Original Research

Impact of a Telehealth and Care Management Program on All-Cause Mortality and Healthcare Utilization in Patients with Heart Failure

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Abstract

Background: *Telehealth has the potential to improve chronic disease management and outcomes, but data regarding direct benefit of telehealth in patients with heart failure (HF) have been mixed. The objective of this study was to determine whether the Health Buddy Program (HBP) (Bosch Healthcare, Palo Alto, CA), a content-driven telehealth system coupled with care management, is associated with improved outcomes in Medicare beneficiaries with HF.* ***Materials and Methods:*** *This was a retrospective cohort study of 623 Medicare beneficiaries with HF offered HBP enrollment compared with a propensity score-matched control group of Medicare beneficiaries with HF from the Medicare 5% sample. Associations between availability of the HBP and all-cause mortality, hospitalization, hospital days, and emergency department visits were evaluated.* ***Results:*** *Beneficiaries offered enrollment in the HBP had 24.9% lower risk-adjusted all-cause mortality over 3 years of follow-up (hazard ratio [HR] = 0.75; 95% confidence interval [CI], 0.63–0.89;* $p = 0.001$*). Patients who used the HBP at least once (36.9%) had 57.2% lower mortality compared with matched controls (HR = 0.43; 95% CI, 0.31–0.60;* $p < 0.001$*), whereas patients who did not use the HBP had no significant difference in survival (HR = 0.96; 95% CI, 0.78–1.19;* $p = 0.69$*). Patients offered the HBP also had fewer hospital admissions following enrollment (*$\Delta = -0.05$ *admissions/quarter;* $p = 0.011$*), which was primarily observed in patients who used the HBP at least once (*$\Delta = -0.10$ *admissions/quarter;* $p < 0.001$*).* ***Conclusions:*** *The HBP, a content-driven telehealth system coupled with care management, was associated with significantly better survival and reduced hospitalization in Medicare beneficiaries with HF. Prospective study is warranted to determine the mechanism of this association and opportunities for optimization.*

Key words: *telemonitoring, survival, Medicare, heart failure, outcomes*

Introduction

Heart failure (HF) is the leading hospital discharge diagnosis in patients >65 years old in the United States and costs approximately $30 billion annually.[1] HF is particularly costly in Medicare patients, accounting for approximately 37% of all costs and 50% of inpatient costs in part because of the high prevalence of comorbid conditions.[2] Despite advances in therapy, approximately 50% of HF patients will die within 5 years of diagnosis.[1] Remote monitoring has been identified as a potential approach to managing HF patients and can range from phone contacts to complex systems that remotely acquire patient data.[3,4] Telehealth is a type of remote monitoring that uses communication technology to transmit patient data to providers.[5] Telehealth can be delivered by interactive systems to engage patients in management of their health and to detect signs of disease progression so providers may intervene prior to decompensation.[6]

Data regarding the impact of telemonitoring on HF outcomes have been mixed, and routine use of telemonitoring is not currently part of management guidelines.[7] A Cochrane Review found that telemonitoring was associated with a reduction in all-cause mortality and all-cause hospitalizations,[8] whereas the Telemonitoring to Improve Heart Failure Outcomes Trial (Tele-HF), the largest trial of telemonitoring to date, showed no improvement in outcomes in recently hospitalized HF patients compared with routine care.[9]

Many studies have focused on associations between patient outcomes and unaccompanied telemonitoring rather than telemonitoring integrated with care plans and/or patient education. For example, Tele-HF sites were encouraged to act on abnormal patient-reported values but were not provided prespecified responses. Indeed, the Cochrane Review of telemonitoring concluded "The aim for future use of

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structured telephone support and telemonitoring should be to use these interventions to tailor HF disease management programs to the population needs and resources, to the geography of the population and most importantly, to patient preferences."[8]

The Health Buddy Program (HBP) (Bosch Healthcare, Palo Alto, CA) couples care management with the Health Buddy, an electronic device with a high-resolution screen and four large buttons located in patients' homes and connected to remote care managers. The Health Buddy asks patients daily for vital signs and other health-related information (e.g., "Are you more fatigued, tired, and/or unable to do routine activities like cooking, dressing, bathing over the past two weeks?"), providing feedback and education based on responses (e.g., "Increased fatigue or tiredness, and an inability to do your daily routine may be a sign of worsening heart failure").[6] After each session, the Health Buddy transmits patient data to the Health Buddy server, after which HBP categorizes patients as low, medium, or high risk based on daily responses using algorithms developed in accordance with evidence-based guidelines. Once a patient's risk status is determined, data are transmitted to the Health Buddy Desktop Application where providers could monitor patient status and triage follow-up. Depending on a patient's estimated risk, care managers may initiate interventions such as calling the patient, notifying the physician, or scheduling an office appointment for the patient. The Health Buddy Desktop Application also identifies patients who have not responded to their daily sessions, and action may be taken by care managers depending on duration and reason for nonresponse.[10]

