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Updates in heart failure 30-day readmission prevention

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Abstract
Heart failure (HF) and HF 30-day readmission rates have been a major focus of efforts to reduce health care cost in the recent era. Since the implementation of the Affordable Care Act (ACA) in 2012 and the Hospital Readmission Reduction Program (HRRP), concerted efforts have focused on reduction of 30-day HF readmissions and other admission diagnoses targeted by the HRRP. Hospitals and organizations have instituted wide-ranging programs to reduce short-term readmissions, but the data supporting these programs is often mixed. In this review, we will discuss the challenges associated with reducing HF readmissions and summarize the rationale and effect of specific programs on HF 30-day readmission rates, ranging from medical therapy and adherence to remote hemodynamic monitoring. Finally, we will review the effect that the focus on reducing 30-day HF readmissions has had on the care of the HF patient.

Keywords Heart failure · 30-day readmission reduction · Medication reconciliation and adherence · Telemonitoring · Remote hemodynamic monitoring · Early follow-up · HRRP · GDMT · Guideline-directed medical therapy

Introduction

Since the passage of the Affordable Care Act (ACA) in 2012 and the Hospital Readmission Reduction Program (HRRP), there has been a concerted effort to reduce 30-day HF readmissions in addition to other admission diagnoses [1]. Under the HRRP, if a hospital's readmission rate for a particular admission diagnosis is below the national average by a predetermined percentage, the hospital suffers reductions in re-imbursement by the Centers for Medicare and Medicaid Services (CMS). From 2008 through 2014, among the top three diagnoses targeted by the HRRP, including acute myocardial infarction (AMI), heart failure (HF), and pneumonia (PNA), HF had the highest number of hospitalizations within the Medicare fee-for-service population over 65 years of age [2]. HF also had the highest rate of 30-day readmissions at 23.5% [2]. Efforts such as the Hospital to Home "See you in 7" program, [3] focusing on follow-up clinic visits within 7 days of discharge from an HF admission, have resulted in a reduction in 30-day readmissions from 21.5 to 17.8% nationally between 2007 and 2015 [4].

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Despite this improvement in the short-term readmission rates, the impact of HF on the US healthcare system will continue to grow. The American Heart Association (AHA) projects that the prevalence of HF will increase by 46% from 2012 to 2030 and the cost is predicted to increase substantially from $307 billion annually to $697 billion by the year 2030 [5]. In 2014, HF was the underlying cause of death in 68,626 patients and listed as a contributing cause of death in 308,976 patients. To some degree, one in every eight deaths was attributed to HF [6].

The increasing prevalence and cost of HF, combined with efforts to avoid CMS and HRRP financial penalties, has led to a surge of research into the efficacy of programs intended to reduce 30-day HF readmissions. In this paper, we present the various strategies previously published, including the rationale and data for or against their effectiveness. We have grouped the programs by the particular aspect of HF care they target, with the major categories being: medication use and adherence, hemodynamic monitoring, telemonitoring, early post-discharge follow-up, nurse-led education, and readmission risk assessment.

The challenge of the heart failure readmission

HF is a complex syndrome encompassing both HF with reduced and preserved ejection fraction. It is the end-common

pathway of a diverse number of disease states, including congenital heart disease, ischemia, arrhythmia, and external factors. The end result of congestion and/or poor perfusion results in negative effects on multiple organ systems. Patients with HF are often medically complex, with multiple comorbidities, a long list of medications, and a wide range of symptoms that can be attributed to a number of etiologies.

A few specific points highlight the challenge of reducing readmissions for HF. About half of patients hospitalized for HF have preserved ejection fraction (HFpEF), for which there is no targeted therapy [7]. As discussed in further detail in the next section, multiple medications have been well described to reduce readmissions and overall improve function in patients with HF with reduced ejection fraction (HFrEF). Despite multiple avenues of research, the same has yet to be established for HFpEF [7].

