-2009	No	Hospital records	Patients hospitalized with HF	Patients who were transferred to another acute care facility or who had an LOS of < 6 hours	High linear probability models; fixed effects	64,391	71 ± 3
Hummel, Katrapati, Gillespie, DeFranco, and Koelling (2014)	Michigan	2002-2003 and 2004	No	Hospital records, Medicare claim files and Social Security Death Index	Medicare patients hospitalized with HF	Patients <65 years	High multilevel mixed-effects LR; random effects by hospital for clustering	1,764	80 ± 8
Jenghua and Jedsadayamnata (2011)	Thailand	2005-2006	Yes	Hospital records	Hospitalized patients admitted with a diagnosis of CHF (ICD10 code I50.0)	Patients who died	High LR	718	65 ± 14
Joynt, Orav, and Jha (2011)	4,560 U.S. hospitals	2006-2008	No	Medicare MedPAR file	Medicare FFS beneficiaries with HF principal diagnosis (ICD9 codes 398.91, 404.x1, 404.x3, and 428.0-428.9)	Patients who were <65 years, treated in federal hospitals, or who died during the postdischarge period without readmission	High multilevel hierarchical LR adjusting for clustering at the hospital level	1,346,768	Median age (interquartile range): Blacks = 76 (70-83); Whites = 81 (74-86)

Citation	Location	Time period	Single facility study (yes/no)	Main data source	Identification of sample	Exclusions	Quality of statistical analysis ^a	Sample size	Mean age ± SD (and/or range)
Keenan et al. (2008)	National Medicare data	2003-2004	No	Medicare Standard Analytic and Enrollment files	Medicare FFS beneficiaries with HF principal diagnosis and Parts A and B enrollment for 12 months prior to index stay	Patients <65 years incomplete data; transfers within 24 hours; HF hospital stay within 30 days prior to index stay	High multilevel hierarchical LR adjusting for clustering at the hospital level	283,919	80
	National Heart Failure Project data from 50 States, DC and Puerto Rico (4,437 hospitals)	1998-2001	No	Hospital records	Medicare FFS beneficiaries with HF principal diagnosis and Parts A and B enrollment for 12 months prior to index stay	Patients <65 years; incomplete data; transfers within 24 hours; HF hospital stay within 30 days prior to index stay	High multilevel hierarchical LR adjusting for clustering at the hospital level	64,329	Not reported
Kossovsky et al. (2000)	Geneva, Switzerland	1993-1998	Yes	Hospital records	Patients with principal diagnosis of HF		High LR	442	76 ± 12 ^b
Krumholz et al. (1997)	33 acute care hospitals in Connecticut	1990-1994	No	Medicare MedPAR file	CT Medicare FFS beneficiaries hospitalized for HF	Patients <65 years; died during follow-up period; 1 stay per beneficiary randomly selected when there were 2+	Medium LR	15,732	Not reported
Krumholz et al. (2000)	18 acute care hospitals in Connecticut	1994-1995	No	Hospital records; and Medicare MedPAR and Enrollment files	CT Medicare FFS beneficiaries hospitalized for HF	Patients <65 years; cases where diagnosis "could not be validated" by medical record review; patients with severe aortic or mitral stenosis; HF caused by a medical illness; patients with primary residence outside CT; those transferred from another hospital	Medium Cox hazard models; no adjustment for clustering	2,176	79 ± 8
Lee et al. (2004)	Canada	1997-2000	No	Canadian Institute for Health Information discharge abstract and morbidity files	First hospitalization with a principal ICD-9 code of HF without any HF diagnosis in the previous 3 years	Use only incident HF cases (i.e., exclude hospitalizations of people with a HF diagnosis in the previous 3 years)	Low bivariate descriptives	83,406	Not reported
Lindenauer et al. (2013)	National Medicare data	2006-2008	No	Medicare claims American Hospital Association Annual Survey Census Bureau's American Community Survey	Patients hospitalized with HF	Patients with incomplete claims for 12-month period preceding index stay or 30-day follow-up period; patients admitted to hospitals with no AHA survey data	High multilevel hierarchical LR adjusting for clustering at hospital and state levels	1,345,909	81 ± 8

