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The E-Coach technology-assisted care transition system: a pragmatic randomized trial

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Abstract

Care transitions from the hospital to home remain a vulnerable time for many patients, especially for those with heart failure (CHF) and chronic obstructive pulmonary disease (COPD). Despite regular use in chronic disease management, it remains unclear how technology can best support patients during their transition from the hospital. We sought to evaluate the impact of a technology-supported care transition support program on hospitalizations, days out of the community and mortality. Using a pragmatic randomized trial, we enrolled patients (511 enrolled, 478 analyzed) hospitalized with CHF/COPD to "E-Coach," an intervention with condition-specific customization and in-hospital and post-discharge support by a care transition nurse (CTN), interactive voice response post-discharge calls, and CTN follow-up versus usual post-discharge care (UC). The primary outcome was 30-day rehospitalization. Secondary outcomes included (1) rehospitalization and death and (2) days in the hospital and out of the community. E-Coach and UC groups were similar at baseline except for gender imbalance ($p = 0.02$). After adjustment for gender, our primary outcome, 30-day rehospitalization rates did not differ between the E-Coach and UC groups (15.0 vs. 16.3 %, adjusted hazard ratio [95 % confidence interval]: 0.94 [0.60, 1.49]). However, in the COPD subgroup, E-Coach was associated with significantly fewer days in the hospital (0.5 vs. 1.6, $p = 0.03$). E-Coach, an IVR-augmented care transition intervention did not reduce rehospitalization. The positive impact on our secondary outcome (days in hospital) among COPD patients, but not in CHF, may suggest that E-Coach may be more beneficial among patients with COPD.

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Keywords

Care transitions, Telehealth, Self-management

Implication

Policymakers: The benefit of post-discharge support in COPD patients suggests different needs from those with heart failure and supports the need for personalized post-discharge care approaches as part of population health policies.

Researchers: Research is still needed to better understand which components of the IVR may be influencing hospital readmission rates so that systems can be further refined for optimal outcomes.

Practitioners: To optimize care after discharge, a tiered approach may be required with patient activation/coaching for those with moderate needs (COPD) and active medical support and guidance added to coaching for particularly complex patients (CHF).

INTRODUCTION

For complex medical patients, the inpatient to home-based care transition is a challenging and vulnerable time. Approximately 20 % of recently discharged patients experience adverse events such as adverse drug events and procedure-related injuries [1, 2]. In addition, a recent survey of more than 15,000 hospitalized patients found that 12 % reported new or worsening symptoms within 5 days of leaving the hospital [3]. Furthermore, one quarter of recently hospitalized Medicare beneficiaries experience readmissions, with 8 % resulting in death during the 30-day post-hospitalization time period [4]. Given the high rate of negative sequelae following hospitalization, it is critically important to identify and evaluate strategies for improving patient management during the transition to home.

Care transition interventions commonly focus on assessment, patient activation, and patient engagement around four common gaps that often occur during the transition from hospital discharge to home. Care transition interventions seek to address (1) lack of patient knowledge of medication self-management, (2) lack of a patient-centered medical record owned and maintained by the patient to facilitate cross-site information transfer, (3) inconsistent follow-up with primary or specialty care, and (4) patient or caregiver

lack of knowledge about warning signs and symptoms indicating a worsening condition and how to respond to them (red flags) [5–9]. One such care transition intervention, conducted by Coleman et al., reduced rehospitalization rates by 30 % at 30 days and 26 % at 90 days among chronically ill older patients [5]. However, the intervention (home visits and proactive phone calls) was resource-intensive. Other successful care transition interventions [6–9] have further demonstrated challenges of scalability, especially in geographically dispersed populations, limiting adoption of the evidence-based interventions as part of standard hospital discharge practices [10]. Technology-assisted interventions (such as automated telehealth) have been used to support the implementation of chronic disease management but have not been extensively evaluated in the context of care transitions.

In the outpatient setting, technology-assisted interventions have been used to enhance the efficiency of care delivery, to remind patients of appointments, to monitor disease status at home, and to increase health-promoting behaviors [11–13]. Technologies, including interactive voice response systems (IVR), could efficiently conduct proactive monitoring, thereby reducing effort required by nurse coaches. In IVR systems, human voice is replaced by an interactive, recorded script which respondents provide answers to by pressing keys on the touchpad of a phone [14]. IVRs have demonstrated some efficacy in chronic disease management, including screening, preventive services, and medication adherence [15–17]. IVR can obtain information from patients, deliver tailored instructions, and allow for remote monitoring [18]. Previous studies of IVR interventions have used quasi-experimental designs [19, 20] and clinical trials [16, 21] but have had mixed results; very little rigorous work has been done to evaluate IVR interventions focused on care transitions; thus a rigorous, real-world study of an IVR-based intervention to support care transitions in congestive heart failure (CHF) and chronic obstructive pulmonary disease (COPD) was needed.