A Centers for Medicare and Medicaid Services (CMS) demonstration study of Medicare beneficiaries with HF, chronic obstructive pulmonary disease, or diabetes mellitus suggested that patients offered the HBP had a risk-adjusted reduction in all-cause mortality over 2 years (20.3% versus 23.0%).[11] Furthermore, patients offered enrollment in the HBP had an 18% reduction in all-cause hospitalizations compared with matched controls, and mortality benefits over 2 years were significant for HF patients in subgroup analysis.[12] We present a retrospective analysis of HF patients who were offered enrollment in the HBP CMS demonstration study over 3 years. We hypothesized that Medicare beneficiaries with HF offered the HBP would have reductions in all-cause mortality and healthcare utilization compared with matched controls. We also hypothesized that HBP patients who actively used the system would have a greater benefit than those who did not.

Materials and Methods

The design of the HBP CMS demonstration project has been described previously.[11] The study used a population-based "community intervention" design within a specific geographic area.[10] The study did not randomize patients but rather compared health status and resource utilization of enrollees at baseline to the demonstration period. An initial cohort was identified in 2006, followed by a second cohort in 2007 to expand the study and account for attrition. Medicare Parts A and B claims data were obtained for all patients offered enrollment in the HBP, and data from control patients were obtained from the CMS 5% sample. Demographics and outcomes were derived using claims data, and disease conditions were identified using International Classification of Disease, Ninth Revision, Clinical Modification-9 (ICD-9 CM) terms. If a patient died, date of death was determined using enrollment files linked to Social Security Administration death records.

For the present analysis, patients were selected if at least one inpatient claim or two claims in any other setting with an ICD-9 CM code for HF (398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 428.xx) occurred within 12 months of the start of the program. Intervention patients were classified as "engaged" if they used the Health Buddy at least once during the study period, whereas patients were classified as "nonengaged" if they never used the Health Buddy. The details of identifying the overall sample of control patients have been described previously.[11] In brief, control HF patients who resided in areas geographically similar to Bend, OR and Wenatchee, WA were selected from Medicare beneficiaries in the CMS 5% sample using the same ICD-9 CM criteria as for the intervention patients.

The primary outcome for this analysis was time to all-cause mortality over 3 years after being offered HBP enrollment. Secondary outcomes were changes in quarterly measures of healthcare resource utilization from baseline to the end of the study period including all-cause inpatient admissions, all-cause hospital days (conditional on hospitalization), and all-cause emergency department (ED) visits. As described previously, data from quarters immediately preceding and following HBP initiation were excluded to account for uncertainty regarding exact start date, and the quarter of a patient's death was excluded due to increased resource utilization immediately prior to death.[11,12]

The HBP demonstration project was designed to improve coordination of care and could potentially impact multiple types of outcomes. Accordingly, we matched on the propensity of being offered the HBP to enable evaluation of multiple outcomes including hospitalization, hospital days, and ED visits. Propensity matching helped identify control patients most similar to HBP patients prior to the intervention as described previously.[11,12] The propensity of being offered the HBP was estimated using logistic regression. Baseline

characteristics potentially associated with being offered HBP enrollment were considered, including demographics, comorbid conditions, overall health indicators (e.g., Medicare Hierarchical Condition Category score, Elixhauser comorbidity index, and high-risk comorbidities), total healthcare costs, all-cause resource utilization (e.g., hospitalizations, outpatient visits, ED visits, and healthcare provider visits), and HF-related healthcare utilization (e.g., hospitalizations and ED visits with a diagnosis of HF). A high-risk comorbidity was defined as any condition that could impede use of the Health Buddy device (see Supplementary Data; available online at www.liebertpub.com/tmj).

Baseline comorbidities were identified based on the presence of at least two claims (excluding laboratory and radiology claims) with related ICD-9 CM codes. Healthcare provider visits were defined as outpatient nonlaboratory services provided by physicians, physician assistants, or nurses. To optimize the match between intervention and control patients, separate algorithms were used for the 2006 and 2007 cohorts. Control and HBP patients were matched 1:1 with replacement based on closest propensity scores. A matched control with a propensity score within 0.01 was required for each intervention patient.

Mortality rates during the study period were compared descriptively using chi-squared tests. Unadjusted survival rates were compared between the intervention and control samples using Kaplan–Meier estimates. Cox proportional hazards models were used to compare the relative risk of all-cause mortality between intervention and control patients adjusting for year of enrollment and significant differences ($p < 0.10$) in baseline characteristics after propensity matching for being offered the HBP. Changes in quarterly healthcare resource utilization in the baseline and study period were compared using *t* tests for continuous variables. Relative utilization changes were estimated using panel negative binomial models adjusting for year of enrollment and significant differences in baseline characteristics after matching. The significance of each prediction was estimated using bootstrapping. Analyses were repeated comparing subgroups of engaged and nonengaged intervention patients to their matched controls. A p value <0.05 was considered significant.