The natural history of HF also lends itself to the underlying problem of frequent readmissions. Unlike other HRRP-targeted admission diagnoses like AMI and PNA, which are most often isolated events that are treated and not expected to imminently recur, HF is a chronic illness which requires daily management to avoid decompensations. Additionally, as depicted in Fig. 1, the natural history of HF is characterized by a series of decompensations, after which the patient does not return to their prior baseline quality of life, and inherently requires a higher intensity of care. This continues in a downward trajectory until ultimate pump failure and death. When access to care, health literacy, and other socioeconomic factors are additionally considered, preventing and reducing HF readmissions seems a lofty goal.

Medical therapy: implementing the guidelines

There is a multitude of data on the utility of specific medications to improve outcomes for HFrEF, not only by improving mortality, but also by reducing rehospitalization. Guideline Directed Medical Therapy (GDMT), the mainstay of prescription therapy for HFrEF, includes beta blockers (BB) [8–10], angiotensin converting enzyme inhibitors (ACE-I), [11–14] aldosterone antagonists (AA) [15, 16], and newer drugs including valsartan-sacubitril, and ivabradine, incorporated in the 2017 ACC/AHA/HFSA focused update of the guideline for the management of heart failure [17].

The data supporting reduction in HF hospitalizations is robust and derived from large, randomized controlled trials (RCT) on outcomes in HFrEF patients. PARADIGM-HF, an RCT comparing Entresto, a combination therapy of valsartan and sacubitril, to enalapril, resulted in significant decreases in mortality and HF readmissions [18]. HF readmissions at 30 days were decreased by 38% in patients randomized to receive Entresto compared to enalapril. A 26% lower all-cause readmission rate was also observed in participants on Entresto compared to enalapril [19]. The SHIFT trial, an RCT of ivabradine, a selective sinus-node inhibitor, found reduced hospitalizations when given to patients on maximally tolerated beta blockers with persistent heart rates greater than 70 beats per minute [20]. In response to these robust findings, the HF guidelines were updated in 2017 to include transitioning patients from an ACE or ARB to Entresto for further reduction in morbidity and mortality, and ivabradine in specific patients for reduction in HF hospitalizations in HFrEF patients [17].

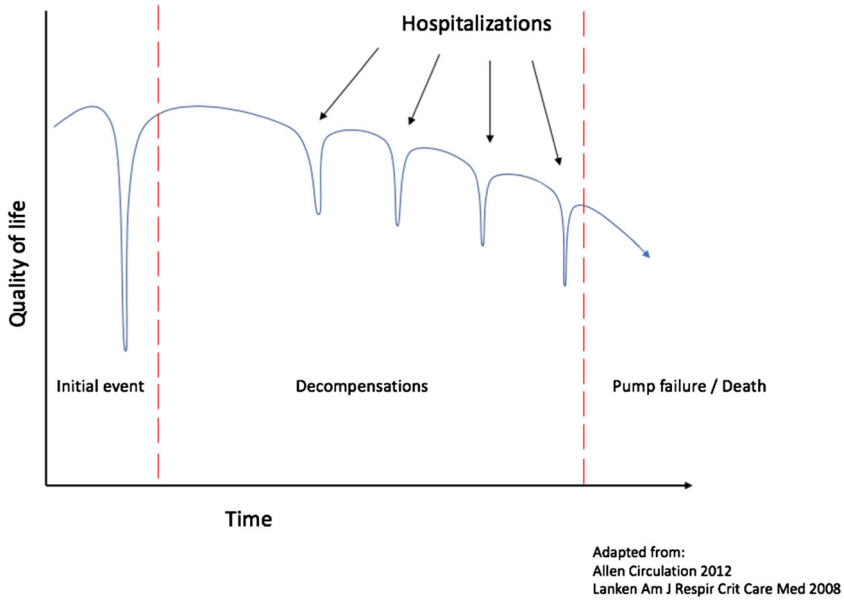

Fig. 1 Hospitalizations and quality of life during the course of heart failure disease progression

Although there are no targeted therapies identified for HFpEF, specific medications have been shown to decrease hospitalizations and thus should be prescribed where appropriate. The TOPCAT (treatment of preserved cardiac function heart failure with an aldosterone antagonist) trial showed efficacy in a post-hoc analysis of HFpEF patients in America of reduced HF hospitalizations in the treatment arm randomized to use of spironolactone [21]. Additionally, the use of ARBs remains in the guidelines with a specific aim to reduce HF hospitalization in this patient population.

