Influence of Risk on Reduction of Readmission and Death by Disease Management Programs in Heart Failure

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ABSTRACT

Objective: Disease management programs (DMPs) may reduce short-term readmission or death after heart failure (HF) hospitalization. We sought to determine if targeting of DMP to the highest-risk patients could improve efficiency.

Methods and Results: Patients (n = 412) admitted with HF were randomized to usual care or an intensive DMP including optimizing intravascular volume status at discharge, increased self-care education, exercise guidance, closer home surveillance, and increased intensity of HF nurse follow-up. Both treatment groups were similar in demographics, medication use, Charlson comorbidity index, ejection fraction, and left ventricular and atrial volumes. Readmission or death occurred in 74/197 (37%) usual care and 50/215 (23%) DMP patients within 30 days (relative risk [RR] 0.62, 95% confidence interval [CI] 0.46−0.84), and 113/197 (57%) usual care and 78/215 (36%) DMP patients within 90 days, (RR 0.63, 9%% CI 0.51−0.78). The predicted risk of death and readmission (estimated from our previously developed risk score) was similar between treatment groups (mean predicted risk 38.6 ± 22.2% vs 39.4 ± 21.9%; $P = .73$) and similar across categories of predicted risk between the treatment groups. For 30-day readmission or death, patients from the 2 highest risk quintiles showed a benefit from intervention, and there was an interaction between intervention and predicted risk ($P = .02$). For 90-day readmission or death, most patients—other than those in the lowest-risk quintile—benefited from the intervention.

Conclusions: Use of a risk score may permit targeting of DMP to reduce HF admission. Intensive DMP may reduce short-term readmission or death, particularly in high-risk patients. (*J Cardiac Fail 2019;25:330−339*)

Key Words: Heart failure, mortality, readmission, intervention, risk score.

Heart failure (HF) is the leading cause of hospitalization and rehospitalization for adults aged >65 years.[1,2] Despite improvement in outcomes due to development in evidence-based HF medication, post-discharge readmissions among HF patients continue to increase.[2] Over the past decade, substantial attention has been focused on early readmission after an index admission of HF, especially since the inclusion of 30-day all-cause readmission or death as a major focus of quality improvement and payment reform.[3] Repeated hospitalizations are a serious economic problem, and many of these readmissions are considered preventable.

Disease management programs (DMPs) for HF have reduced early readmissions in some,[4,5] but not all,[6] studies, reflecting heterogeneity in both study populations and the DMPs themselves. Moreover, these programs are expensive, and financial constraints usually become a problem if they are applied indiscriminately to all patients.[7,8] Our recent findings show that post-discharge outcomes in HF vary substantially among different hospitals,[9] with these variations being mostly due to differences in the availability of DMPs.[9] A process of targeting high-risk patients who are most likely to benefit from the interventions would maximize efficiency, but such a process requires both an effective intervention and a risk score that is able to accurately identify high-risk patients who are most likely to benefit. We previously developed a risk score of 30-day readmission or death in HF that provides excellent discriminatory power by combining clinical and nonclinical factors,[10] and validated it on a national sample of HF patients.[11] In the

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present randomized controlled trial of a multiparametric DMP to reduce early readmission or death in HF, we applied that risk score to determine if targeted intervention is feasible and at what risk level a DMP should be initiated.

Methods

Study Sample

The multicenter Tasmanian study of heart failure readmission (ETHELRED) recruited 412 patients from 2 major Tasmanian public hospitals into a randomized controlled trial of interventions to reduce HF readmissions. These patients were identified by the confirmed primary diagnosis of HF by their treating doctors. Exclusion criteria were <18 years of age, inability to provide written consent, admission due to HF in the previous 6 months, moderate or worse primary mitral or aortic valve disease, concomitant unstable angina or acute myocardial infarction, cardiac device malfunction, endocarditis, left ventricular assist device, potentially reversible left ventricular dysfunction (including postpartum, alcoholic cardiomyopathy, and hyperthyroidism), and concomitant terminal noncardiac illnesses that could influence short-term prognosis.

Patients were entered into the study after provision of written informed consent. The trial was approved by the Tasmanian Health and Medical Human Research Ethics Committee, and the trial was registered with the Australia and New Zealand Clinical Trials Registry (ACTRN12616001303437).

Outcomes

The primary outcomes of this study were all-cause readmission (defined as at least 24 hours' unplanned stay in hospital) or death within 30 and 90 days of discharge.

Randomization and Treatment Protocol

HF patients were randomized to either usual care (n = 197) or intervention (n = 215), with stratification by left ventricular ejection fraction (LVEF <40% or ≥40%). The slightly different numbers of patients (4%) in the 2 treatment groups were probably due to having patients randomized from 2 study sites and the stratification by LVEF.