Citation	Location	Time period	Single facility study (yes/no)	Main data source	Identification of sample	Exclusions	Quality of statistical analysis ^a	Sample size	Mean age $\pm$ SD (and/or range)
Mansi, Shi, Altenburg, Mukoosa, and Huang (2011)	Louisiana	2003-2004	Yes	Hospital records	Patients admitted with a diagnosis of HF	Patients belonging to a different health care system	High LR	357	57 $\pm$ 13 ^b
McHugh, Brooks Carthon, and Kang (2010)	National Medicare data	2008	No	Medicare MedPAR file	Index hospital admission with a diagnosis of HF	Age exclusions not reported	High GEE adjusting for clustering	239,953	80 $\pm$ 9
Muus et al. (2010)	National VA data	200S-2007	No	VA patient treatment file	Index VA hospital admissions with a diagnosis of HF	Patients who died during the postdischarge period without readmission; transferred to another hospital; admitted for trauma or malignancies; had a missing or invalid home address	Medium LR	36,566	Not reported
Peterson et al. (2012)	Denver, Colorado	2000-2007	Yes	Hospital records	Index hospital admission with a diagnosis of HF	Remained in the hospital at study close; no contact with the DH system after hospital discharge	High LR	1,268	59 $\pm$ 14
Rodriguez, Joynt, Lopez, Saldana, and Jha (2011)	National Medicare data	2006-2008	No	Medicare MedPAR file	Medicare patients hospitalized with a diagnosis of HF	Patients aged 65 years and younger; Black patients; federal hospitals and those located outside the 50 states and the District of Columbia	High GEE adjusting for clustering	1,197,010	80 ^b
Roe-Prior (2004)	Pennsylvania	1989-1992 and 1992-1996	No	Hospital records	English speaking patients with discharge diagnosis of HF	Patients <65 years; in an institution before admission; died during 12-week follow-up period	Low bivariate correlations	103	78
Uthamalingam, Gurm, Daley, Flynn, and Capodilupo (2011)	New Hampshire	2006-2009	Yes	Hospital records	Hospitalized patients with a discharge diagnosis of HF	Patients <65 years; who resided in acute rehabilitation or nursing facility before admission, had acute delirium, were intubated, had a history of cancer in prior 6 months, or were lost to follow-up	High Cox hazard models	883	79 $\pm$ 8
Watson et al. (2011)	Massachusetts	2007-2008	Yes	Hospital records	Hospitalized patients with a discharge diagnosis of HF	Patients who died during the postdischarge period without readmission, cardiac transplant patients, and those missing key demographic data	High LR	729	71 $\pm$ 14

Prospective studies

Citation	Location	Time period	Single facility study (yes/no)	Main data source	Identification of sample	Exclusions	Quality of statistical analysis ^a	Sample size	Mean age ± SD (and/or range)
Howie-Esquivel and Dracup (2007)	California	2004-2005	Yes	Hospital records and patient interview	Hospitalized with HF; read or understand English or Korean; alert and oriented; 6MWT completed within 48 hours of discharge	Concurrent MI or unstable angina, inability to consent, inability to complete the 6MWT, intubation or unwillingness to participate	Low Cox hazard bivarates	72	61 (range: 27-100)
Howie-Esquivel and Dracup (2008)	California	2004-2005	Yes	Hospital records	Hospitalized with HF; read or understand English or Korean; alert and oriented; 6MWT completed within 24 hours of discharge	Concurrent MI or unstable angina, inability to consent, inability to complete the 6MWT, intubation or unwillingness to participate	Medium Cox hazard models	44	60 ± 19
Kolipara et al. (2008)	Texas	2003-2004	Yes	Hospital records and data collection surveys	Hospitalized with decompensated HF	Non-English speaking	Medium LR	97	55 ^b
Logeart et al. (2004)	France	Not reported	No	Hospital records and follow-up call to patient or general practitioner	Hospital admission to Cardiology Department for decompensated CHF	Acute MI, severe valve disease, surgical patients, or poor adherence to therapy	Medium Cox hazard models	114 In derivation and 109 in validation	70 ^b
Song, Lennie, and Moser (2009)	South Korea	2005-2005	No	Hospital records	Patients admitted with a diagnosis of HF with a NYHA classification of II	NYHA classification of I; patients who died	Medium Cox hazard models	165	62 ± 13

Note. VA = Veterans Affairs; FFS = Fee-for-Service; LOS = length of stay; CHF = chronic heart failure; GEE = generalized estimating equation; 6MWT = 6-minute walk test; MI = myocardial infarction; SE = standard error; AHA = American Hospital Association; NYHA, New York Heart Association; LR, logistic regression.

^aQuality of the statistical analysis: low = only report bivariate associations; medium = used multivariate methods but no adjustment for clustering where there are multiple facilities or, sample size < 100; high = single facility study using multivariate methods or, multivariate methods including clustering adjustment for studies with multiple sites.

^bCalculated from reported data.

Table 2

Study Readmission Measures by Length of Follow-up.

Citation	All-cause, heart failure, or other readmission measure	Overall percent rehospitalized	Method of determining rehospitalization
<i>7 Days</i>			
Eastwood et al. (2014)	All-cause	6	Hospital records
	Heart failure	2	
<i>Approximately 30 days</i>			
Allen, Smoyer-Tomic, Smith, Wilson, and Agodoa (2012)	All-cause	17	Medicaid database
		12	Commercial database
	Heart failure	7	Medicaid database
		4	Commercial database
Amarasingham et al. (2010)	All-cause	25	Hospital records
Amin, Deitelzweig, Friend, Lin, and Lowe (2013)	All-cause	Hyponatremia patients 25, nonhyponatremia patients 22	
Armola and Topp (2001)	Heart failure	24	Hospital records
Coffey et al. (2012)	Heart failure	Female 9, Male 10	Hospital discharge data from 14 states (Healthcare Cost and Utilization Project data files)
Eapen et al. (2014)	All-cause	Reduced ejection fraction with and without atrial fibrillation 24; 22	National Medicare data
		Preserved ejection fraction with and without atrial fibrillation 21; 20	
	Heart failure	Reduced ejection fraction with and without atrial fibrillation 11; 10	
		Preserved ejection fraction with and without atrial fibrillation 8; 6	
Eastwood et al. (2014)	All-cause	18	Hospital records
	Heart failure	7	
Habal et al. (2014)	Any cardiovascular cause	16	Hospital records
	Heart failure	12	
Harjai et al. (1999)	All-cause	26	Hospital records and patient interview
Harjai, Thompson, Turgut, and Shah (2001)	All-cause	26	Hospital records
	Heart failure	16	