We developed E-Coach, a technology-assisted care transition intervention designed to reduce the burden on care transition nurses (CTN) engaging in traditional care transition interventions, which often involves home visits and multiple live "proactive" phone calls [22]. E-Coach integrates a proactive daily assessment IVR system (which eliminates proactive calls by CTNs) with a web-accessible dashboard for CTN. We hypothesized that the E-Coach intervention would result in improvements in 30-day care transition outcomes (outcomes include (1) readmission rates (primary outcome), (2) readmission or death, and (3) number of days in hospital vs. community), compared with a usual care control group. This manuscript summarizes the use of the system and readmission outcomes of a pragmatic randomized trial of E-Coach in a diverse sample of complex adults with CHF or COPD from a wide geographic region in the southern USA.

METHODS

Study design

The E-Coach study was a stratified randomized controlled clinical trial. Randomization was stratified by condition (CHF and COPD), self-rated health status based on the SF-1, and race. The SF-1 is a single item assessment of generic health status. It is the first question of the well-validated Medical Outcomes Study Short-form 35 (SF-36) instrument and asks "In general, how would you rate your health?" with response options of "excellent, very good, good, fair, or poor" [23]. A detailed study protocol, including the statistical analysis plan, has been previously published [22]. The trial had a number of pragmatic aspects [24], including that the implementation of the system was supported by our healthcare system partner, not research funding [22]. We also allowed flexibility on the part of CTNs in recruitment and follow-up. Although we did provide patient incentives for follow-up data collection, note that we did not incentivize patients for completing IVR calls, allowing for heterogeneity of intervention fidelity, or intervention dose, as further detailed below.

Setting and participants

Recruitment was conducted at an urban academic hospital, which serves as a safety net for low resourced rural and urban populations and serves central and northern Alabama, between February 2010 and November 2011. Participants were identified through daily census lists and environmental scans of floors that commonly admit COPD and CHF patients. Upon identification of a potential participant, a research assistant (RA) met with the patient and/or their caregiver, described the study, and obtained written consent to enroll in the cohort. This cohort was followed for a period of 90 days, which ended in March 2012. The sample consisted of English-speaking patients who were included in the study if they were admitted to the hospital from home with CHF or COPD, had an estimated prognosis of greater than 6 months, had a telephone, and were expected to be discharged to their home. Patients with impaired cognition as defined by a Short Blessed Test of Orientation, Memory, and Concentration [25] of 6 or greater were eligible for the intervention if they had a caregiver available and willing to serve as proxy. Patients were excluded from participation if they were being considered for heart transplant or placement of a ventricular assist device (VAD), receiving ongoing dialysis or receiving intensive monitoring services for cystic fibrosis.

Full ethical approval was received from the University of Alabama at Birmingham Institutional Review Board. All subjects (or their proxies) provided written informed consent for study participation.

Randomization and interventions

E-Coach intervention–The E-Coach intervention included an in-hospital assessment and discretionary post-

discharge support by a CTN, an IVR-supported care transition system that called patients after discharge, and a dashboard for the CTN to review the data recorded by the patient in the computer system. These three intervention components were predicated on patient activation to avoid unnecessary hospitalizations and are detailed below.

CTNs received training in motivational interviewing [26] and in care transition intervention approaches [5]. Patients allocated to the intervention were seen by a CTN prior to discharge, at which time the CTN assessed patient and caregiver goals. Based on patient goals that were specified during motivational interviews, the CTN addressed relevant issues including medication self-management, use of a patient-centered record, primary care and specialist follow-up, and knowledge of warning signs and symptoms. The framework underlying the self-management approach was adapted from the Care Transition Model [5, 27, 28]. The focus of the CTN was on skill transfer to the patient with ongoing monitoring through E-Coach to gauge adequacy of this skill transfer. Caregivers were not precluded from participating in the patient's care; however, the focus of the IVR calls and the CTN follow-up was on the patient, not the caregiver. The IVR was used to measure red flags during follow-up.

The CTN also provided training on the IVR care transition support and monitoring system. The IVR was introduced as "Ida" (Interactive Discharge Assistant). The Ida IVR was programmed [22] to perform three primary functions: (1) collect data from patients tailored to CHF or COPD that would be considered transitional care "red flags" in accordance with the care transitions literature [5] (e.g., questions about medications, escalating symptoms, insufficient clinical follow-up); (2) provide customized patient education and motivation during the Ida IVR calls based on patients' response to questions; and (3) alert the CTN when patient responses to the Ida IVR indicated patient red flags. Ida IVR calls, though structured similarly, differed in content between COPD and CHF (see Table 1 for example questions for both conditions). Ida calls were designed to have a typical duration of less than 5 min. Following a practice call, participants informed the CTN what time of day would be the preferred time to receive a call from Ida. After discharge, Ida was programmed to call all patients daily for 7 days and then either daily or every 3 days, depending on patient preference, for an additional 21 calls (28 calls total).