The usual care group received a standard DMP that included guideline-based care, self-care education during the hospital stay, a standard discharge plan with a formal discharge summary and advice sent to primary care physicians, treatment plan for comorbidity, and routine preventive care from treating physicians. A follow-up telephone call was conducted within a month after discharge.

In the treatment group, we undertook a multicomponent intervention that included the following.

1. Optimizing discharge timing was achieved with the use of handheld echocardiography[12] (or, if unavailable, B-type natriuretic peptide [BNP][13]) to optimize intravascular volume status at hospital discharge.[14] In patients with inadequate control of volume status, the investigators sought to delay discharge, pending better control of fluid status.
2. Additional leaflet and video instruction was provided to improve education about self-care and exercise. The self-care component was specifically designed for guiding patients on how to control HF risk factors and precipitants of exacerbations, identify warning signs, and improve self-care at home. Many of these elderly patients had impaired functional status, so exercise guidance (provided once by an exercise physiologist during the hospital stay) included strength and aerobic training.
3. Improvement of transition care sought to improve communication with primary care to reduce the change of early deterioration due to interruption of treatment, as well as to continue assessment and education in the home environment.[15] Patients in the intervention group were provided with a "transition coach" to provide at least one telephone call within 3 days after discharge and another telephone call within the second week of discharge to provide discharge support. A cardiac nurse also visited the patient at home during the first and second weeks of discharge. Additional telephone calls were provided if patients were assessed as having poor weight control or adherence to medications. These services provided an opportunity to react to any outstanding or emerging issues to prevent them from growing into more serious events, as well as to provide patients with mental and physical support. Better transition care was also targeted at enhancing the routine up-titration of HF therapy.
4. Close surveillance after discharge involved a a transition coach, an HF nurse, and a cardiologist. Early contact at home permitted reassessment of HF status (including vital signs and body weight), and patients were required to record their daily weight in a diary and notify their nurse if they gained >2 kg/wk. A scale was provided to patients who did not have one. Handheld echocardiography was used to identify hypervolemia and guide diuretic use.
5. Enhancing the response to instability: detection of possible deterioration by the surveillance team prompted discussion with the treating physician (and if necessary, hospital cardiologist) to assess the precipitant, plan drug titration (especially diuretics), and expedite review and urgent treatment if needed.

Measurements

Clinical Data. Clinical data including medical history, medications, physical measurements, and blood tests were collected. Length of hospital stay was calculated as days from admission to discharge. Weight change was calculated as the difference between admission and discharge body weight. Two-dimensional echocardiographic parameters were measured with the use of standard techniques and

procedures following the American Society of Echocardiography guidelines.[16] HF functional class was defined according to the New York Heart Association (NYHA) functional class.[17] The Charlson comorbidity index was calculated as previously described.[18] Patients' cognitive function was assessed before discharge by trained personnel with the use of the Montreal Cognitive Assessment (MoCA).[19] MoCA cutoff points of 23 and 17 were used to define mild and moderate cognitive impairment, as previously suggested.[20] Patients who did not finish college or grade 12 had 1 point added, as instructed in the MoCA protocol.[21] Depression was assessed with the use of the Patient Health Questionnaire (PHQ-9), with cutoff points of 5, 10, and 15 used to define mild, moderate, and moderately severe/severe depression, respectively.[22] Anxiety was assessed with the use of the Generalized Anxiety Disorder scale (GAD-7), with cutoff points of 5, 10, and 15 used to define mild, moderate, and severe anxiety, respectively.[23] All comorbidities with a confirmed diagnosis by the treating physicians were recorded.

Biochemistry. Blood urea, creatinine, estimated glomerular filtration rate (eGFR), and hematocrit were measured at both admission and discharge. Hematocrit was used to calculate actual plasma volume (aPV) with the use of a previously validated formula.[24] These values of aPV have been reported to mirror those measured by means of the criterion standard.[25] The ideal plasma volume (iPV) was calculated using a well established formula based solely on body weight.[26] Death and readmission in HF has been associated with the calculated relative plasma volume status (PVS),[25] calculated as PVS (%) = [(aPV − iPV)/iPV] × 100.

Demographic Data. Nonclinical data included age, sex, language background, marital status, living alone or with others, education, residential address, medical insurance, and any home care services provided. Socioeconomic status based on residential postcode was derived from the Australian Bureau of Statistics Index of Relative Socioeconomic Disadvantage.[27] The remoteness index—based on residential address—reflects how far away a geographic area is from service towns of different sizes based on road distance.[28]

A previously developed risk score of 30-day readmission or death was applied to this study.[10] This prediction model included a wide range of clinical and nonclinical predictors of HF readmission or death to provide the greatest discrimination to date (C-statistic = 0.82) and has been externally validated.[11] The intercept and regression coefficients described in the original paper were applied to each patient to estimate their predicted risk of readmission or death.