Citation	All-cause, heart failure, or other readmission measure	Overall percent rehospitalized	Method of determining rehospitalization
Hockenberry, Burgess, Glasgow, Vaughan-Sarrazin, and Kaboli (2013)	All-cause	20	Hospital records
Hummel, Katrapati, Gillespie, DeFranco, and Koelling (2014)	All-cause	27	National Medicare data
Jenghwa and Jedsadayamata (2011)	All-cause	14	Hospital records
Joynt, Orav, and Jha (2011)	All-cause	Blacks 28, Whites 27	National Medicare data
Keenan et al. (2008)	All-cause	24	National Medicare data
Kosovsky et al. (2000)	All-cause	Not reported	Hospital records
Lee et al. (2004)	Heart failure	Not reported	
	Heart failure	9	Canadian Institute for Health Information database
Lindenauer et al. (2013)	All-cause	25	National Medicare data
McHugh, Brooks Carthon, and Kang (2010)	All-cause	23	National Medicare data
Muus et al. (2010)	Clinically related to heart failure	17	Hospital records
Peterson et al. (2012)	All-cause	15	Hospital records
Rodriguez, Joynt, Lopez, Saldana, and Jha (2011)	All-cause	Blacks 28, Whites 26	National Medicare data
Uthamalingam, Gurm, Daley, Flynn, and Capodilupo (2011)	Heart failure	16	Hospital records
Watson et al. (2011)	All-cause	13	Hospital records
<i>Approximately 90 days</i>			
Howie-Esquivel and Dracup (2007)	Heart failure	43	Hospital records
Howie-Esquivel and Dracup (2008)	All cardiac causes	52	Hospital records
Kollipara et al. (2008)	Heart failure	17	Hospital records
Lee et al. (2004)	Heart failure	14	Canadian Institute for Health Information database
Mansi, Shi, Altenburg, Mukoosa, and Huang (2011)	Heart failure	19	Hospital records
Roe-Prior (2004)	All-cause	42	Telephone interview of patients
	Heart failure symptoms	33	
Uthamalingam et al. (2011)	Heart failure	26	Hospital records
<i>Approximately 180 days</i>			
Hamner and Ellison (2005)	Heart failure	40	Hospital records
Krumholz et al. (1997)	All-cause	44	Medicare data for CT hospitals
Krumholz et al. (2000)	All-cause	49	National Medicare data

Citation	All-cause, heart failure, or other readmission measure	Overall percent rehospitalized	Method of determining rehospitalization
Logeart et al. (2004)	Heart failure	23	Hospital records and patient interview
Song, Lennie, and Moser (2009)	Heart failure	32 ^a	Hospital records

^aCalculated from reported data.

Table 3

Association of Patient Characteristics With Rehospitalization by Domain.

Patient characteristic	Citation	Quality of statistical analysis ^a	Outcome measure	Bivariate association (+ or –) and (p value) ^b	Multivariate estimate (OR or HR, unless otherwise indicated) ^c (95% CI) ^d (p value)
<i>Individual predisposing factors: Sociodemographics and health beliefs</i>					
Gender					
Male	Amarasingham et al. (2010)	High	30-Day all-cause		1.4 (1.0, 1.8) ($p = .03$)
	Harjai, Thompson, Turgut, and Shah (2001)	High	30-Day heart failure		2.7 (1.4, 5.4) ($p < .05$)
	Keenan et al. (2008; charts)	High	30-Day all-cause		0.9 (0.9, 1.0) ($p < .05$)
	Howie-Esquivel and Dracup (2007)	Low	90-Day heart failure	2.3 (1.1, 4.7) ($p = .02$)	
	Krumholz et al. (1997)	Medium	180-Day all-cause		1.1 (1.1, 1.2) ($p < .01$)
	Lee et al. (2004)	Low	30-Day heart failure	+($p = .01$)	
			90-Day heart failure	+($p < .01$)	
Female	Coffey et al. (2012)	High	30-Day heart failure		0.9 ($p < .01$)
	Hockenberry, Burgess, Glasgow, Vaughan-Sarrazin, and Kiboli (2013)	High	30-Day all-cause		–0.03 ^e ($p = .01$)
	Howie-Esquivel and Dracup (2008)	Medium	90-Day cardiac readmissions		2.5 (1.0, 6.0) ($p = .04$)
	Muus et al. (2010)	Medium	30-Day clinically related to heart failure		+($p = .02$)
Age					
Continuous	Hockenberry et al. (2013)	High	30-Day all-cause		–0.0004 ^e ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.0 ^f (1.0, 1.0) ($p < .01$)
	Eastwood et al. (2014)	Medium	30-Day all-cause		1.4 (1.1, 1.7) ($p < .05$)
			30-Day heart failure		1.4 (1.0, 2.1) ($p < .05$)
	Keenan et al. (2008; charts)	High	30-Day all-cause		0.9 (0.9, 1.0) ($p < .05$)
					0.9 (0.8, 0.9) ($p < .05$)
75–84 years (Ref = 65–74)					3.3 (1.3, 8.5) ($p = .01$)
85 years (Ref = 65–74)					4.1 (1.6, 11) ($p = .004$)
65–79 years (Ref < 65)					3.9 (1.3, 12) ($p = .02$)
80 years (Ref < 65)					