As noted above, the Ida IVR was designed to denote red flags of concerning patient responses that were then communicated to the CTN through a web-accessible care transition dashboard and did not specifically look at the goals set during the in-person visit with the CTN. Patients who were experiencing high symptom burden or significant gaps related to medication management, patient follow-up, or understanding of their overall treatment plan would trigger red flags within the system. When red flags were triggered, the CTN contacted the patient to offer additional support, based on the patient-entered data. Support for patient self-management was provided through telephone-based coaching interactions when needed, up to 60 days after discharge.

Usual discharge care comparison–The E-Coach intervention group was compared to usual discharge care for CHF and COPD patients. Usual care at our hospital constituted standardized discharge and post-discharge care received by CHF and COPD patients. Floor nurses conducted discharge planning activities that included identifying and giving patients written discharge instructions covering activity level, diet, follow-up, disease monitoring, what to do if symptoms worsen, and discharge medications. A subset of patients received additional support from social work services or a referral for home health services. Usual discharge care patients did not receive post-discharge Ida IVR calls, monitoring, or coaching.

Randomization–We conducted a stratified randomized trial. Patients with COPD and CHF were randomized separately, using two separate randomization trials. Participants were identified through daily census lists of hospital units where patients with COPD or CHF are often admitted. After informed consent and baseline data collection was completed by the research assistant, participants were randomized, stratified by condition (COPD or CHF), using a permuted block design (block sizes of 2 and 4). For each condition additional stratification was performed at the time of randomization. To assure balance, randomization was further stratified by health status (dichotomized as SF-1: excellent/very good/good vs. fair/poor). Race was over-sampled in order to assure an adequate sample of African-Americans in the sample (goal: 40 % of the sample). Randomization was performed through a computer-based random number generator. For patients randomized to the intervention, a computer-generated alert was sent to the CTNs, who then met with the patient prior to discharge. Research personnel recruiting patients and study team members assessing outcomes were blinded to random group assignment. Each study participant received $50 for participation in the study.

Outcomes and follow-up

Outcomes–As stated, our hypothesis was that the E-Coach intervention would result in improvements in 30-day care transition outcomes compared with a usual care control. Outcomes were measured including rehospitalization, mortality, and measure of community tenure.

Our prespecified primary outcome was 30-day rehospitalization. Rehospitalization was defined as any all-cause readmission within a specific timeframe (30 days). A related secondary outcome combined 30-day rehospitalization and mortality.

An additional secondary outcome, community tenure (number of patient days spent in the hospital vs. in the home) at 30 days was a count of days. These numbers included those without any admissions (e.g., number of

Table 1 | Exemplar interactive voice response systems questions for congestive heart failure (**a**) and chronic obstructive pulmonary disease (**b**)

CHF_WtGain	Have you had weight gain greater than 2 pounds in the past 24 hours?	1	Yes
		2	No
CHF_WtGainSeverity	How much weight have you gained?		
CHF_Swelling	Do you have swelling in your legs?	1	Yes
		2	No
CHF_SwellSeverity	Would you say that you have mild, moderate or severe swelling?	1	Mild
		2	Moderate
		3	Severe
CHF_SwellNewSXDay1	For SurveyNo1 (Is this a change in swelling from when you left the hospital?)	1	Yes
		2	No
CHF_SwellNewSx	For SurveyNo2-28 (Is this a change in swelling from when you last called you?)	1	Yes
		2	No

COPD_COUGH	Are you coughing up stuff?	1	Yes
		2	No
COPD_StfColorThk	Has the stuff you cough up changed in color or thickness?	1	Yes
		2	No
COPD_Fever	Do you have a fever?	1	Yes
		2	No
COPD_PufferUse	Are you using your puffer or inhaler more than usual on a daily basis?	1	Yes
		2	No

days in hospital = 0). The rationale for this outcome is to provide more detail on a patient-centered measurement (the number of days at home). This outcome adds information beyond dichotomous 30-day rehospitalization, recognizing that not all hospitalizations are the same and that longer rehospitalizations are less desirable.

All outcomes were assessed by patient/caregiver self-report via telephone interview by trained data collectors blinded to study arm. Rehospitalization data were verified for patients rehospitalized to the same academic health center through chart abstraction.

Intervention dosing (intervention fidelity)–To measure the "dose" of intervention received, we tracked IVR participation rates, number of red flags detected, and number of nurse coach follow-up calls completed using Ida and the CTN dashboard. A "full dose" of E-Coach was defined as answering all Ida calls. We define answering a call as a patient completing the questions on that call. An "optimal dose" in the most vulnerable post-discharge period was defined as daily response to the IVR during the first seven days.