Statistical Analyses

Descriptive statistics are presented in Table 1 as percentages and number for categoric variables and as mean and standard deviation for continuous variables. Logistic regression was used to estimate the odds ratios of death or readmission within 30 and 90 days of discharge. Cox proportional hazards regression and Kaplan-Meier survival curves were used to compare days to first readmission or death between the 2 treatment groups. Stata 14.2 (Statacorp, College Station, Texas) was used for analyses.

Results

Patient Enrollment

Of 698 consecutive patients admitted due to HF, 440 were eligible for recruitment (Supplemental Fig. 1). The most common reason of exclusion was admission due to HF in the previous 6 months. Of these 440 eligible patients, 28 patients declined to participate. During the follow-up period, 13 patients (6 usual care and 7 intervention) withdrew from the study but agreed for outcome data to be collected. They were allocated according to the randomized "intention to treat" in our analyses.

Baseline Characteristics

Table 1 presents the baseline characteristics at admission of patients in the usual care and intervention groups. The majority of patients (>80%) were >65 years of age at admission and nearly one-half were living alone. Approximately 70% of patients were classified as NYHA functional class III−IV. The most common comorbidity was atrial fibrillation, followed by renal disease and diabetes.

There was no significant difference between the usual care and intervention group in any variable, including age, sex, cognitive function, mental health, medications, NYHA functional class, comorbidities, and physiologic measurements. Mean doses of commonly used HF medications at discharge are shown in Supplemental Table 1, and showed no significant differences between usual care and intervention patients.

The mean predicted risk score was similar between groups (38.6% vs 39.4%, $P = .73$) and similar across the predicted risk categories between the treatment groups (Table 1). The discriminatory power of the prediction model when applied to this study was very good for 30-day readmission or death (C-statistic = 0.75; 95% confidence interval [CI] 0.70−0.80]), but only fair for 90-day readmission or death (C-statistic = 0.65; 95% CI 0.60−0.70]).

Primary Outcomes and the Associations With Intervention

Within 30 days of discharge, there was a 38% reduction in risk of 30-day readmission or death and a 37% reduction in 30-day readmission (Table 2). The findings regarding 30-day mortality also favored the intervention group but were nonsignificant, possibly owing to the small number of deaths within the follow-up period.

Table 2 also presents a 37% reduction in risk of 90-day readmission or death, and a 38% reduction in 90-day readmission. Findings regarding 90-day mortality also favored the intervention group but were nonsignificant. This was

Table 1. Patient Baseline Characteristics

Characteristic	Usual Care (n = 197)		Intervention (n = 215)		*P* Value
Age (y)	73.9	(11.8)	74.7	(12.0)	.46
Male	51%	(101)	58%	(125)	.16
Living alone	41%	(81)	40%	(86)	.82
Length of hospital stay (d)	9.0	(16.2)	9.7	(12.4)	.33
MoCA score	19.4	(5.0)	19.1	(5.5)	.57
PHQ-9 score	7.9	(6.0)	7.6	(6.1)	.61
GAD-7 score	5.2	(5.0)	4.9	(5.1)	.52
Beta-blocker use	75%	(147)	78%	(166)	.29
ACEi/ARB use	80%	(157)	84%	(180)	.29
Diuretic use	95%	(186)	96%	(206)	.50
Aldosterone antagonist	41%	(81)	47%	(101)	.23
NYHA functional class					.34
≤II	35%	(69)	30%	(64)	
III	42%	(83)	46%	(99)	
IV	23%	(45)	24%	(52)	
Charlson comorbidity index	7.3	(2.5)	7.3	(2.4)	.98
Atrial fibrillation	55%	(107)	50%	(107)	.31
Life-threatening arrhythmia (VT or VF)	4%	(9)	4%	(9)	.85
COPD	27%	(54)	32%	(68)	.28
Chronic kidney disease	38%	(75)	36%	(76)	.61
Diabetes					.74
No	61%	(121)	63%	(135)	
Mild, without complications	29%	(58)	28%	(59)	
Complications and/or end-organ damage	9%	(18)	9%	(19)	
Heart rate (beats/min)	81	(17)	79	(18)	.10
Respiratory rate (breaths/min)	19	(3)	19	(3)	.71
NT-proBNP (pg/mL)	3676	(3218)	3506	(3092)	.64
Hematocrit (%)	38	(6)	38	(6)	.90
Serum creatinine (μmol/L)	127	(72)	132	(89)	.51
Blood urea nitrogen (mg/dL)	11.8	(6.7)	11.9	(7.3)	.81
Left ventricular ejection fraction (%)	40	(16)	39	(15)	.24
Left ventricular volume index (mL/m^2)	74	(33)	78	(36)	.20
Left atrial volume index (mL/m^2)	54	(24)	56	(23)	.31
Right atrial pressure (mm Hg)	8	(5)	8	(5)	.69
Predicted risk (%)	38.6	(22.2)	39.4	(21.9)	.73