Patient characteristic	Citation	Quality of statistical analysis ^a	Outcome measure	Bivariate association (+ or -) and (p value) ^b	Multivariate estimate (OR or HR, unless otherwise indicated) ^c (95% CI) ^d (p value)
Four categories: 20-54; 55-64; 65-74; 75+	Lee et al. (2004)	Low	30-Day heart failure	-(p < .01)	
Race/ethnicity					
Black	Joynt, Orav, and Jha (2011)	High	30-Day all-cause		1.0 (1.0, 1.1) (p < .01)
	McHugh, Brooks Carthon, and Kang (2010)	High	30-Day all-cause		1.1 (1.1, 1.1) (p < .01)
Non-White	Howie-Esquivel and Dracup (2007)	Low	90-Day heart failure	2.2 (1.0, 4.5) (p = .04)	
Hispanics	Rodriguez, Joynt, Lopez, Saldana, and Jha (2011)	High	30-Day all-cause		1.1 (1.1, 1.1) (p < .01)
Race missing	Hockenberry et al. (2013)	High	30-Day all-cause		-0.01 ^e (p < .01)
Social network					
Single	Amarasingham et al. (2010)	High	30-Day all-cause		1.5 (1.1, 2.0) (p = .02)
Number of home address changes					1.1 (1.1, 1.2) (p < .01)
Living with family	Hammer and Ellison (2005)	Low	180-Day heart failure	+(p = .05)	
Health beliefs including knowledge					
Low knowledge related to dietary sodium	Kolipara et al. (2008)	Medium	90-Day heart failure		5.0 (1.3, 19.0) (p = .02)
Low acculturation	Peterson et al. (2012)	High	30-Day from Index Admit all-cause		1.7 (1.1, 2.7) (p < .05)
Individual enabling factors: Financing and organization					
Low income among VA patients	Muus et al. (2010)	Medium	30-Day clinically related to heart failure		+(p = .02)
Medicare	Amarasingham et al. (2010)	High	30-Day all-cause		1.6 (1.2, 2.2) (p < .01)
	Coffey et al. (2012)	High	30-Day heart failure		1.1 (p < .01)
	Hammer and Ellison (2005)	Low	180-Day heart failure	+(p = .05)	
Medicaid	Allen, Smoyer-Tomic, Smith, Wilson, and Agodoa (2012)	Medium	30-Day all-cause		1.3 (1.1, 1.6) (p < .01)
			30-Day heart failure		1.7 (1.3, 2.2) (p < .01)
Individual need factors: Prior utilization and index hospital stay					
Number of prior hospital admissions	Coffey et al. (2012)	High	30-Day heart failure		1.7 (p < .01)