Results

In total, 644 intervention and 658 potential matched controls were analyzed. Of the 644 intervention patients, 21 were excluded because matched controls could not be identified based on propensity scores. Therefore, 623 patients and 623 matched controls were included in the analysis. Baseline characteristics were similar between the cohorts with the exception of age, depression, diabetes mellitus, ocular disorders, and high-risk comorbidities (*Table 1*). Among the intervention beneficiaries, 230/623 patients (36.9%) used the Health Buddy at least once. Those who engaged the Health Buddy entered information 389 ± 310 days on average during the study period. Characteristics of engaged and nonengaged patients are shown in *Table 2*. The only significant differences between engaged and nonengaged beneficiaries were age (76.9 ± 8.8 versus 79.8 ± 9.1 years; $p < 0.001$) and baseline outpatient visits in the previous year (16.0 ± 12.2 versus 14.0 ± 12.8; $p = 0.005$).

All-cause mortality during the study period was 39.0% in the intervention group and 46.4% among matched controls ($p = 0.008$) (*Table 3*). Mortality risk in the intervention cohort was significantly lower than the control cohort (adjusted hazard ratio [HR] = 0.75; 95% confidence interval [CI], 0.63–0.89; $p < 0.001$) (*Fig. 1*) adjusting for age, liver disease, depression, diabetes mellitus, ocular disorders, sleep disorders, end-stage renal disease, and high-risk comorbidities. The reduction in mortality risk was greatest among engaged patients who had substantially lower overall mortality (25.2% versus 47.8%; $p < 0.001$) (*Table* 3) and adjusted mortality risk compared with matched controls (adjusted HR = 0.43; 95% CI, 0.31–0.60; $p < 0.001$) (*Fig. 2*). Engaged intervention patients showed reduced mortality within the first study year (6.1% versus 15.2%; $p < 0.001$) that persisted throughout the study period. There was no significant difference in either overall mortality (47.1% versus 45.5%; $p = 0.67$) or adjusted mortality risk among nonengaged patients offered the HBP compared with matched controls (HR = 0.96; 95% CI, 0.78–1.19; $p = 0.69$) (*Fig. 3*).

Changes in healthcare utilization are shown in *Table 4*. A reduction of 22.7% in quarterly hospitalizations was noted in intervention patients versus matched controls ($\Delta = -0.05$ hospitalizations/quarter; 95% CI, −0.09 to −0.01; $p = 0.012$). As with mortality, this reduction was limited to engaged patients who had a 43.5% reduction in quarterly hospitalizations ($\Delta = -0.10$; 95% CI, −0.16 to −0.04; $p = 0.002$), whereas the difference between nonengaged patients and matched controls was not significant ($\Delta = -0.02$; 95% CI, −0.07 to 0.03; $p = 0.49$). There were no significant differences between intervention and matched control cohorts in all-cause hospital days per quarter or all-cause ED visits. Results were similar after adjusting for significant differences in baseline characteristics between the two groups.

Discussion

This propensity score-matched cohort analysis of Medicare beneficiaries is one of the largest HF studies to date of

Table 1. Baseline Characteristics of Intervention Heart Failure Patients Versus Matched Controls