Data are presented as mean (SD) for continuous variables and % (n) for categoric variables. MoCA, Montreal Cognitive Assessment; PHQ-9, Patient Health Questionnaire 9 items; GAD-7, Generalized Anxiety Questionnaire 7 items; ACEi/ARB, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker; NYHA, New York Heart Association; VT, ventricular tachycardia; VF, ventricular fibrillation; COPD, chronic obstructive pulmonary disorder; NT-proBNP, N-terminal pro−B-type natriuretic peptide.

again possibly due to small number of deaths within the follow-up period.

Taking total days in hospital into consideration, the usual care patients stayed 1 more day ($P = .30$) in hospital than those in the intervention group within the 30-day follow-up, and 3 more days ($P = .024$) within the 90-day follow-up.

Table 3 presents readmission or death at 30 and 90 days after discharge for patients in the 2 groups, stratified by quintiles of predicted risk. Within 30 days of discharge, there was a 38% reduction in 30-day readmission or death in the intervention compared with the usual care group. Patients from the 2 study sites were slightly different in age

Table 2. Readmission or Death at 30 and 90 Days After Discharge Among Patients in the Usual Care and Intervention Groups

Primary Outcome		Group	n/N	RR	(95% CI)
30-day outcomes	Readmission or death	Usual care	74/197	1.00	Ref
		Intervention	50/215	0.62	(0.46−0.84)
	Readmission only	Usual care	64/197	1.00	Ref
		Intervention	44/215	0.63	(0.45−0.88)
	Death only	Usual care	18/197	1.00	Ref
		Intervention	12/215	0.61	(0.30−1.24)
90-day outcomes	Readmission or death	Usual care	113/197	1.00	Ref
		Intervention	78/215	0.63	(0.51−0.78)
	Readmission only	Usual care	88/197	1.00	Ref
		Intervention	60/215	0.62	(0.48−0.81)
	Death only	Usual care	30/197	1.00	Ref
		Intervention	23/215	0.70	(0.42−1.17)

RR, relative risk.

Table 3. Readmission or Death at 30 and 90 Days After Discharge, Cross-Classified by Level of Risks and Treatment Arm

	Predicted Risk (%)		30-Day Readmission or Death				90-Day Readmission or Death			
			Usual Care		Intervention		Usual Care		Intervention	
Quintile of Predicted Risk	Usual Care Mean ± SD	Intervention Mean ± SD	n/N	(%)	n/N	(%)	n/N	(%)	n/N	(%)
1st	13 ± 4	12 ± 4	1/44	(2%)	3/39	(8%)	17/44	(39%)	8/39	(21%)
2nd	24 ± 3	24 ± 3	10/40	(25%)	9/42	(21%)	26/40	(65%)	11/42	(26%)
3rd	35 ± 4	36 ± 4	11/35	(31%)	8/48	(17%)	20/35	(57%)	16/48	(33%)
4th	51 ± 5	49 ± 5	24/42	(57%)	11/40	(28%)	31/42	(74%)	17/40	(42%)
5th	74 ± 9	73 ± 10	28/36	(78%)	19/46	(41%)	29/36	(81%)	27/46	(59%)
Overall			74/197	(37%)	50/215	(23%)	113/197	(57%)	78/215	(36%)

at admission (2 years; $P = .013$). However, there was no significant association of study sites with outcomes ($P = .5$ for 30-day outcomes; $P = .45$ for 90-day outcomes). Adjusting for study sites did not alter our results.

With each increment in predicted risk, there was an increase in 30-day readmission or death in both treatment groups, with a steeper slope for usual care patients (Fig. 1A). Thus, patients with higher risks appeared to benefit more from the interventions in reducing 30-day readmission or death. Specifically, only intervention patients within the 4th and 5th quintiles of predicted risk had significantly lower probability of 30-day readmission or death compared with their counterparts in the usual care group.

There was a 37% reduction in 90-day readmission or death in the intervention compared with the usual care group (Table 2). HF patients, except those in the 1st quintile of predicted risk, benefited from the interventions in reducing 90-day readmission or death (Fig. 1B).

Figure 2 shows days to readmission or death among HF patients from the 2 groups stratified by quintiles of predicted risk. Patients in the intervention group—except those within the 1st quintile of predicted risk—had significantly delayed readmission or death compared with their counterparts in the usual care group. On average, the intervention group delayed their first readmission by 32 days compared with the usual care group ($P = .005$).