Patient characteristic	Citation	Quality of statistical analysis ^a	Outcome measure	Bivariate association (+ or -) and (p value) ^b	Multivariate estimate (OR or HR, unless otherwise indicated) ^c (95% CI) ^d (p value)
Continuous	Amarasingham et al. (2010)	High	30-Day all-cause		1.2 (1.1, 1.3) ($p < .01$)
	Harjai et al. (2001)	High	30-Day all-cause		1.4 (1.2, 1.5) ($p < .05$)
			30-Day heart failure		1.3 (1.2, 1.4) ($p < .05$)
	Krumholz et al. (1997)	Medium	180-Day all-cause		1.6 (1.5, 1.8) ($p < .01$)
	Krumholz et al. (2000)	Medium	180-Day all-cause		1.3 (1.1, 1.5) ($p < .01$)
1 (Ref = 0)	Hummel, Katrapati, Gillespie, DeFranco, and Koelling (2014)	High	30-Day all-cause		4.7 (3.4, 6.5) ($p < .01$)
2+ (Ref = 0)					6.5 (4.9, 8.6) ($p < .01$)
Route to index hospital stay					
Presented to ER 6 am-6 pm	Amarasingham et al. (2010)	High	30-Day all-cause		1.4 (1.1, 1.8) ($p = .02$)
Admitted via ER	Hamner and Ellison (2005)	Low	180-Day heart failure	+ ($p < .01$)	
Transferred to the index hospital	Eastwood et al. (2014)	Medium	7-Day all-cause		1.2 (1.0, 1.5) ($p < .05$)
			30-Day all-cause		1.2 (1.1, 1.4) ($p < .05$)
Length of index hospital stay					
Continuous	Howie-Esquivel and Dracup (2008)	Medium	90-Day cardiac readmissions		1.0 (1.0, 1.1) ($p = .02$)
	Hockenberry et al. (2013)	High	30-Day all-cause		0.002 ^e ($p < .01$)
LOS >5 days	Jenghwa and Jedsadayannmata (2011)	High	30-Day all-cause		1.4 ($p = .02$)
LOS >7 days	Allen et al. (2012)	Medium	30-Day all-cause		1.0 (1.0, 1.0) ($p < .05$)
	Muus et al. (2010)	Medium	30-Day heart failure	+ ($p < .01$)	
	Krumholz et al. (1997)	Medium	180-Day all-cause		1.3 ($p < .01$)
LOS >30 days	Eastwood et al. (2014)	Medium	7-Day all-cause		0.7 (0.5, 0.9) ($p < .05$)
<i>Individual need factors: Comorbidities and other clinical factors</i>					
Previous diagnosis of heart failure	Hummel et al. (2014)	High	30-Day all-cause		2.1 (1.5, 2.9) ($p < .01$)
	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.1, 1.1) ($p < .05$)
	Keenan et al. (2008; charts)	High	30-Day all-cause		1.3 (1.2, 1.3) ($p < .05$)
	Kossovsky et al. (2000)	High	31-Day all-cause		2.9 (1.7, 4.8) ($p < .01$)
			31-Day heart failure		4.5 (2.3, 8.8) ($p < .01$)
	Krumholz et al. (2000)	Medium	180-Day all-cause		1.3 (1.0, 1.5) ($p = .03$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) ($p < .01$)

Patient characteristic	Citation	Quality of statistical analysis ^a	Outcome measure	Bivariate association (+ or -) and (p value) ^b	Multivariate estimate (OR or HR, unless otherwise indicated) ^c (95% CI) ^d (p value)
Severity of heart failure					
Higher New York Heart Association classification	Armola and Topp (2001)	Low	30-Day heart failure	+(p = .02)	
Low LVEF	Harjai et al. (1999)	High	30-Day all-cause		2.1 (p = .02)
Unknown LVEF			30-Day heart failure		5.7 (p = .01)
Heart failure APR DRG	Keenan et al. (2008; charts)	High	30-Day all-cause		1.2 (1.1, 1.2) (p < .05)
Moderate loss of function	Coffey et al. (2012)	High	30-Day heart failure		
Major loss of function					1.2 (p < .01)
Extreme loss of function					1.2 (p < .01)
High predischage BNP level					1.2 (p < .01)
Prior cardiac procedures	Logeart et al. (2004)	Medium	180-Day heart failure		1.3 (1.2, 1.4) (p < .01)
Prior CABG	Keenan et al. (2008; claims)	High	30-Day all-cause		0.9 (0.9, 1.0) (p < .05)
	Lindenauer et al. (2013)	High	30-Day all-cause		0.9 ^f (0.9, 0.9) (p < .01)
History of myocardial revascularization	Kossovsky et al. (2000)	High	31-Day all-cause		2.1 (1.2, 3.9) (p = .01)
History of PTCA	Keenan et al. (2008; charts)	High	30-Day all-cause		1.1 (1.0, 1.2) (p < .05)
Stent	Allen et al. (2012)	Medium	30-Day all-cause		1.7 (1.0, 2.7) (p < .05)
Cardiac events					
Cardiorespiratory failure and shock	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.1, 1.1) (p < .05)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) (p < .01)
Cardiac arrest	Hummel et al. (2014)	High	30-Day all-cause		6.7 (1.3, 34.7) (p < .05)
Hypertension					
Uncomplicated	Hockenberry et al. (2013)	High	30-Day all-cause		0.03 ^e (p < .05)
Complicated			30-Day all-cause		0.03 ^e (p < .05)
Systolic BP < 125 mm Hg	Keenan et al. (2008; charts)	High	30-Day all-cause		1.2 (1.1, 1.2) (p < .05)
Other heart disease or disorder					
Valvular and rheumatic heart disease	Allen et al. (2012)	Medium	30-Day all-cause		1.3 (1.1, 1.5) (p < .05)