Covariates–Baseline demographics, socioeconomics characteristics, and other patient background information were collected by data collectors before patient discharge from the hospital and before randomization. A single item, asking "How confident are you filling out medical forms by yourself?", from the Wallace health literacy assessment was used to measure health literacy status [29]. Cumulative illness rating scale geriatrics (CIRS-G) was used to assess comorbidity and illness severity [30].

Sample size

Our target sample size was 241 subjects per group to provide 80 % power to detect a difference in the main outcome, rehospitalization rates, of 17.7 versus 8.7 or 22 versus 12 % using two-sided chi-square tests [22].

Statistical analysis

Participants who died or became ineligible for the intervention prior to discharge (e.g., discharged to institution) were excluded from analyses (see Fig. 1). All patients for whom follow-up data was available were analyzed as randomized regardless of the dose of the E-Coach intervention they had received. Chi-square tests were used to test for differences between randomization groups in categorical variables, while Student's t tests were used to test for differences in continuous variables.

We hypothesized that the E-Coach intervention would result in improvements in 30-day care transition outcomes (outcomes include 1) readmission rates (primary outcome), (2) readmission or death, and (3) number of days in hospital vs. community), compared with a usual care control group. For testing of outcomes, bivariate and multivariable models were conducted. For the primary outcome (readmission), we calculated Kaplan-Meier curves and developed multivariable models using Cox proportional hazards regression (for time to rehospitalization) adjusting for baseline differences between groups. For the second outcome (readmission or death), Kaplan-Meier curves and Cox proportional hazards analyses also were performed to examine the composite endpoint. For our secondary hypothesis (sub-hypothesis 3), adjusted quasi-Poisson regressions were conducted for our secondary outcome of days in hospital versus at home (community tenure). All analyses were performed with CHF and COPD groups combined and also stratified by condition.

We also report the number of red flags and number of calls completed by CTNs to patients, as an estimate

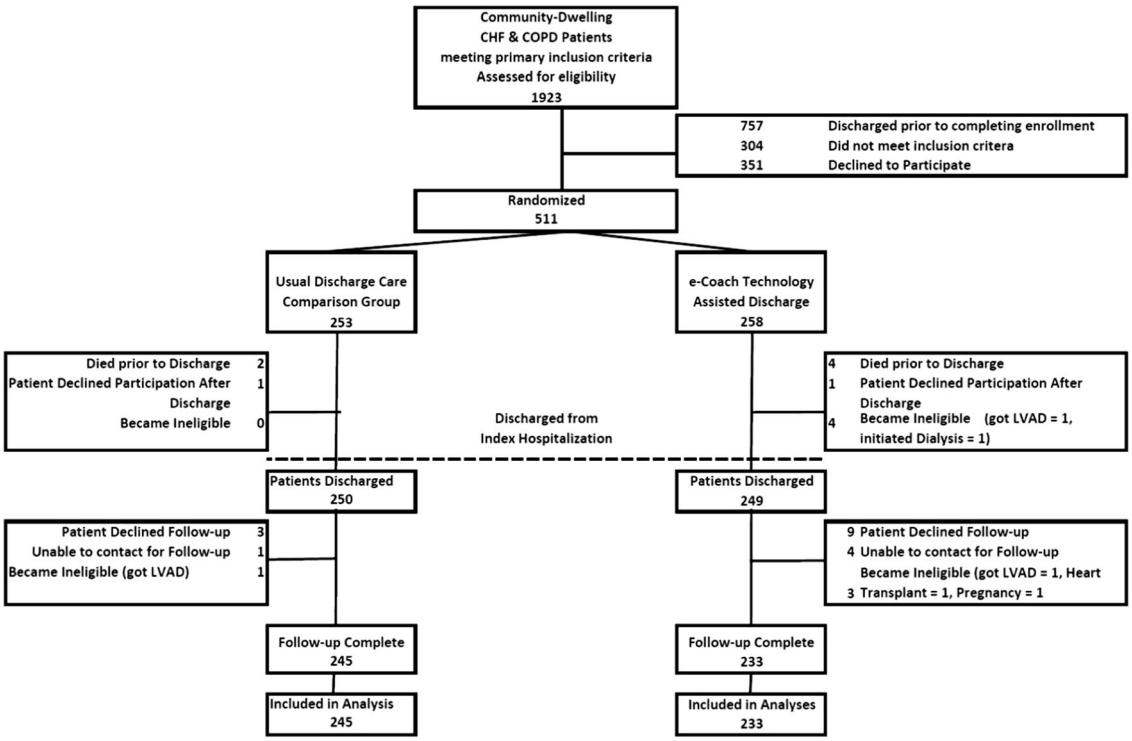

Fig. 1 | E-Coach participant flow diagram

of the effort (and marginal cost) of implementing the E-Coach system.