Risk-Targeting Intervention

Figure 3 illustrates the relationship between predicted risk (as a continuous variable) and observed 30-day readmission or death among the intervention and usual care group. Consistent with findings from Figure 1, there was a significant interaction between intervention and predicted risk for 30-day readmission or death. Specifically, the reduction in 30-day readmission or death was greatest for patients with highest predicted risks. This interaction was, however, not significant for 90-day readmission or death.

Results of Intervention

Table 4 summarizes the in-hospital progress of each group. The greater change in estimated PVS in the treatment group matched a nonsignificant greater weight loss. PVS at both admission (relative risk [RR] 1.01; $P = .028$) and discharge (RR 1.02; $P = .002$) were associated with 30-day readmission or death. When mutually adjusted, PVS at discharge had a more dominant effect on outcomes than that of PVS at admission. There was no difference in eGFR.

When further stratifying by quintiles of predicted risk, differences in length of hospital stay between groups increased with the level of predicted risk. Patients from the highest risk category (5th quintile) had the greatest difference in length of hospital stay ($P = .045$) between the

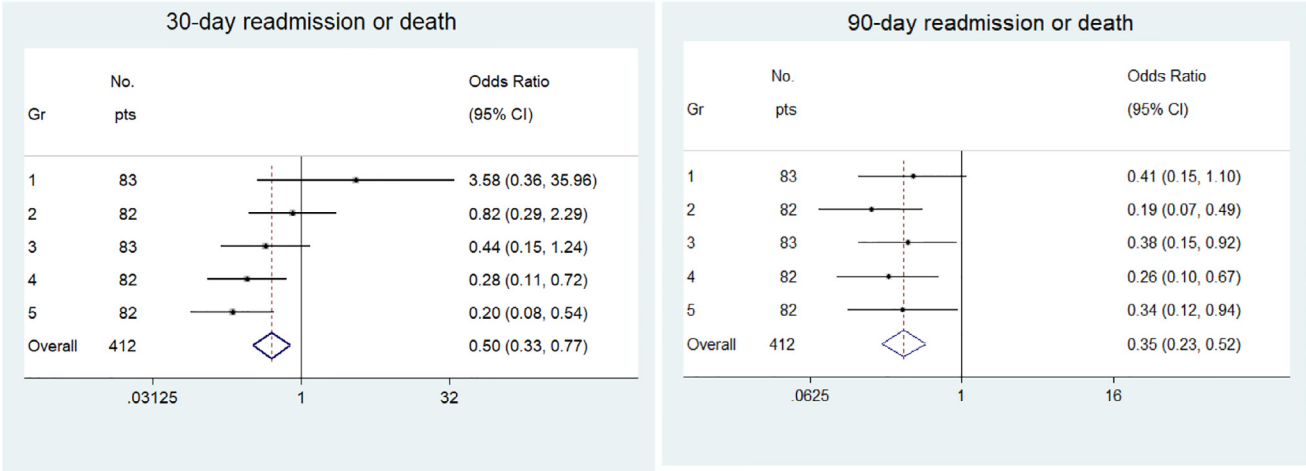

Fig. 1. The effects of interventions on readmission or death at (A) 30 days and (B) 90 days after discharge, stratified by quintile of predicted risk.