Patient characteristic	Citation	Quality of statistical analysis ^a	Outcome measure	Bivariate association (+ or -) and (p value) ^b	Multivariate estimate (OR or HR, unless otherwise indicated) ^c (95% CI) ^d (p value)
	Hockenberry et al. (2013)	High	30-Day all-cause		0.02 ^e ($p < .01$)
	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.1, 1.1) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) ($p < .01$)
Ratio of mitral to early diastolic velocity of mitral annulus	Song, Lennie, and Moser (2009)	Medium	180-Day heart failure		1.1 (1.0, 1.1) ($p < .01$)
Acute coronary syndrome	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) ($p < .01$)
History of CAD	Keenan et al. (2008; Charts)	High	30-Day all-cause		1.2 (1.1, 1.2) ($p < .05$)
	Hockenberry et al. (2013)	High	30-Day all-cause		0.02 ^e ($p < .01$)
Atrial fibrillation	Eapen et al. (2014)	High	30-Day all-cause		1.1 (1.0, 1.1) ($p < .01$)
	Eastwood et al. (2014)	Medium	30-Day heart failure		1.1 (1.0, 1.3) ($p < .05$)
Arrhythmia	Hockenberry et al. (2013)	High	30-Day all-cause		0.02 ^e ($p < .01$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.0, 1.1) ($p < .01$)
Discharge heart rate >90 bpm	Habal et al. (2014)	Medium	30-Day all-cause		1.3 (1.0, 1.5) ($p = .02$)
Discharge heart rate > 100 bpm	Keenan et al. (2008; charts)	High	30-Day cardiovascular disease		1.3 (1.1, 1.5) ($p < .01$)
Other heart disease	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.0, 1.1) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 (1.0, 1.1) ($p < .05$)
			30-Day all-cause		1.0 ^f (1.0, 1.0) ($p < .01$)
Vascular disease					
Aortic stenosis	Keenan et al. (2008) (Charts)	High	30-Day all-cause		1.1 (1.1, 1.2) ($p < .05$)
Chronic atherosclerosis	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.1, 1.1) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.0, 1.1) ($p < .01$)
Cerebrovascular accident	Keenan et al. (2008; charts)	High	30-Day all-cause		1.1 (1.0, 1.2) ($p < .05$)
Cerebrovascular disease	Eastwood et al. (2014)	Medium	30-Day all-cause		0.7 (0.6, 0.9) ($p < .05$)
			30-Day heart failure		0.6 (0.4, 1.0) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.0 ^f (1.0, 1.0) ($p < .01$)
Vascular or circulatory disease	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) ($p < .01$)

Patient characteristic	Citation	Quality of statistical analysis ^a	Outcome measure	Bivariate association (+ or -) and (p value) ^b	Multivariate estimate (OR or HR, unless otherwise indicated) ^c (95% CI) ^d (p value)
Diabetes	Hockenberry et al. (2013)	High	30-Day all-cause		0.01 ^e ($p < .05$)
Diabetes	Hockenberry et al. (2013)	High	30-Day all-cause		0.05 ^e ($p < .01$)
	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.1, 1.1) ($p < .05$)
	Keenan et al. (2008; charts)	High	30-Day all-cause		1.1 (1.1, 1.1) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) ($p < .01$)
Diabetes without chronic complications	Coffey et al. (2012)	High	30-Day heart failure		1.1 ($p < .01$)
Glucose >200 mg/dL	Keenan et al. (2008; charts)	High	30-Day all-cause		1.1 (1.0, 1.1) ($p < .05$)
Kidney disease					
Renal failure	Allen et al. (2012)	Medium	30-Day all-cause		1.3 (1.1, 1.7) ($p < .01$)
	Coffey et al. (2012)	High	30-Day heart failure		1.5 (1.1, 2.0) ($p < .05$)
	Eastwood et al. (2014)	Medium	7-Day all-cause		1.2 ($p < .01$)
			30-Day all-cause		1.3 (1.1, 1.5) ($p < .05$)
			30-Day heart failure		1.4 (1.2, 1.5) ($p < .05$)
			30-Day all-cause		1.4 (1.2, 1.7) ($p < .05$)
ESRD/dialysis	Hockenberry et al. (2013)	High	30-Day all-cause		0.14 ^e ($p < .05$)
	Keenan et al. (2008; claims)	High	30-Day all-cause		1.2 (1.1, 1.2) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.2) ($p < .01$)
	Keenan et al. (2008; claims)	High	30-Day all-cause		1.2 (1.1, 1.2) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.2) ($p < .01$)
BUN	Harjai et al. (2001)	High	30-Day all-cause		1.0 (1.0, 1.0) ($p < .01$)
BUN >40 or creatinine >2.5 mg/dL	Keenan et al. (2008; charts)	High	30-Day all-cause		1.4 (1.3, 1.5) ($p < .05$)
Creatinine >2.5 mg/dL at discharge	Krumholz et al. (2000)	Medium	180-Day all-cause		1.7 (1.4, 2.2) ($p < .01$)
Nephritis	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) ($p < .01$)
Lung disease					
Chronic obstructive pulmonary disease	Harjai et al. (2001)	High	30-Day all-cause		1.9 (1.0, 3.5) ($p < .01$)