CHARACTERISTIC	INTERVENTION	CONTROL	*P* VALUE[a]
Number of patients	623	623	
Demographics			
Mean age (years)	78.76 ± 9.08	77.39 ± 8.59	0.005
Male	353 (56.7%)	326 (52.3%)	0.125
Under 65 years of age	28 (4.5%)	29 (4.7%)	0.892
Baseline comorbidities[b]			
CHF-related comorbidities			
Anemia	113 (18.1%)	113 (18.1%)	1.000
Anxiety, somatoform disorders, and personality disorders	24 (3.9%)	17 (2.7%)	0.266
Chronic atherosclerosis	233 (37.4%)	225 (36.1%)	0.638
Chronic liver disease	3 (0.5%)	9 (1.4%)	0.082
COPD	208 (33.4%)	187 (30.0%)	0.201
Dementia	9 (1.4%)	5 (0.8%)	0.282
Depression	26 (4.2%)	12 (1.9%)	0.021
Diabetes mellitus	262 (42.1%)	217 (34.8%)	0.009
Hypercholesterolemia	52 (8.3%)	63 (10.1%)	0.282
Hypertension	309 (49.6%)	314 (50.4%)	0.777
Malnutrition	2 (0.3%)	1 (0.2%)	1.000
Cancer	152 (24.4%)	140 (22.5%)	0.422
Myocardial infarction	25 (4.0%)	24 (3.9%)	0.884
Ocular disorder	217 (34.8%)	258 (41.4%)	0.017
Osteoporosis and osteoarthritis	11 (1.8%)	14 (2.2%)	0.544
Peripheral vascular disease	55 (8.8%)	48 (7.7%)	0.471
Renal failure	79 (12.7%)	92 (14.8%)	0.285
Respiratory failure	20 (3.2%)	16 (2.6%)	0.499
Cerebrovascular disease	36 (5.8%)	41 (6.6%)	0.556
Valvular heart disease	60 (9.6%)	72 (11.6%)	0.269
Obesity	11 (1.8%)	10 (1.6%)	0.826
Thyroid disorder	37 (5.9%)	34 (5.5%)	0.714
Sleep disorder	9 (1.4%)	3 (0.5%)	0.082
Pneumonia	77 (12.4%)	86 (13.8%)	0.450
Overall health indicators			
Mean adjusted Elixhauser comorbidity index	1.95 ± 1.29	2.00 ± 1.36	0.584
Mean HCC score	2.55 ± 0.97	2.58 ± 1.03	0.995
End stage renal disease	8 (1.3%)	16 (2.6%)	0.099
Exclusionary comorbidity	55 (8.8%)	77 (12.4%)	0.043
Cost categories			
Mean total healthcare costs	$19,838 ± $22,671	$20,383 ± $24,422	0.685
Resource utilization			
All-cause resource utilization			
Mean number of all-cause inpatient visits	0.86 ± 1.16	0.87 ± 1.11	0.428
Mean number of all-cause outpatient visits	14.71 ± 12.57	16.47 ± 14.83	0.306
Mean number of all-cause ED visits[c]	1.29 ± 1.65	1.57 ± 2.19	0.409
Mean number of all-cause healthcare provider visits[d]	24.98 ± 19.22	26.22 ± 18.53	0.072
CHF-related resource utilization			
Mean number of CHF-related inpatient visits	0.18 ± 0.51	0.12 ± 0.35	0.220
Mean number of CHF-related ED visits[c]	0.18 ± 0.55	0.20 ± 0.59	0.684

[a]Univariate comparisons of central tendencies used Wilcoxon tests for continuous variables and chi-squared tests for categorical variables.

[b]Baseline comorbidities were diagnosed based on at least two claims with the related ICD-9 codes, excluding laboratory or radiology claims.

[c]Emergency department (ED) visits were defined by claims in an institutional setting (inpatient and outpatient) with revenue center code "045."

[d]Healthcare provider visits were defined as services (excluding lab-related) provided by physicians, physician assistants, and nurses in any noninstitutional setting.

CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; HCC, hierarchical condition categories.

Table 2. Baseline Characteristics of Engaged Heart Failure Patients Versus Nonengaged Intervention Heart Failure Patients

CHARACTERISTIC	ENGAGED HEALTH BUDDY[a]	NONENGAGED[a]	*P* VALUE[b]
Number of patients	230	393	
Demographics			
Mean age (years)	76.90 ± 8.79	79.84 ± 9.08	< 0.001
Male	141 (61.3%)	212 (53.9%)	0.074
Under 65 years of age	12 (5.2%)	16 (4.1%)	0.505
Baseline comorbidities[c]			
CHF-related comorbidities			
Anemia	42 (18.3%)	71 (18.1%)	0.952
Anxiety, somatoform disorders, and personality disorders	12 (5.2%)	12 (3.1%)	0.176
Chronic atherosclerosis	97 (42.2%)	136 (34.6%)	0.060
Chronic liver disease	1 (0.4%)	2 (0.5%)	1.000
COPD	81 (35.2%)	127 (32.3%)	0.459
Dementia	3 (1.3%)	6 (1.5%)	1.000
Depression	14 (6.1%)	12 (3.1%)	0.068
Diabetes mellitus	92 (40.0%)	170 (43.3%)	0.427
Hypercholesterolemia	21 (9.1%)	31 (7.9%)	0.589
Hypertension	115 (50.0%)	194 (49.4%)	0.878
Malnutrition	(0.0%)	2 (0.5%)	0.534
Cancer	58 (25.2%)	94 (23.9%)	0.716
Myocardial infarction	12 (5.2%)	13 (3.3%)	0.241
Ocular disorder	81 (35.2%)	136 (34.6%)	0.877
Osteoporosis and osteoarthritis	5 (2.2%)	6 (1.5%)	0.545
Peripheral vascular disease	19 (8.3%)	36 (9.2%)	0.703
Renal failure	26 (11.3%)	53 (13.5%)	0.430
Respiratory failure	10 (4.3%)	10 (2.5%)	0.218
Cerebrovascular disease	12 (5.2%)	24 (6.1%)	0.646
Valvular heart disease	29 (12.6%)	31 (7.9%)	0.054
Obesity	1 (0.4%)	10 (2.5%)	0.062
Thyroid disorder	12 (5.2%)	25 (6.4%)	0.560
Sleep disorder	6 (2.6%)	3 (0.8%)	0.083
Pneumonia	29 (12.6%)	48 (12.2%)	0.885
Overall health indicators			
Mean adjusted Elixhauser comorbidity index	1.99 ± 1.40	1.92 ± 1.23	0.867
Mean HCC score	2.63 ± 1.03	2.51 ± 0.93	0.236
End stage renal disease	2 (0.9%)	6 (1.5%)	0.717
Exclusionary comorbidity	18 (7.8%)	37 (9.4%)	0.500
Cost categories			
Mean total healthcare costs	$21,471 ± $23,492	$18,882 ± $22,152	0.186
Resource utilization			
All-cause resource utilization			
Mean number of all-cause inpatient visits	0.87 ± 1.10	0.85 ± 1.19	0.519
Mean number of all-cause outpatient visits	15.98 ± 12.16	13.97 ± 12.75	0.005
Mean number of all-cause ED visits[d]	1.18 ± 1.44	1.35 ± 1.76	0.453
Mean number of all-cause healthcare provider visits[e]	27.12 ± 21.13	23.74 ± 17.91	0.066
CHF-related resource utilization			
Mean number of CHF-related inpatient visits	0.15 ± 0.48	0.19 ± 0.53	0.170
Mean number of CHF-related ED visits[d]	0.17 ± 0.52	0.19 ± 0.57	0.533