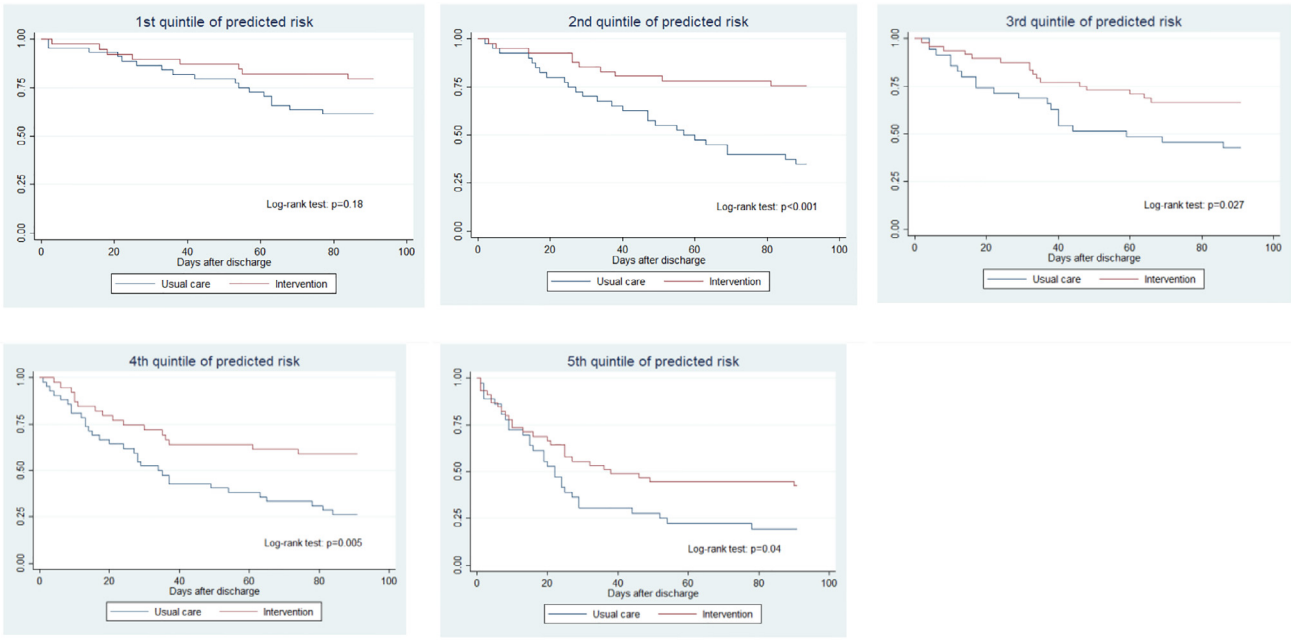

Fig. 2. Days to readmission or death stratified by treatment group and quintile of predicted risk.

intervention (16.7 ± 13.3 days) and usual care (10.5 ± 12.2 days) groups, as the result of our intervention to delay discharge to optimize volume status. Differences in changes of PVS were greatest among the 2nd highest risk category (4th quintile: −3.5%; $P = .024$), followed by the highest risk category (5th quintile: −2.3%; $P = .05$). These data are presented in Supplemental Table 2. Weight and eGFR changes were quite similar across the risk categories.

Supplemental Table 3 presents the results of the intervention among HF patients who were cross-classified by treatment groups and whether they experienced an event (death or readmission) within 30 days of discharge. Compared with usual care patients, intervention patients had significantly greater changes in PVS regardless of whether or not they had an event within 30 days. The magnitude of changes in PVS was, however, greater among intervention patients without an event than those with an event.

Discussion

This randomized trial shows that a multicomponent intervention provides reduction of events within 30 and 90 days after discharge. There was evidence of benefit in HF patients with high predicted risk of readmission or death for the 30-day outcomes, and in most HF patients—except those in the lowest-risk quintile—for the 90-day outcomes. The reduction in risk of 30-day readmission or death among patients in the intervention group compared with the usual

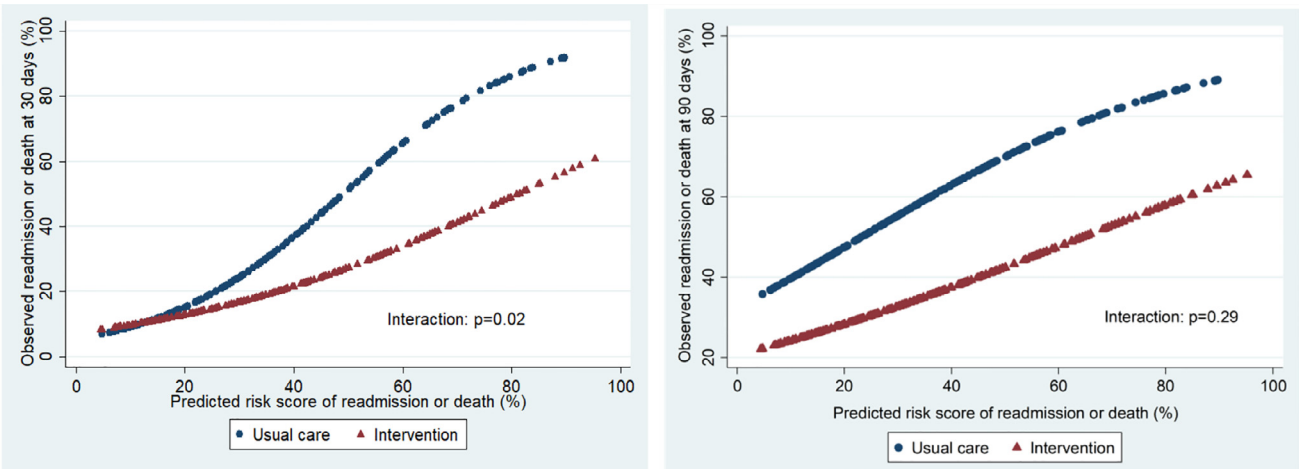

Fig. 3. The relationship between predicted risk and observed probability of readmission or death at (A) 30 days and (B) 90 days after discharge.