Patient characteristic	Citation	Quality of statistical analysis ^a	Outcome measure	Bivariate association (+ or -) and (p value) ^b	Multivariate estimate (OR or HR, unless otherwise indicated) ^c (95% CI) ^d (p value)
Asthma	Hockenberry et al. (2013)	High	30-Day heart failure		2.2 (1.1, 4.5) ($p < .05$)
	Keenan et al. (2008; claims)	High	30-Day all-cause		0.02 ^e ($p < .01$)
	Keenan et al. (2008; charts)	High	30-Day all-cause		1.2 (1.1, 1.2) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.2 (1.1, 1.2) ($p < .05$)
	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) ($p < .01$)
Pneumonia	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 (1.0, 1.1) ($p < .05$)
	Keenan et al. (2008; claims)	High	30-Day all-cause		1.0 ^f (1.0, 1.0) ($p < .01$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 (1.1, 1.1) ($p < .05$)
Pulmonary disease	Howie-Esquivel and Dracup (2007)	Low	90-Day heart failure	1.1 (1.0, 1.3) ($p = .03$)	1.1 ^f (1.1, 1.1) ($p < .01$)
	Eastwood et al. (2014)	Medium	30-Day all-cause		1.1 (1.1, 1.2) ($p < .05$)
Pulmonary hypertension	Hockenberry et al. (2013)	High	30-Day all-cause		-0.02 ^e ($p < .01$)
	Hamner and Ellison (2005)	Low	180-Day heart failure	+($p = .01$)	
Fibrosis of lung	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.0, 1.1) ($p < .01$)
	Eastwood et al. (2014)	Medium	30-Day all-cause		1.4 (1.1, 1.9) ($p < .05$)
Liver and biliary disease	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.0, 1.1) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.0, 1.1) ($p < .01$)
Blood deficiency or disorder	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.1, 1.1) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) ($p < .01$)
Deficiency anemia	Hockenberry et al. (2013)	High	30-Day all-cause		0.02 ^e ($p < .01$)
	Keenan et al. (2008; claims)	High	30-Day all-cause		1.2 (1.1, 1.2) ($p < .05$)
Severe hematologic disorder	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) ($p < .01$)
	Mansi, Shi, Altenburg, Mukoosa, and Huang (2011)	High	90-Day heart failure		+($p < .05$)
Low hemoglobin	Hummel et al. (2014)	High	30-Day all-cause		1.4 (1.0, 1.9) ($p < .05$)
Hematocrit <30%					

Patient characteristic	Citation	Quality of statistical analysis ^a	Outcome measure	Bivariate association (+ or -) and (p value) ^b	Multivariate estimate (OR or HR, unless otherwise indicated) ^c (95% CI) ^d (p value)
<i>Low sodium</i>	Keenan et al. (2008; charts)	High	30-Day all-cause		1.2 (1.2, 1.3) ($p < .05$)
Hyponatremia	Amin, Deitelzweig, Friend, Lin, and Lowe (2013)	Medium	30-Day all-cause		1.2 (1.1, 1.2) ($p < .01$)
Sodium < 130 mg/dL	Hummel et al. (2014)	High	30-Day all-cause CMS model 30-Day all-cause CMS model and prior readmissions		1.7 (1.1, 2.6) ($p < .05$) 1.8 (1.1, 2.9) ($p < .05$)
Serum sodium < 135 mEq/L	Roe-Prior (2004)	Low	84-Day all-cause		+($p = .04$)
Fluid, electrolyte disorder	Allen et al. (2012)	Medium	30-Day all-cause		1.3 (1.0, 1.6) ($p < .05$)
	Coffey et al. (2012)	High	30-Day heart failure		1.1 ($p < .01$)
	Hockenberry et al. (2013)	High	30-Day all-cause		0.01 ^e ($p < .05$)
	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.1, 1.1) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) ($p < .01$)
Protein-calorie malnutrition	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.0, 1.1) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) ($p < .01$)
Hypothyroidism	Hockenberry et al. (2013)	High	30-Day all-cause		0.02 ^e ($p < .01$)
Malignancy	Hockenberry et al. (2013)	High	30-Day all-cause		0.04 ^e ($p < .05$)
Metastatic cancer	Eastwood et al. (2014)	Medium	30-Day all-cause		1.3 (1.1, 1.6) ($p < .05$)
	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.1, 1.2) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.2) ($p < .01$)
Urinary track disorders	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.1, 1.2) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) ($p < .01$)
Skin ulcer	Allen et al. (2012)	Medium	30-Day all-cause		1.6 (1.1, 2.4) ($p < .05$)
	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.1, 1.1) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) ($p < .01$)
Gastrointestinal disorder	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.0, 1.1) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.0 ^f (1.0, 1.1) ($p < .01$)