RESULTS

Participants came primarily from 53 counties in Alabama as well as six other states (Georgia, Tennessee, Mississippi, Florida, Texas, and Michigan). The Consolidated Standards of Reporting Trials (CONSORT) flow diagram is shown in Fig. 1. Mean age was 63 years (±12) with over 40 % African-American, nearly half women, and 20 % with less than high school education. Participant characteristics were well-balanced across intervention and comparison groups (Table 2) with the exception of gender (more women in E-Coach than usual care (UC) control group, overall and within the COPD group).

Intervention dosing

Of the 233 randomized to the intervention group, 91.2 % of E-Coach patients answered one or more IVR calls, and one third (29.2 %) answered all seven surveys within the first 7 days (i.e., received an optimal dose). The mean number of days to complete seven calls was 12 days. Among CHF patients, 144 (86 %) answered all 28 surveys (i.e., received a full dose; among COPD patients, 55 (85 %) answered all 28 surveys.

For the first Ida call, 63.1 % had one or more red flags. At 7 days, a mean of 13.94 (SD = 8.38) red flags were identified. CTNs completed a median of 4.6 calls per patient in the intervention group over the 30 days of follow-up (IQR 2–5). Audits of CTN records demonstrated consistent fidelity to addressing the red flags identified by the IVR.

Among patients discharged from the hospital while enrolled in the study, follow-up was 93 % in the E-Coach group and 98 % in the UC control group. Loss to follow-up was almost exclusively in the CHF arm, with only one COPD patient lost.

OUTCOMES

Rehospitalization at 30 days (and 30-day rehospitalization or mortality)

After adjusting for gender, 30-day rehospitalization rates were similar in the E-Coach intervention group (15.0 %) and the UC control group (16.3 %) (adjusted hazard ratio [HR] 0.94; 95 % confidence interval [CI] 0.60, 1.49), as depicted in Table 3. When analyses were stratified by condition, there were nonsignificant trends toward reduced risk of 30-day rehospitalization with E-Coach versus UC in patients with COPD (12.3 vs. 20.9 %; HR 0.56; 95 % CI 0.23, 1.38) but not with CHF (16.1 vs. 14.6 %; HR 1.14; 95 % CI 0.67, 1.96), with a p-for-interaction by condition of 0.18. Kaplan-Meier curves for the combined outcome of 30-day rehospitalization or death showed no difference by 30 days in CHF patients (Fig. 2, left) and nonsignificant trends toward reduced rehospitalizations or death,

Table 2 | Participant characteristics by randomization group

Variable, mean (standard deviation) or number (percent)	Combined		Congestive heart failure		Chronic obstructive pulmonary disease	
	E-Coach (n = 233)	Usual care group (n = 245)	E-Coach (n = 168)	Usual care group (n = 178)	E-Coach (n = 65)	Usual care group (n = 67)
Age, year	63.0 (12.1)	63.8 (12.8)	62.7 (12.5)	63.8 (13.5)	63.8 (10.9)	63.4 (11.0)
Gender						
Male	109 (46.8)	142 (58.0)[a]	82 (48.8)	96 (53.9)	27 (41.5)	46 (68.7)[b]
Female	124 (53.2)	103 (42.0)	86 (51.2)	82 (46.1)	38 (58.5)	21 (31.3)
Race						
White	123 (52.8)	131 (53.5)	79 (47.0)	86 (48.3)	44 (67.7)	45 (67.2)
Black/other	110 (47.2)	114 (46.5)	89 (53.0)	92 (51.7)	21 (32.3)	22 (32.8)
Education						
‹High school	48 (20.6)	47 (19.2)	30 (17.9)	29 (16.3)	18 (27.7)	18 (26.9)
High school/GED	87 (37.3)	96 (39.2)	60 (35.7)	67 (37.6)	27 (41.5)	29 (43.3)
Some college	59 (25.3)	58 (23.7)	46 (27.4)	46 (25.8)	13 (20.0)	12 (17.9)
≥College graduate	38 (16.3)	44 (18.0)	31 (18.5)	36 (20.2)	7 (10.8)	8 (11.9)
Marital status						
Married	111 (47.6)	113 (46.1)	80 (47.6)	86 (48.3)	31 (47.7)	27 (40.3)
Not married	121 (51.9)	131 (53.5)	87 (51.8)	91 (51.1)	34 (52.3)	40 (59.7)
Respondent						
Patient	201 (86.3)	209 (85.3)	152 (85.4)	148 (88.1)	53 (81.5)	57 (85.1)
Proxy	32 (13.7)	36 (14.7)	26 (14.6)	20 (11.9)	12 (18.5)	10 (14.9)
Financial security						
No	78 (33.5)	77 (31.4)	54 (32.1)	56 (31.5)	24 (36.9)	21 (31.3)
Yes	154 (66.1)	167 (68.2)	122 (68.5)	113 (67.3)	41 (63.1)	45 (67.2)
Health literacy [29]						
Extremely	137 (58.8)	148 (60.4)	102 (60.7)	109 (61.2)	35 (53.8)	39 (58.2)
Quite a bit	38 (16.3)	36 (14.7)	28 (16.7)	23 (12.9)	10 (15.4)	13 (19.4)
Somewhat	27 (11.6)	34 (13.9)	19 (11.3)	26 (14.6)	8 (12.3)	8 (11.9)
A little bit	16 (6.9)	10 (4.1)	10 (6.0)	8 (4.5)	6 (9.2)	2 (3.0)
Not at all	15 (6.4)	17 (6.9)	9 (5.4)	12 (6.7)	6 (9.2)	5 (7.5)
Smoking status						
Never	80 (34.3)	81 (33.1)	73 (43.5)	76 (42.7)	7 (10.8)	5 (7.5)
Current	34 (14.6)	41 (16.7)	16 (9.5)	20 (11.2)	18 (27.7)	21 (31.3)
Former	119 (51.1)	123 (50.2)	79 (47.0)	82 (46.1)	40 (61.5)	41 (61.2)
Cumulative illness rating scale for geriatrics [30]						
Total score	15 (4.8)	15 (4.8)	15 (4.8)	15 (4.9)	14 (4.7)	14 (4.4)
Severity index	2.23 (0.3)	2.27 (0.4)	2.27 (0.3)	2.30 (0.3)	2.13 (0.3)	2.20 (0.4)