Table 4. Responses to Treatment in the Usual Care and Intervention Groups

Variable	Usual Care	Intervention	*P* Value
Length of hospital stay (d)	9.1 ± 13.5	9.7 ± 12.4	.67
Weight at admission (kg)	83.9 ± 24.1	83.4 ± 24.2	.82
Weight change (kg)	−2.0 ± 6.2	−2.6 ± 3.8	.15
Estimated PVS at admission (%)	−7.2 ± 11.2	−6.5 ± 11.9	.54
Estimated PVS change (%)	0.7 ± 6.1	−1.9 ± 5.9	<.001
eGFR at admission ($mL \cdot min^{-1} \cdot 1.73\ m^{-2}$)	56.9 ± 26.8	55.9 ± 25.5	.69
eGFR change ($mL \cdot min^{-1} \cdot 1.73\ m^{-2}$)	−3.4 ± 14.2	−1.4 ± 14.0	.17

PVS, plasma volume status; eGFR, estimated glomerular filtration rate.

care group was greatest in those at high risk. The interventions also resulted in a delay of approximately 1 month before the first readmission.

Risk-Targeting Intervention

Although targeting DMPs to high-risk patients has been suggested previously,[29] models of predicting readmission risk were insufficiently discriminatory to permit them to guide intervention. The present application of our previously validated model[10,11] to patients from a randomized controlled trial has proven for the first time that targeting intervention is feasible and that patients at higher risks may benefit more from the interventions.

Although the exact level of risk showing a benefit from intervention will require closer study, findings from this study suggest that it may depend on the outcome of interest. For a short-term outcome such as 30-day readmission or death, only high-risk patients within the 4th and 5th quintiles of predicted risk showed significant benefits from the interventions. For a longer-term outcome such as 90-day readmission or death, the benefits of interventions may extend to a lower threshold of predicted risks (from the 2nd quintile of predicted risk). Regardless of what outcomes may be used, our findings suggest that it is feasible to identify low-risk patients who are unlikely to benefit from interventions.

The nonsignificant interaction between the intervention and predicted risk for 90-day outcomes may be due to the following. First, the predictive risk score we applied to this study was specifically developed for predicting 30-day readmission or death.[10] Its discrimination was therefore much greater for the 30-day outcomes (C-statistic = 0.77) than for the 90-day outcomes (C-statistic = 0.71) as shown in our validated study,[11] and might have been insufficient to provide an accurate risk stratification for 90-day outcomes. Our interventions were also confined to the 30-day follow-up period and were therefore more effective in preventing adverse outcomes at 30 days, especially for the high-risk patients. This may explain the noninteraction between the intervention and outcomes at 90 days that was observed in our study. Second, HF patients are at highest risk of an adverse outcome during the short period after hospital discharge. Indeed, a recent study of >3 million patients from nearly 5000 hospitals showed that risk of first readmission—which peaked during the first month—declined by 50% by 38 days after discharge and reached a plateau by 7 weeks after discharge.[30] These findings suggest that patients who made it through the first month after discharge without an adverse outcome may have progressed to a new phase of recovery with a lower level of risk. This speculation is supported by our recent findings from an Australia-wide observational study of HF that whereas variations in 30-day readmission among hospitals were explained by both the availability of a DMP and HF severity, variations in 90-day readmission were explained mostly by DMP.[9] This may explain the much lower risk of 90-day readmission or death in our intervention patients compared with the usual care patients.

Control of Volume Status in Heart Failure

Although clinical signs and symptoms (weight gain, dyspnea, peripheral edema, and elevated jugular venous pressure) are features of HF, they are neither sensitive nor specific markers of volume status.[31−33] In this study, we used handheld echocardiography to examine the inferior vena cava (IVC), lung comets, and pleural effusion, which are closely related to congestion and decompensation among HF patients. These signs are easily assessable with the use of ultrasound but may be difficult to detect with the use of clinical examination and chest x-ray.[34,35] Previous studies have also shown that ultrasound assessment of IVC and pleural cavities are predictive of adverse outcomes[35] and right atrial pressure,[36] which has been identified as an important predictor of 30-day readmission or death in HF.[10]

Although HF patients show marked reduction in symptoms following diuretic therapy despite consistent elevations in BNP and poor IVC collapsibility,[37] discharging patients based simply on clinical signs and symptoms may leave a number of patients still hypervolemic at discharge. Although vital signs, clinical signs/symptoms and routine laboratory tests (including assessment of renal function) all failed to predict 30-day readmission, HF patients with repeated hospitalizations had larger IVC size, lower IVC collapsibility and greater pre-discharge BNP.[37] Although BNP may not predict instantaneous volume status as echocardiography does owing to its slow response to hemodynamic changes, it has been suggested to better reflect long-term volume status.[38,39] Combining echo and BNP as in our study may therefore provide the benefit of having a bigger

picture of volume changes over time and thereby better guide treatment.