However, initiation of proven medical therapies alone is not sufficient. Subsequent attention should be turned to achieving the target doses studied in the seminal trials. A retrospective study of BIOSTAT-CHF, a European database of HF patients, evaluated the effect of GDMT dosing on HF outcomes [22]. The database included 2100 patients from 69 European countries. The investigators noted that only 22% of patients were prescribed the recommended target doses of ACE-I/ARB and only 12% received the target doses of BB. Accordingly, they noted that patients on < 50% target dose had increased rates of death and HF hospitalizations. Similar findings were reported in QUALIFY, an international, prospective study including 6669 outpatients with HFrEF [23]. They concluded that at 6-month follow-up, patients who achieved greater than 50% target dose had better clinical outcomes, including lower mortality, HF exacerbation, and hospitalization.

As described, expansive data is available on the utility of medical therapy to improve HF clinical outcomes, including reducing HF hospitalizations. However, recent studies have shown that the uptake in prescription of the newer GDMT agents has been slow. In particular, Luo et al. recently reported that rates of Entresto prescription in appropriate HF patients remains low 5 years after the ground-braking PARADIGM-HF results were published [24]. Implementing strategies that improve awareness of and adherence to HF management guidelines is thus a prime focus for reducing HF readmission rates and improving quality of care for HF patients.

Pitfalls in medical therapy: medication intolerance and non-adherence

Many barriers exist to implementing GDMT effectively. Medication intolerance including renal and hemodynamic effects, as well as electrolyte disturbances are the most common limitations of these groups of medications. Hemodynamic limitations are perhaps the most ominous and necessary to recognize. The European Society of Cardiology Heart Failure Long-Term Registry (ESC-HF-LT) included both acute and chronic HF patients from 21 European countries [25]. In this population, rates of use of ACE-I/ARB, beta blocker, and ivabradine differed significantly between chronic ambulatory HF patients and patients hospitalized with acute decompensated HF (ADHF). Patients admitted with ADHF had lower rates of GDMT use compared to their ambulatory cohorts, highlighting the challenge of understanding the root of medication use limitations. Rather than concluding that patients admitted with ADHF are "under-treated" and thus more likely to be admitted, one must recognize that inability to initiate or up-titrate GDMT due to side effects or intolerance often reflects overall low reserve, more comorbidities, and higher mortality. This is especially true when use of these agents is limited by low blood pressure or poor renal function. HF patients that do not tolerate use or up-titration of GDMT should be considered for evaluation for advanced heart failure therapies.

Hyperkalemia is another potential limiting factor, particularly for ACE-I/ARB and the newer agent Entresto. A rise in serum potassium does not necessitate discontinuation of a medication with proven mortality benefits. A reduction of the dose, institution of a low potassium diet, or strategic use of loop or thiazide type diuretics can stabilize serum potassium and allow for continued use of these agents. Additionally, several medications have been studied for the treatment of chronic hyperkalemia. Patiromer, a potassium binding resin, has been approved by the FDA in 2015 for use [26, 27] and can be used concomitantly with GDMT agents.