Patient characteristic	Citation	Quality of statistical analysis ^a	Outcome measure	Bivariate association (+ or -) and (p value) ^b	Multivariate estimate (OR or HR, unless otherwise indicated) ^c (95% CI) ^d (p value)
Peptic ulcer	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.1, 1.1) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.0, 1.1) ($p < .01$)
Depression	Amarasingham et al. (2010)	High	30-Day all-cause		1.4 (1.0, 2.1) ($p = .05$)
	Song et al. (2009)	Medium	180-Day heart failure		1.1 (1.0, 1.1) ($p < .01$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.0 ^f (1.0, 1.0) ($p = .01$)
Delirium	Uthamalingam, Gurm, Daley, Flynn, and Capodilupo (2011)	High	30-Day all-cause		4.2 (2.8, 6.5) ($p < .01$)
Dementia	Lindenauer et al. (2013)	High	90-Day all-cause		3.7 (2.5, 5.5) ($p < .01$)
Psychoses; major psychiatric disorders	Coffey et al. (2012)	High	30-Day all-cause		1.0 ^f (1.0, 1.0) ($p = .03$)
			30-Day heart failure		1.2 ($p < .01$)
Other psychiatric disorders	Lindenauer et al. (2013)	High	30-Day all-cause		1.0 ^f (1.0, 1.0) ($p < .01$)
	Allen et al. (2012)	Medium	30-Day all-cause		1.7 (1.2, 2.4) ($p = .01$)
	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.1, 1.1) ($p = .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) ($p < .01$)
Hemiplegia, paraplegia, paralysis, functional disability	Coffey et al. (2012)	High	30-Day heart failure		0.8 ($p < .01$)
	Hockenberry et al. (2013)	High	30-Day all-cause		-0.15 ^e ($p < .05$)
	Keenan et al. (2008; claims)	High	30-Day all-cause		1.0 (1.0, 1.1) ($p < .05$)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.0 ^f (1.0, 1.0) ($p < .01$)
Rheumatoid arthritis	Coffey et al. (2012)	High	30-Day heart failure		0.8 ($p < .01$)
Obesity	Coffey et al. (2012)	High	30-Day heart failure		0.8 ($p < .01$)
	Hockenberry et al. (2013)	High	30-Day all-cause		-0.02 ^e ($p < .01$)
Disease burden					
Number of unique 3-digit ICD-9-CM codes	Allen et al. (2012)	Medium	30-Day all-cause		1.0 (1.0, 1.0) ($p < .01$)
Lower QOL symptom stability score	Howie-Esquivel and Dracup (2007)	Low	90-Day heart failure	1.0 (1.0, 1.0) ($p = .02$)	
Deyo comorbidity score of > 1	Krumholz et al. (1997)	Medium	180-Day all-cause		1.6 ($p < .01$)

Patient characteristic	Citation	Quality of statistical analysis ^a	Outcome measure	Bivariate association (+ or -) and (p value) ^b	Multivariate estimate (OR or HR, unless otherwise indicated) ^c (95% CI) ^d (p value)
Fair or poor self-reported health status	Roe-Prior (2004)	Low	84-Day all-cause		+(p = .02)
<i>Individual need factors: Health behavior</i>					
Refusing health services	Watson et al. (2011)	High	30-Day all-cause		1.8 (1.1, 2.9) (p = .03)
Nonadherence					1.7 (1.1, 2.8) (p = .03)
Missed appointments					1.7 (1.1, 2.8) (p = .03)
Discharged against medical advice	Coffey et al. (2012)	High	30-Day heart failure		1.9 (p < .01)
	Eastwood et al. (2014)	Medium	7-Day all-cause		4.5 (3.1, 6.5) (p < .05)
			7-Day heart failure		4.6 (2.7, 7.9) (p < .05)
			30-Day all-cause		3.1 (2.3, 4.1) (p < .05)
			30-Day heart failure		3.2 (2.2, 4.6) (p < .05)
Drug/alcohol abuse					
History of cocaine use	Amarasingham et al. (2010)	High	30-Day all-cause		1.8 (1.2, 2.7) (p = .01)
Drug abuse	Coffey et al. (2012)	High	30-Day heart failure		1.6 (p < .01)
	Mansi et al. (2011)	High	90-Day heart failure		+(p < .05)
Drug/alcohol abuse	Keenan et al. (2008; claims)	High	30-Day all-cause		1.1 (1.0, 1.1) (p < .05)
	Lindenauer et al. (2013)	High	30-Day all-cause		1.1 ^f (1.1, 1.1) (p < .01)

Note. OR = odds ratio; HR = hazards ratio; CI = confidence interval; VA = Veterans Affairs; CMS = Centers for Medicare and Medicaid Services; LOS = length of stay; CABG = coronary artery bypass graft; BNP = B-type natriuretic peptide; LVEF = left ventricular ejection fraction; ESRD = end-stage renal disease; BUN = blood urea nitrogen; PTCA = percutaneous transluminal coronary angioplasty; CAD = coronary artery disease; APR DRG = all patient refined diagnosis-related groups; QOL = quality of life; ER = emergency room.

^a See Table 1 notes.

^b Bivariate associations reported only when multivariate models were not available; no standard error or CI reported.

^c Hockenberry et al. (2013) report linear probability estimates; Lindenauer et al. (2013) report risk ratios.

^d A small number of studies do not report CIs or the information needed to calculate CIs.

^e Linear probability estimate.

^f Risk ratio.