[a]Patients "engaged" the Health Buddy if they inputted information into the Health Buddy device at least once during the study period. Otherwise they were classified as "nonengaged."

[b]Univariate comparisons of central tendencies used Wilcoxon tests for continuous variables and chi-squared tests for categorical variables.

[c]Baseline comorbidities were diagnosed based on at least two claims with the related ICD-9 codes, excluding laboratory or radiology claims.

[d]Emergency department (ED) visits were defined by claims in an institutional setting (inpatient and outpatient) with revenue center code '"045."

[e]Healthcare provider visits were defined as services (excluding lab-related) provided by physicians, physician assistants, and nurses in any noninstitutional setting.

CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; HCC, hierarchical condition categories.

Table 3. Mortality Rates During the Study Period for Intervention Heart Failure Patients Versus Matched Controls

SAMPLE	INTERVENTION	CONTROL	*P* VALUE[a]
Engaged Health Buddy ($n=230$/arm)[b]	58 (25.2%)	110 (47.8%)	<0.001
Nonengaged ($n=393$/arm)[b]	185 (47.1%)	179 (45.5%)	0.668
Overall ($n=623$/arm)	243 (39.0%)	289 (46.4%)	0.008

Patients were followed up for 3 years or until death in the study period.

[a]*p* values were calculated using chi-squared tests.

[b]Patients "engaged" the Health Buddy if they inputted information into the Health Buddy device at least once during the study period. Otherwise they were classified as "nonengaged."

telehealth coupled with care management and shows availability of the HBP was associated with a 24.9% reduction in all-cause mortality and a 22.7% reduction in quarterly hospitalizations relative to matched controls. These findings were driven by a 57.2% reduction in mortality and a 43.5% reduction in quarterly hospitalizations in the 36.9% of beneficiaries who used the HBP at least once during the study period. Although our findings need validation, they suggest that the success of a telehealth system in improving outcomes in HF may be related to two important factors beyond the remote clinical data collected by the system: (1) the degree of patient engagement with the system and (2) the patient population itself. The manner in which remote monitoring data are presented to and used by providers and the inclusion of interactive patient education may also be a factor but was not directly addressed in this analysis. Optimization of data management and presentation, integration into provider workflow, and better understanding of predictors of patient engagement with telehealth systems like the HBP might also improve effectiveness, and further study is warranted.

The association between the HBP and improved survival might be explained by at least three mechanisms: (a) a direct beneficial effect of the HBP on clinical care delivery, (b) improved patient self-management associated with the HBP leading to better outcomes, or (c) HBP engagement as a marker for patients predisposed to effective self-management and healthcare utilization. Prior studies have found that use of the HBP was associated with greater compliance with prescription medications,[13] titration of medications,[14] and compliance with nonpharmacologic recommendations,[15] suggesting the HBP likely improved both care delivery and patient self-management, which may have contributed to reductions in mortality and hospitalization observed in the present study. In addition, secondary analyses of multiple randomized trials have shown improved outcomes in patients who demonstrate high pharmacologic adherence in the placebo arm comparable to those receiving the study drug, supporting the possibility that patient engagement may be a marker for other beneficial characteristics.[16–18] The lack of patient-level data in this analysis, particularly data on adherence to non-HBP interventions and provider responses to evidence of patient deterioration, makes it difficult to determine the mechanism of potential benefit from the HBP. Prospective studies to elucidate the mechanism linking HBP engagement and improved survival in this trial may help define the role of the HBP and other telehealth technologies in HF management.