If no physiologic barriers to prescribed regimens exist, then identifying adherence limitations becomes crucial to the success of HF treatment. Medication non-adherence has been shown to significantly increase mortality and hospitalizations in HF patients [28], and can be attributed to both patient and facility-level factors. Facility-based practices can improve adherence even before a patient leaves the hospital. Initiation of GDMT prior to discharge, rather than at a follow-up outpatient visit, leads to higher adherence rates at 60-day follow-up [29]. Pre-discharge checklists and reminders built into electronic medical record (EMR) systems help discharging physicians identify opportunities to augment a patient's medication regimen. "Get with the guidelines" is an example of this type of strategy [30]. The complexity of medication regimens is also a factor. Ziaeian et al. found that after discharge, 81.4% of patients had discharge medication reconciliation errors, either secondary to provider error, or due to patients' poor understanding of medication changes [31]. HF therapy is inherently complicated and multiple medications are often added during a single admission. Strategies to minimize errors in medication reconciliation have thus been an area of opportunity.

On a patient level, there are many opportunities for optimizing adherence if care givers understand the reasons for "non-compliance." In a population of Medicare part D patients, adherence to GDMT at 1-, 3-, and 12-month post-discharge was initially reasonable, but declined steadily throughout the year of follow-up (70%, 61%, and 53% at 1, 3, and 12 months respectively for ACEI/ARB; 76%, 66%, and 62% for BB; and 75%, 68%, and 59% for diuretics) [32]. Many

reasons for non-compliance were cited, including cost of medications, poor understanding of medication changes, and intolerance of side effects [32].

Diuretics are particularly difficult for elderly patients due to urinary incontinence, often compounded by poor mobility. Some patients may forgo diuretics when they plan to spend time out of the house and prefer not to worry about the logistics of finding a restroom. Unfortunately, missing medications even for short periods of time can have negative effects on clinical status. Dovancescu et al. reported that even 48 h of missed medications in patients identified as stable outpatients led to development of subclinical signs of congestion, in particular increased left atrial volume and NT-proBNP, and increased measures of transthoracic bio-impedance [33].

Interventions implemented to improve adherence to medication regimens have been shown to decrease HF hospitalizations and mortality [34]. A wide range of strategies have been studied. Early outpatient follow-up visits post-discharge help identify medication reconciliation errors or issues with compliance [3]. Some pharmacies now utilize pre-filled medication boxes which improve regimen adherence. Pre-filled blister packs is a specific packaging method found to have the best effect on adherence, based on one meta-analysis [35]. A novel electronic pill box, MedSentry, resulted in a trend towards decreased all cause readmissions in a small RCT of HF patients [36]. The use of phone text message reminders has been studied, however not shown to improve adherence [37]. Researchers have also investigated if financial incentives improve medication adherence and achieving goal cholesterol levels. One such study used four groups: incentive for the patient, incentive for the physician, incentive for both parties, and no incentive at all. This study found that 49% of patients in the shared-incentive group reached their previously determined cholesterol compared with 36% to 40% in the remaining groups [38]. Volpp et al. studied AMI patients and evaluated a combination of interventions integrating electronic pill bottles, financial incentives, and social support. These efforts did not significantly improve medication adherence or readmission outcomes for AMI survivors [39]. Although medication adherence is known to improve outcomes, as shown above data supporting specific methods to improve adherence are lacking.

Measures of congestion: hemodynamic measurement and other markers

The major pathophysiologic reason for readmission is congestion. Elevated filling pressures may be present for some time prior to clinically recognized symptoms of congestion, making it difficult to detect in a timely manner to prevent rehospitalization [40]. Early detection of fluid accumulation can trigger outpatient interventions which may result in a decrease in acute HF exacerbations and hospitalizations. Subtle changes in pulmonary congestion have been shown to correlate with right ventricular (RV) overload and dysfunction, and increased mortality [41]. These changes can be monitored through invasive and non-invasive means as a way to prevent HF readmissions [40]. A patient's hemodynamic information is relayed to the health care team, who then adjust medications in an effort to optimize changes in filling pressures before overt clinical signs of congestion result in need for hospitalization.

Studies investigating intrathoracic impedance as a surrogate for intracardiac hemodynamics in patients with defibrillators have not proven to reduce HF hospitalizations reliably. The OptiLink HF study randomized 1002 patients to either an intervention group, with information regarding intrathoracic impedance sent to the care team, vs. standard care [42]. The study followed the patients for 1.9 years and found no difference in all cause death or hospitalizations. The development of other novel techniques for remote hemodynamic monitoring thus ensued.