Echocardiography is the single most useful diagnostic test in the evaluation of patients with HF and an accurate methodology to assess volume status.[12] However, doing a full scan on every HF patient before discharge to optimize intravascular volume status is expensive and time consuming. Handheld echocardiography as used in our study—which has not been described in other studies in this context—not only offers a cheap and rapid assessment of volume status, but also provides high sensitivity and specificity.[14]

Self-Care and Education

Self-care is key to improving outcomes in HF, but it is often poor because of impaired cognition, depression, anxiety, presence of multiple comorbidities, and older age, all of which are highly prevalent in the HF population. In our study, patients were assessed for cognitive impairment (MoCA), depression (PHQ-9), and anxiety (GAD-7), which are all potential contributors to poor health maintenance, treatment adherence and capacity for self-care. Our previous findings have shown that cognitive function is a strong predictor of readmission or death in HF, second only to HF severity,[10] and that even mild cognitive impairment independently predicts short-term adverse outcomes in HF.[40]

Cognition in HF patients might respond to improvement of cardiac function with heart transplantation,[41] medications,[42,43] and exercise training,[44] and often shows some improvement after hospital discharge, matching the resolution of acute illness and inpatient sleep deprivation. This is a problem for most previous trials because they provided HF education during the inpatient stay.[45] We provided increased education (through leaflet and video instruction and direct counseling) after discharge to ensure understanding of the causes and consequences of HF, symptom recognition, purpose of medicines, the need of fluid restriction, and HF risk factors.

Previous findings have demonstrated that patients delay for days before reacting to HF symptoms, probably because of a failure to routinely monitor symptoms or an inability to recognize or interpret symptoms when they occur.[46] Despite educational efforts, most HF patients do not weigh themselves even intermittently and do not consider weight change to be of significant concern.[47,48] Patients who weigh themselves regularly are reported to have been associated with better health outcomes.[47] In our study, scales were provided and intervention patients were required to record their daily weight in a diary and notify the research nurse if they gained >2 kg/wk.

Intensity of Follow-Up

Previous home-visiting trials have reported 30-day all-cause readmission rates in HF. Jaarsma et al,[6] who provided 1 telephone call within 7 days of discharge and 1 home visit within 10 days of discharge, reported no reduction in readmission rate (RR 0.89, 95% CI 0.43−1.85]). Naylor et al[4] provided a highly intensive follow-up with a series of at least 8 home visits (including the first visit within 24 hours after discharge). Although those investigators reported a major reduction (RR 0.3, 95% CI 0.19−0.62]) in risk of all-cause readmission in the intervention group, the adoption of a high-intensity home-visiting program to reduce 30-day readmission in HF would be costly. Identifying the highest risk patients and periods may maintain effectiveness and reduce cost.

HF patients are most vulnerable for deterioration in the first and second weeks of discharge, and effective follow-ups during this period allow early assessment and improvement of patients' self-care ability.[15] Our intensive interventions within the first 2 weeks after discharge included early follow-up telephone calls (one call within the first 3 days discharge and another call within the second week) and home visits (1 visit/wk during the first 2 weeks after discharge). These services provided us with an opportunity to react to any outstanding or emerging issues to prevent them from growing into more serious events, as well as to provide patients with mental and physical support. Although determining the right frequency of follow-up for maximal cost-effectiveness requires closer study, our program is at least as effective as previous interventions[6] with limited resources.[4]

In the present study, about one-half of the readmissions were due to non-HF causes, which was consistent with findings from previous studies.[49,50] This reflects the high frequency of multiple comorbidities in the HF population and stresses the importance of multidisciplinary interventions.

Study Limitations

This study has several limitations. First, we excluded patients who had an admission due to HF during the 6 months before study entry. This condition helped us to filter out patients with repeated cycles of decompensated HF, among whom reductions in readmission might be most difficult, but may limit the generalizability of our findings. Second, the process of evaluation and selected high-intensity follow-up with this strategy is potentially costly, although this cost is likely offset by savings from reduced admissions. Nonetheless, a detailed cost-effectiveness analysis would be important. Third, reduction in short-term readmission or death was likely a result of the combined effects from multiple interventions, and we were unable to determine which element was most important. Clearly, eliminating unnecessary interventions would improve the cost-effectiveness of this strategy. Finally, it was impossible to blind patients from whether or not they were receiving the intervention during the study. However, readmission (defined as $\geq$24-hour stay in hospital) was not within the control of the study investigators, so this design was unlikely to have influenced our findings.

Conclusion

Intensive intervention may reduce 30-day readmission or death in HF, particularly in high-risk patients. The use of an effective risk score may permit targeting of interventions to reduce HF admission. Further follow-up of this study will inform how long the effects of these interventions may remain and whether it is cost-effective to repeat the interventions to maintain long-term effects.

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Disclosures

None.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.cardfail.2019.01.015.

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