The Telemonitoring in Patients with Heart Failure (TEHAF) trial was a randomized study that investigated the association

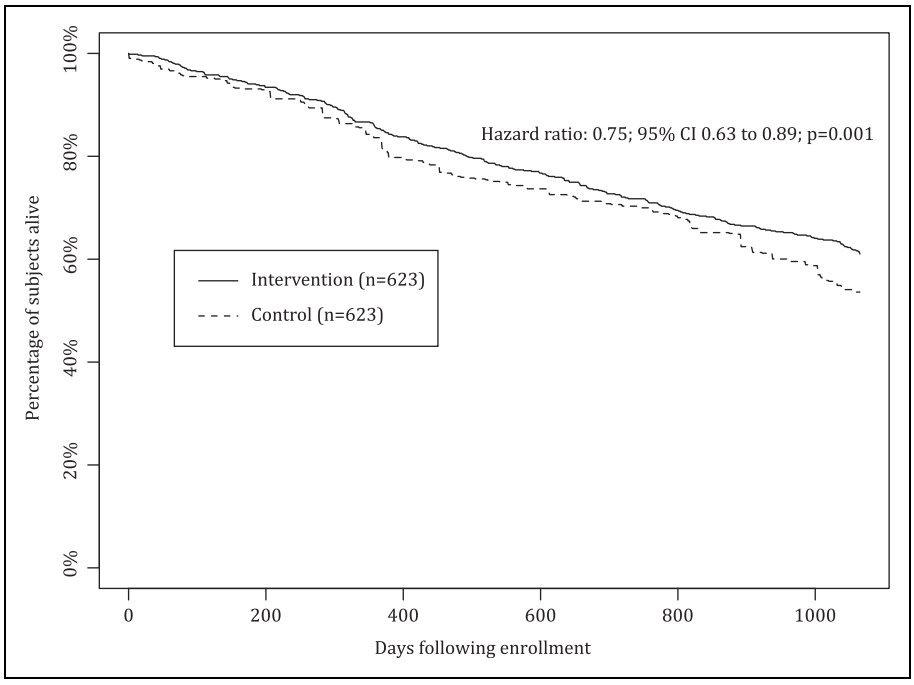

Fig. 1. Overall survival for intervention heart failure patients versus matched controls. The primary outcome of mortality risk in the intervention cohort was significantly lower than that in the control cohort (adjusted hazard ratio = 0.75; 95% confidence interval [CI], 0.63–0.89; $p=0.001$).

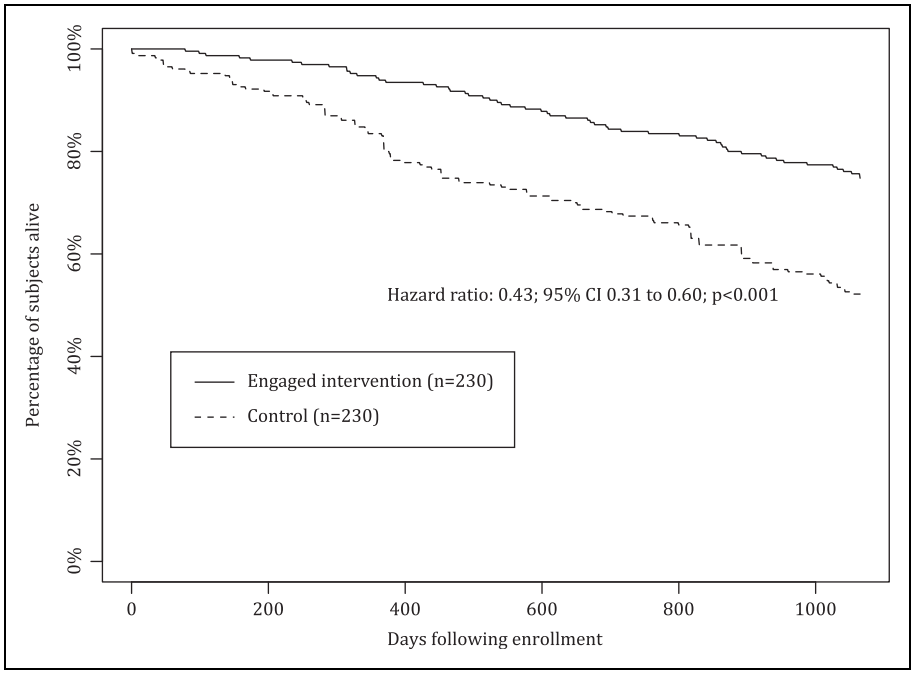

Fig. 2. Overall survival for engaged intervention heart failure patients versus matched controls. The reduction in mortality risk was greatest among the engaged patients, who had substantially lower relative mortality risk compared with matched controls (adjusted hazard ratio = 0.43; 95% confidence interval [CI], 0.31–0.60; $p < 0.001$).