The COMPASS-HF study evaluated the use of a specific pressure monitoring device implanted in the right ventricle [43]. This study randomized 274 HF patients to implantable RV hemodynamic monitor vs. control. The device measured RV pressures, which were then reviewed weekly by the health care team. When appropriate, a change in medical regimen was then initiated. At the conclusion of the study, they found a non-significant reduction of HF events by 21%.

The CHAMPION trial subsequently investigated use of a wireless implantable hemodynamic monitor placed in the left pulmonary artery. This device measures and transmits pulmonary artery pressure measurements to clinicians via use of a sensor device located in the patients' home [43]. When readings were transmitted on a nightly basis for 6 months, a 37% reduction in HF-related admissions was found. This result has propelled the use of remote pulmonary artery hemodynamic monitoring devices, commercially available as "Cardiomems." The CHAMPION trial thus reinvigorated the concept of hemodynamic monitoring. A follow-up review of the first 2000 CardioMems devices implanted in the community revealed an even greater decrease in pulmonary pressures than that reported in the trial, as well as retained patient compliance with frequent data transmission [44]. Based on this report, remote pulmonary artery pressure monitoring is reasonable to use and effective in decreasing pulmonary pressures and HF admissions in the community, not only in a controlled study population.

Detection of pulmonary congestion can also be used as a prognostic indicator at the time of hospital discharge. The "Prognostic value of residual pulmonary congestion at discharge assessed by lung ultrasound imaging in heart failure" study performed in Italy evaluated the use of lung ultrasound (US) prior to discharge from an HF hospitalization [45]. Lung US was performed to evaluate for B-lines, an indicator of pulmonary congestion. The probe was placed in a number of

locations throughout the thorax, and the number of B-lines seen in each field were added together for a B-line score. A total of 60 patients were included and were subsequently followed for 3 months. They found that a higher B-line score correlated with higher short-term mortality and number of HF hospitalizations. This technique is relatively inexpensive, safe, and can be performed easily at the bedside. Patients can then be stratified to high or low risk of readmission, and further diuresis or closer outpatient follow-up can be provided to those with residual pulmonary congestion, with an aim to decrease HF exacerbations and readmissions.

The use of B-type natriuretic peptide (BNP) as a marker of congestion is now part of the evaluation and diagnosis of HF, and is useful to predict long-term prognosis and re-hospitalization. The Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients with Heart Failure (OPTIMIZE-HF) linked clinical data for hospitalizations in patients > 65 years to Medicare claims and found that discharge BNP predicts 1-year mortality and 1-year mortality and rehospitalization among older patients hospitalized with HF [46]. Separately, Hamatani et al. subclassified patients to either HF with reduced, mid-range or preserved ejection fraction and found BNP to most predictive in the HFrEF group, as compared to mid and preserved ejection fraction sub-groups [47]. Targeting a lower BNP at discharge has also been theorized to improve outcomes. The PRIMA II Randomized Controlled Trial (Can NT-ProBNP-Guided Therapy During Hospital Admission for Acute Decompensated Heart Failure Reduce Mortality and Readmissions?) evaluated this idea. Patients were randomized to the study group, which aimed to reduce NT-ProBNP by greater than 30% from admission values, versus conventional therapy. They found no improvement in outcomes at 6 months with this strategy [48]. A systematic review by McQuade et al. reported similar results [49].

Of the described strategies of monitoring congestion to prevent HF readmissions, pulmonary artery monitoring has become an adjunctive component to many facilities providing HF care across the country. “Cardiomems” programs can be implemented with training of a cardiac catheterization laboratory team in placement of the device and designing a workflow focused on patient education and provider familiarization with use of the web-based interface to monitor patient measurements.