Data missing as follows: education (n = 1), marital status (n = 2), financial insecurity (n = 2), and cumulative illness rating scale for geriatrics (n = 1). No significant differences between randomization groups overall or by condition except for gender in combined and chronic obstructive pulmonary disease group

[a] Odds ratio (95 % confidence interval): 1.57 (1.09–2.25)

[b] Odds ratio (95 % confidence interval): 3.08 (1.51–6.30)

Table 3 | Primary outcome: 30-day rehospitalization in E-Coach and usual care groups

	30-day rehospitalization		
	E-Coach	Usual care group	Hazard ratio (95 % confidence interval)[a]
All participants	35/233 (15.0 %)	40/245 (16.3 %)	0.94 (0.60, 1.49)
Congestive heart failure	27/168 (16.1 %)	26/178 (14.6 %)	1.14 (0.67, 1.96)
Chronic obstructive pulmonary disease	8/65 (12.3 %)	14/67 (20.9 %)	0.56 (0.23, 1.38)

[a] Adjusted for gender

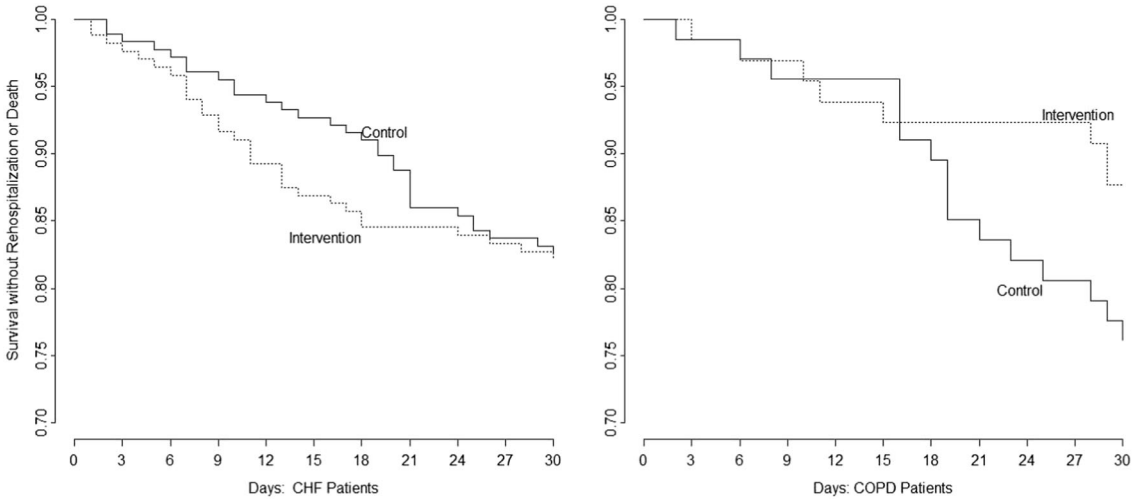

Fig. 2 | Kaplan-Meier curves demonstrating time to rehospitalization or death in the E-Coach intervention or usual care control groups in the first 30 days, stratified by condition. In the congestive heart failure (*CHF*) group (*left panel*), there was a nonsignificant trend toward faster time to rehospitalization or death in the E-Coach intervention group (*dotted line*) versus the usual care control group (*solid line*) over the first 20 days with no difference between the groups by 30 days. In the chronic obstructive pulmonary disease (*COPD*) group (*right panel*), there was a nonsignificant trend toward less rehospitalization and mortality in the E-Coach group (*dotted line*) than the usual care group (*solid line*)

especially from days 15 to 30, in COPD patients (Fig. 2, right).