between the HBP and HF outcomes but found no reduction in HF hospitalizations or mortality during 1 year of follow-up.[19] Due in part to a lower than expected hospitalization rate and shorter study period compared with the present analysis (1 versus 3 years), TEHAF was underpowered to evaluate its outcomes. The rate of adverse outcomes may also have been low because patients were recruited from HF clinics and had high degrees of adherence at baseline to recommended HF therapies such as beta-blockers (82%) and angiotensin-converting enzyme inhibitors or angiotensin receptor antagonists (90%). Impact of patient engagement was not tested, but the authors reported an overall daily dialogue compliance of 90% with the HBP, a metric of compliance not available in our study. Limitations of the present study and TEHAF preclude firm conclusions that explain the contrasting results, but it is likely that patient populations and baseline management strategies were different. It is therefore possible that the HBP benefits some patient populations more than others.

Tele-HF randomized 1,653 patients recently hospitalized with HF to either telephone-based monitoring or guideline-based usual care and failed to detect a difference in the composite endpoint of readmission or death over 18 months.[9] In total, 85.6% of patients activated the system at least once, suggesting a higher level of engagement than in the present study. Unlike the HBP, the voice-response system in Tele-HF was not interactive and did not contain an education component. Patient contact was driven by clinician assessment of patient status rather than as an integral part of the system design, and the authors speculated that an interactive system may have been more effective.[9]

The Telemedical Interventional Monitoring in Heart Failure (TIM-HF) randomized stable ambulatory HF patients on optimal medical therapy from internal medicine

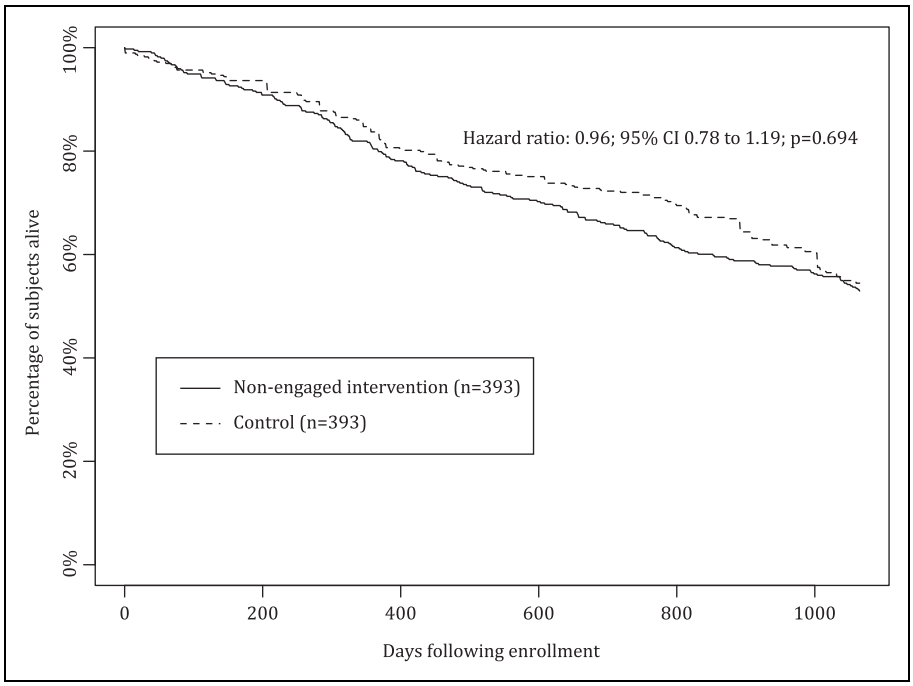

Fig. 3. Overall survival for nonengaged intervention heart failure patients versus matched controls. There was no significant difference in mortality risk among nonengaged patients who were offered the Health Buddy Program compared with matched controls (adjusted hazard ratio = 0.96; 95% confidence interval [CI], 0.78–1.19, $p = 0.69$).

Table 4. Healthcare Resource Use Comparison for Intervention Heart Failure Patients Versus Matched Controls