Telemonitoring

Home telemonitoring is a general concept related to electronic communication between the patient and the provider. This communication is usually via phone interactions or electronic transmission of patient variables including blood pressure, weight, and clinical symptoms, at regular time points. Based on this data, the provider can detect changes in patient status and initiate outpatient management changes early in the course so as to avoid hospitalizations. These interventions can be simple medication adjustments such as increasing diuretics and up-titrating GDMT, which can safely be done while remotely monitoring heart rate and blood pressure response and tolerability. Some programs also include telephone interviews with patients by trained medical professionals, allowing them to detect changes in symptoms. Changes in patient status can then be met with medication adjustments, referral to outpatient providers, or to infusion clinics.

Although practically intuitive, the literature has been mixed regarding the efficacy of home telemonitoring programs. A meta-analysis of 25 studies evaluating the effectiveness of telephone interview and telemonitoring programs found a decrease in HF readmissions, decreased all-cause mortality, and improved quality of life [50]. However, an RCT by Blum et al. evaluating the effect of telemonitoring on 30-day readmissions and overall cost of Medicare claims found that despite a decrease in 30-day readmissions, there was no decrease in overall Medicare claims [51].

Subsequently, the Telemonitoring to Improve Heart Failure Outcomes (Tele-HF) trial was performed which randomized 1653 patients to standard care or a telemonitoring intervention protocol, which involved daily self-reporting of symptoms and weight [52]. The primary endpoint was 180-day readmission or 180-day death from any cause. The study concluded that there was no difference between conventional management and the telemonitoring group. Another negative trial, BEAT-HF, was a large RCT that randomized patients to either standard care or telemonitoring [53]. The intervention group included telephone-based health coaching as well as telemonitoring. Unfortunately, there was no significant difference in 30-day or 180-day readmission rates. The MORE-CARE trial, an international RCT, investigated the use of previously implanted CRT-D devices to remotely transfer data regarding atrial arrhythmias and pulmonary congestion to the provider [54]. The remote arm alternated data transfer remotely with in-office visits, and the control arm patients proceeded with standard in- office device checks. After a median of 24-month follow-up, there was no difference between the two arms with regard to mortality or hospitalization; however, there was a reduction in cost of care associated with less office visits. Although a promising concept, the lack of supportive data has led to limited use and funding of many telemonitoring programs in recent years.

Early follow-up and transition of care

The transition from hospital discharge to the outpatient setting is a critical time-point for patient care and safety. HF patients are at especially high risk for poor outcomes early post-discharge if they have multiple comorbidities, residual congestion, or evidence of end organ damage at the time of discharge [55]. When comparing stable ambulatory chronic heart

failure patients to acute heart failure patients requiring hospitalization, the ESC–HF–LT registry found that the acute heart failure patients had higher rates of comorbidities including ischemic heart disease, atrial fibrillation, diabetes mellitus, hypertension, COPD, previous stroke, renal dysfunction, and hepatic dysfunction. The increased mortality and hospitalizations with acute heart failure patients may be due to these multiple comorbidities or the interaction of these comorbidities with heart failure. Thus, early follow-up can help to ensure medical comorbidities are stable and optimized, in addition to HF.

Although intuitively focusing on improving transitions of care would seem to have a significant impact on HF readmissions, the support in the literature has been limited. Bradley et al. reviewed post-discharge protocols associated with lower 30-day HF readmissions, and found six strategies in particular that correlated with a decrease in readmissions [56]. Of these practices, most focused on the transition of care and included partnering with community physicians, arranging early follow-up appointments prior to discharge, and having systems in place for all discharge information to be sent directly to the primary care physician (PCP).