Days in hospital versus at home (secondary outcome of community tenure)

COPD patients in the E-Coach intervention group had one third the mean number of days out of the community in the hospital, as compared with the COPD control patients (0.5 vs. 1.6 days, range 0 to 26, $p=0.03$), whereas there was no difference between groups in CHF patients (1.6 vs. 1.5 days, range 0 to 26, $p=0.76$). There were no other significant differences between the E-Coach and UC groups, in both the total study population (data not shown) and within the CHF and COPD groups (Table 4). All results were similar after adjusting for gender.

Perspectives of the CTNs

The CTNs found that eCoach identified patients with legitimate needs. CHF patient needs were often related to need for medication changes and required the patient's cardiologist or primary care provider for input to address questions or concerns. Conversely, COPD patients had more self-management needs (compared to the CHF patients who had more clinical guidance needs). Self-management needs included questions around medication adherence and use of inhalers, management of diet, anxiety, and depression.

Costs of implementation: perspective of the hospital system

With respect to the costs of the intervention, there were "sunk costs" to build IVR system, which included the intellectual and programming efforts of building the system.

Additionally, there were marginal costs associated with personnel. The continuous marginal costs for the system predominantly were comprised of the effort of the nurses. Per person enrolled in the intervention, there was a median of 4.6 red flags. Each of these red flags required, on average, 10–15 min of effort. In addition, CTNs scanned their dashboards at least twice daily contributing to another 10 min per person during their 30-day follow-up. We therefore estimate that the per patient CTN time cost of eCoach was approximately 90 min.

Note that because there no significant effect of eCoach on rehospitalization, we did not estimate cost savings from saved rehospitalizations. Because the COPD eCoach group had shorter rehospitalizations, compared with control, there may have been some relative cost saving among the COPD patients.

DISCUSSION

In summary, 30-day rehospitalization rates did not statistically differ between the E-Coach and UC groups. Although, in the COPD subgroup, E-Coach was associated with significantly fewer days in the hospital (0.5 vs. 1.6, $p=0.03$) indicating that IVR interventions may need to be disease-specific to increase effectiveness in decreasing rehospitalization rates and increasing adequate post-discharge care.

In E-Coach, multiple red flags were identified for each patient, suggesting a great need for post-discharge care and follow-up in this complex patient population. COPD patients appeared to benefit from the standpoint of increased community tenure (with beneficial nonsignificant trends related to rehospitalization and death), while E-Coach in CHF patients trended toward

Table 4 | Secondary outcomes in E-Coach and usual care groups, stratified by condition

Condition		Congestive heart failure					
		Usual care group (n = 178)		E-Coach (n = 168)			
Outcome	Days	n	%	n	%	p	Hazard ratio (95 % confidence interval)
Death	30	5	2.8	4	2.4	0.93	0.85 (0.2–3.2)
Rehospitalization or death	30	31	17.4	30	17.9	0.97	1.03 (0.6–1.8)
		Mean (SD)		Mean (SD)		p	Beta (95 % confidence interval)
Community tenure	30	1.48	(4.1)	1.62	(4.6)	0.76	−0.11 (−1.0–0.9)
Condition		Chronic obstructive pulmonary disease					
		Usual care group (n = 67)		E-Coach (n = 65)			
Outcome	Days	n	%	n	%	p	Hazard ratio (95 % confidence interval)
Death	30	2	3.0	0	0.0	0.49	[a]
Rehospitalization or death	30	16	23.9	8	12.3	0.09	0.44 (0.2–1.2)
		Mean (SD)		Mean (SD)		p	Beta (95 % confidence interval)
Community tenure	30	1.6	(3.5)	0.52	(1.8)	0.03	1.12 (1.11–2.12)
	90	6.14	(14.1)	4.17	(8.1)	0.33	1.96 (−2.0–6.0)

Community tenure = number of patient days spent in the hospital versus in the home

[a] No deaths in intervention group at 30 days

increasing rehospitalizations in the early days after discharge. One important point to consider is the effect that severity of illness could have on rehospitalization. The sicker the patient, the less likely that hospitalization may be preventable, therefore limiting our ability to detect differences in this real-world implementation study. This may relate to the differential effects seen in the CHF and COPD subsamples.

Recent reports of IVR-assisted care transition interventions have been mixed [31–33]. Two randomized trials of telemonitoring in CHF patients [21] and COPD [34] patients did not show a reduction in rehospitalizations. A recent Cochrane review of telemonitoring in heart failure that included studies where participants were recruited from the hospital showed no consistent benefit relative to hospitalization or mortality but improved quality of life [35]. IVR interventions appear to have the potential to affect positive quality of life outcomes on both patients and their care partners [36]; however, these outcomes were not the focus of this study.