	INTERVENTION		CONTROL		UNADJUSTED RELATIVE CHANGE (95% CI)[b]	P VALUE[c]	ADJUSTED RELATIVE CHANGE (95% CI)[d]	P VALUE[c]
	BASELINE	STUDY[a]	BASELINE	STUDY[a]				
Quarterly number of inpatient admissions[e]								
Engaged Health Buddy	0.23	0.14	0.18	0.19	−0.10 (−0.16, −0.04)	0.002	−0.12 (−0.18, −0.05)	<0.001
Nonengaged	0.21	0.19	0.21	0.19	−0.02 (−0.07, 0.03)	0.491	−0.01 (−0.05, 0.05)	0.956
Overall	0.22	0.17	0.20	0.19	−0.05 (−0.09, −0.01)	0.012	−0.05 (−0.09, −0.01)	0.011
Hospital days per quarter, conditional on hospitalization[e]								
Engaged Health Buddy	5.04	6.11	5.72	5.96	0.83 (−1.33, 2.99)	0.449	0.91 (−0.39, 3.13)	0.127
Nonengaged	5.23	6.09	5.73	6.16	0.44 (−0.89, 1.76)	0.518	0.68 (−0.54, 1.83)	0.287
Overall	5.15	6.10	5.72	6.09	0.59 (−0.56, 1.73)	0.316	0.60 (−0.21, 1.65)	0.131
Quarterly number of emergency room visits[f]								
Engaged Health Buddy	0.28	0.24	0.31	0.29	−0.01 (−0.09, 0.07)	0.776	−0.05 (−0.13, 0.03)	0.254
Nonengaged	0.34	0.33	0.37	0.32	0.05 (−0.03, 0.12)	0.226	0.07 (0.01, 0.16)	0.033
Overall	0.32	0.29	0.35	0.31	0.02 (−0.04, 0.07)	0.492	0.02 (−0.03, 0.08)	0.310

[a]Patients were followed up for 3 years or until death in the study period.

[b]Unadjusted relative change was calculated as (Intervention sample study period outcome – Intervention sample baseline period outcome) – (Control sample study period outcome – Control sample baseline period outcome).

[c]Univariate comparisons of central tendencies used *t* tests for continuous variables.

[d]Predictions were estimated with panel-negative binomial models. Control variables were those criteria with p values of < 0.1 after matching.

[e]Quarterly number of inpatient admissions was calculated based on the average total number of inpatient claims in each quarter. Inpatient admissions that occurred during the last quarter of a patient's baseline year, the first quarter of a patient's study period, and the same quarter that a patient died were not included in the analysis.

[f]Emergency room visits were defined by claims in an institutional setting (inpatient and outpatient) with revenue center code "045." Quarterly number of emergency room visits was calculated based on the average total number of emergency room visits in each quarter. Emergency room visits that occurred during the last quarter of a patient's baseline year, the first quarter of a patient's study period, and the same quarter that a patient died were not included in the analysis.

CI, confidence interval.

practices to usual care or telemonitoring using a wireless system to collect electrocardiogram measurements, blood pressure, weight, and a patient self-assessment. As with Tele-HF, patient contact was initiated based on patient data. The system was not interactive and had no education component.[20] No reduction in mortality was observed after 26 months. A high rate of patient engagement was observed, but outcomes in engaged and nonengaged patients were not compared.[21] Based on these results, the authors concluded that remote telemonitoring does not improve survival in stable, optimally treated patients with HF. In addition to the intrinsic differences in the telemonitoring systems between TIM-HF and the present study, it was not possible to determine whether patients in the present study were receiving optimal HF treatment at baseline or how this may have changed following HBP initiation. It is therefore possible that baseline medical therapy and/or medical compliance after HBP enrollment may partially explain differences in outcomes between the studies.

This study has several limitations. It was a retrospective study, and all findings must be validated. Although the control cohort was constructed using rigorous propensity-score matching, unobserved differences between the intervention and control cohorts may have affected outcomes. Predictors of patient engagement that were unavailable may also lead to improved HF outcomes independent of HBP use, in which case the propensity match may have been incomplete. Because they were taken from the CMS 5% sample, control patients received care from different clinical sites than intervention patients, and some observed differences in outcomes could have been due to clinic-specific variations in care. Because the current study was restricted to HF patients in the Pacific Northwest, results may not be generalizable to other regions or patient populations. Temporal granularity in the Medicare data was limited to quarters, and associations between daily HBP data were not studied. Future analyses that associate patient-level data from the HBP with clinical events may help

determine the role of the HBP in improving outcomes. In addition, this study was based solely on Medicare claims data but did not include Medicare Part D, so patient-level clinical and pharmacy data were not available to verify accuracy of diagnoses, determine quality of HF therapy, or assess medical compliance. Consequently, a prospective randomized controlled trial of the HBP including medication adherence data is necessary to validate our findings.

Conclusions

Availability of the HBP, a content-driven telehealth system coupled with care management, was associated with improved survival and reduced hospitalization for Medicare beneficiaries with HF driven by substantial benefits to patients who used the system. Further investigation into the mechanisms of this benefit and methods for optimizing patient engagement may enhance the benefit of the HBP and other telehealth platforms.

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Disclosure Statement

J.L. has consulted for Medtronic, Boston Scientific, St. Jude, Abbott, and RESMED. D.P.K. has consulted for Gliimpse, Inc. D.M., H.G.B., J.L.J., and U.S.D. are employees of Analysis Group, Inc. R.L.P. II declares no competing financial interests exist.

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