A clear post-discharge follow-up appointment and discharge communication have been investigated as points of focus. High-quality discharge summaries have been shown to reduce the risk of readmission for HF patients by improving communication with the PCP or primary cardiologist regarding the hospital course and the post-discharge care plan [57]. Early follow-up appointments in a relatively small population with an outpatient heart failure clinic have shown significant reduction in HF readmissions [3]. These results are not consistent; however, a large retrospective review of general medicine hospital discharge instructions found no difference in readmission rates between patients who had a follow-up appointment scheduled prior to discharge versus those without [58], while a 2004 meta-analysis by Phillips et al. found that comprehensive discharge planning combined with early post-discharge support significantly reduced readmissions [59].

These mixed results likely reflect the fact that follow-up and care-transition programs are not a one-size-fits-all solution. Interventions must be tailored to the specific institution, with knowledge of available resources, institution-specific pitfalls, and the specific patient population served.

Patient education: the pivotal role of nurses

During a hospital admission, patients spend a great deal of time with bedside nurses, developing a relationship that is ideal for the patient education necessary to help prevent readmissions. Through conversations with the patients and their families, the nurses may develop a deeper understanding of challenges patients face in managing their disease. A large component of readmission reduction programs is patient education of their disease and management techniques. This education can be performed by the bedside nurse as well as specialized HF nurse educators.

A systematic review of RCTs evaluating multidisciplinary strategies stressed the importance of nursing involvement in HF readmission reduction efforts [60]. Nurse education can be performed in any number of ways. Motivational interviewing by specialty trained HF nurses has been shown to significantly reduce HF readmissions [61]. Telephone-based interviews and education have shown similar benefits [62].

Nurse-led clinics have even been established. An RCT from Sweden evaluated the utility of nurse-led HF clinics [63]. Patients randomized to follow-up in a nurse-led clinic had an appointment 2–3 weeks after an HF hospital discharge. The clinic was run by nurses with specialty training in HF, and spent the visits educating the patients and families, evaluating volume and clinical status, and titration of medications under physician guidance. The nurse-led HF clinics reduced mortality and HF readmissions at three and 12 months, and decreased length of stay when those in the intervention group were readmitted. Another study randomized 88 patients to either usual care or nurse driven education [64]. The intervention group had a face-to-face meeting within 2 weeks of discharge from an HF hospitalization, followed by telemedicine-based education and follow-up. Cardiac trained nurses educated patients in five domains of chronic illness, including knowledge of illness, the relationship between medications and illness, the relation between behaviors and illness, recognition of early signs and symptoms of decompensation and when and how to obtain assistance. Patients in the intervention group were found to have decreased readmissions as well as decreased mortality.

The results are relatively consistent that nurse-driven education, follow-up, and interventions can reduce readmissions and decrease mortality. Specialized HF nurse educators have developed a prominent role in HF care and are a prime focus for developing strategies to reduce HF readmissions on a single-facility level.

Readmission risk calculators

Preventing unplanned short-term re-hospitalization as a target for quality improvement can address unresolved acute illness, ongoing chronic illness, and gaps in in-patient and out-patient care. Identifying patients at high risk of readmission can help not only mitigate the clinical and financial burdens of patient care but also allocate appropriate resources to these patients. Several risk scoring systems have been developed to identify patients in the general medicine population at high risk for short-term readmission. One scoring system with a significant positive predictive value is the HOSPITAL score [65]. It is composed of seven variable scores of hemoglobin, discharge from an oncology service, hyponatremia, procedure

performed at index hospitalization, urgency of index admission, number of hospitalizations in the last year, and index length of stay. The LACE index is also one of the most commonly used in predicting unplanned 30-day readmissions in the USA [66], which calculates four index scores from length of hospital stay (L), acuity of the admission (A), comorbidities of patients (C), and emergency department use of patients (E). A composite score of HOSPITAL and LACE models can predict all-cause readmission within 30 days after discharge. These predictive score models provide moderately high discriminatory power in identifying patients at high risk of 30-day readmission.

There is no such predictive risk score widely implemented in the HF population. There are few studies applying the LACE and HOSITAL predictive score systems to the HF population, but the concordance statistics level are borderline for predicting discrimination and calibration [67, 68]. Another systemic review of 26 readmission prediction models found poor performance of the prediction models in practice [69].