In settings other than just after hospitalizations, telemonitoring has suggested more benefit, albeit not consistently. A randomized trial using IVR in patients with acute coronary symptoms demonstrated reduction in adverse events and improvement in medication adherence but no impact on ED visits and hospitalizations [37]. An observational study of patients with cirrhosis demonstrated that IVR could predict (but not necessarily influence) hospitalization [38]. To our knowledge, this is the first study using IVR-assisted care transition coaching for COPD to suggest improved outcomes.

There are several possible explanations for the difference in response to the E-Coach intervention between the CHF and COPD groups. First, the E-Coach intervention may have led to increased rehospitalizations due to the complexity of CHF patients and their condition and the fact that medication management decisions often require provider involvement [1, 39, 40]. Since this was a patient self-management intervention that did not rescue the patient by calling his/her provider, the patients' interaction with their provider and with the health care system was contingent on their successful use of the strategies suggested to them by the care transition coaches. If the complexity of either the condition or system prevented successful interaction, then the intervention may have increased appropriate rehospitalization. For example, a CHF patient notices more shortness of breath and is encouraged by his/her transition nurse or by the IVR to contact his provider. After seeing the patient, the provider may elect to admit the patient. Alternatively, if his/her provider is not able to see the patient urgently, the provider might feel that her only recourse is to send the patient to the emergency room where they may be subsequently admitted. The number of red flags in the CHF group was considerable, and the number of CTN calls was higher than that of the COPD group. This difference suggests that CHF patients in particular were somehow different than the COPD group early after discharge.

Readmission to the hospital, namely all-cause readmission within a specific timeframe, has limitations as a quality measure. There is currently no way to deem if readmissions are "appropriate" or avoidable. We hypothesize that likely, many of the hospitalizations "induced" by the E-Coach intervention were appropriate, and not preventable. The current findings are strictly focused on number of rehospitalizations and do not take into consideration whether rehospitalizations within 30 days are avoidable or are needed to avoid potentially worsening sequelae of delayed intervention. Though this study was not designed to evaluate the nature of the readmission, it leads to an appreciation of community tenure as a meaningful metric to evaluate post-discharge outcomes.

As noted earlier, studies have used IVR for chronic disease management in the outpatient setting, although few have been evaluated for care transitions. Two recent studies initiated IVR calls to follow-up outpatient visits [41, 42]. These studies had considerably lower engagement rates. For E-Coach, we needed to keep the patients involved over multiple calls and took several steps to engage the patient. This included allowing the patient to meet the person behind the "voice" of Ida while they were in the hospital, where they also had an opportunity to practice responding. We used a recorded human voice rather than a speech recognition system that would sound too much like a computerized voice, and we built in social responses, such as having Ida provide encouraging statements in response to prespecified responses on the part of the patient. These efforts may have enhanced adherence as compared to other IVR studies [42].

E-Coach has limitations. First, the study was underpowered to detect differences by condition; therefore, our finding of beneficial effects on community tenure in the COPD group should be interpreted as hypothesis generating for future studies. In addition, our single healthcare system may have unique characteristics that could limit the generalizability of our findings. Finally, a number of secular trends related to care transition support occurred during the study period. Care transition interventions became more common during the study period due to the Centers for Medicare and Medicaid Services' 9th Scope of Work that highlighted care transition interventions (particularly towards patients with CHF). Four care transition interventions were rolled out during the study period at the study institution alone, and others were initiated throughout the healthcare community. Though not completely similar to E-Coach, many had similar elements (including assurance of post-discharge follow-up and provision of educational materials) and likely influenced the readmission rates of the comparison group.

This study demonstrated a clinically meaningful reduction in 30-day rehospitalization rates in COPD patients when using an IVR-enhanced care transition intervention within a geographically and ethnically diverse population. It is one of the first studies evaluating the impact of this intervention in COPD patients and demonstrating potential benefit. No "gold standard" IVR intervention has emerged. To date, a combination of IVR and personal contact with care management clinicians appears to have the most beneficial effect on reducing preventable readmissions and providing optimal transitional support for patients. Research is still needed to better understand which components of the IVR may be influencing these results so that systems can be further refined for optimal outcomes. Additionally, research is also needed to evaluate the effects of the IVR system compared to person-only coaching systems. Although providers were notified anytime a patient's safety was in question, this intervention was not targeted to providers nor was the E-Coach data fully integrated into the electronic health record, which might have positively influenced provider communication and coordination. Likewise, there is a need to further evaluate the role of the care manager-patient interactions and to include informal family caregivers, to better understand how IVR can maximize effectiveness while at the same time maximizing the efficiency of clinical support for patients.

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Compliance with ethical standards

Research involving human participants: Ethical approval for the study was granted by the University of Alabama at Birmingham Institutional Review Board. All subjects (or their proxies) provided written informed consent for study participation.

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