The lack of utility of these risk models implies that additional explanatory factors must be considered to accurately predict readmissions in HF patients. Major discriminatory features of heart failure patients are elderly age ($\geq$ 65 years) and multiple medical comorbidities which require complex medication regimens. To account for these features, a recent meta-analysis of 69 studies reported that various risk factors, in addition to those classically considered in the general medicine population, are necessary to accurately predict HF readmissions. These include poor physical condition, failure to use evidence-based medication, history of admission, and non-cardiovascular co-morbidities [70].

Most predictive score models for short-term HF readmission have relied on administrative claims data to capture HF hospitalizations, which has implicit limitations to evaluating the risk of disease progression and acuity. Using administrative data, risk factors such as disease complexity and disease acuity can be evaluated from ICD-codes at the time of discharge. However, the ability to fully address the physiologic complexity and acute illness severity without the clinical data is limited. The clinical information of diagnosis, out-patient visit, emergency room visit, medication, and laboratory outcomes, as obtained from the electronic health record system can be potential predictors that explain risk of readmission. Additionally, qualitative surveys are essential to capture non-clinical psychological, cognitive, and social environmental factors that may contribute to short-term readmissions. A recent HF prediction model by Huynh et al. in 2016 included consideration of non-clinical factors such as cognitive function, socioeconomic status, and mental health, in concert with clinical data of echocardiography findings, and produced good discrimination in predicting 30-day death or readmission [71]. However, large external validation studies are still necessary to determine its reliability.

Once well-performing prediction models are perfected and validated in larger HF populations, further studies evaluating the benefit of targeted interventions can be performed. Ideally, providers and facilities will be able to identify patients at high-risk for readmission by use of a well-validated risk calculator. Readmission reduction strategies can then be targeted to this population to increase the yield of resources devoted to reducing HF readmissions.

Patient outcomes and future directions

HF is a complex disease associated with multiple comorbidities and is greatly affected by the interaction of both health care and patient-related factors. The disease itself is characterized by a relatively high rate of short-term readmissions. In order to be effective, addressing the problem of HF readmissions should be aligned with an awareness of the natural history of the disease. HF is characterized by a series of decompensations and progressive decline in quality of life until the patient succumbs to either sudden cardiac death or pump failure and death. Once a patient's status changes from ambulatory heart failure to acute decompensated heart failure requiring hospital admission, their prognosis immediately changes. All-cause mortality jumps to 23.6% from 6.4% over the next year, and their risk for HF hospitalization over the following year doubles [25]. Thus, there is likely a limit to our collective ability to prevent HF readmissions, as estimates suggest that less than one in four readmissions for HF are truly preventable [72].

Even when we are effective at reducing HF readmissions, it has not been clearly documented that we improve patient outcomes as well. Walrave et al. recently concluded that while efforts to reduce 30-day readmissions have been successful across the country [73], with reduced readmission rates we have also seen an increase in 30-day mortality by 1.3% [2]. The other targeted diagnosis, AMI and PNA, did not suffer an increase in mortality. This data calls to question whether, for HF in particular, an arbitrary 30-day readmission rate benchmark is the best marker of hospital care effectiveness, and what the justifiable benefit to patient outcomes and cost ultimately is.

Conclusion

In response to recent institution of ACA and HRRP financial penalties, many interventions have been proposed to decrease 30-day readmission rates for a diagnosis of HF. The interventions that have been shown to be most effective focus on the initiation and identification of barriers to GDMT. The guidelines for the management of HF have been updated as of 2017 to include new medical therapies that improve survival and decrease hospital admissions. Additionally, there is robust

data for monitoring pulmonary artery pressures with an implantable device to identify pre-clinical congestion. A range of other novel and common-sense interventions have also been studied, with mixed support in the literature. The bulk of readmission reduction is likely to be achieved as a result of a comprehensive multifactorial approach [56, 74, 75] with understanding of a facility's particular patient population needs and the resources available.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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