

ORIGINAL RESEARCH

Association of Home-Based Cardiac Rehabilitation With Lower Mortality in Patients With Cardiovascular Disease: Results From the Veterans Health Administration Healthy Heart Program

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BACKGROUND: Home-based cardiac rehabilitation (HBCR) and traditional facility-based cardiac rehabilitation (CR) programs have similar effects on mortality in clinical trials and meta-analyses. However, the effect of HBCR on mortality in clinical practice settings is less clear. Therefore, we sought to compare mortality rates in HBCR participants versus nonparticipants.

METHODS AND RESULTS: We evaluated all patients who were referred to and eligible for outpatient CR between 2013 and 2018 at the San Francisco Veterans Health Administration. Patients who chose to attend facility-based CR and those who died within 30 days of hospitalization were excluded. Patients who chose to participate in HBCR received up to 9 telephonic coaching and motivational interviewing sessions over 12 weeks. All patients were followed through June 30, 2021. We used Cox proportional hazards regression models with inverse probability treatment weighting to compare mortality in HBCR participants versus nonparticipants. Of the 1120 patients (mean age 68, 98% male, 76% White) who were referred and eligible, 490 (44%) participated in HBCR. During a median follow-up of 4.2 years, 185 patients (17%) died. Mortality was lower among the 490 HBCR participants versus the 630 nonparticipants (12% versus 20%; $P < 0.01$). In an inverse probability weighted Cox regression analysis adjusted for patient demographics and comorbid conditions, the hazard of mortality remained 36% lower among HBCR participants versus nonparticipants (hazard ratio, 0.64 [95% CI, 0.45–0.90], $P = 0.01$).

CONCLUSIONS: Among patients eligible for CR, participation in HBCR was associated with 36% lower hazard of mortality. Although unmeasured confounding can never be eliminated in an observational study, our findings suggest that HBCR may benefit patients who cannot attend traditional CR programs.

Key Words: cardiac rehabilitation ■ mortality/survival ■ motivational interviewing ■ veterans' health

Referral to cardiac rehabilitation (CR) is a class I recommendation from the American College of Cardiology and American Heart Association for patients with recent myocardial infarction (MI) or acute coronary syndrome, chronic stable angina, heart failure, coronary artery bypass surgery, percutaneous coronary intervention, cardiac valve surgery, or heart

transplantation.^{1–3} Despite robust evidence of reduction in cardiovascular mortality and readmissions and improvement in health-related quality of life with CR, participation remains low across the United States.^{4–9} Among patients hospitalized for MI, percutaneous coronary intervention (PCI), or coronary artery bypass grafting between 2007 and 2011, only 16% of Medicare patients and

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CLINICAL PERSPECTIVE

What Is New?

- This observational study provides pragmatic evidence of survival benefit with home-based cardiac rehabilitation in patients with heart disease.

What Are the Clinical Implications?

- Patients who underwent home-based cardiac rehabilitation had 36% lower hazard of mortality after 4.2 median years of follow-up.
- Our study findings suggest that home-based cardiac rehabilitation may benefit eligible patients who are unable to attend traditional cardiac rehabilitation programs.

Nonstandard Abbreviations and Acronyms

CBCR	center-based cardiac rehabilitation
CR	cardiac rehabilitation
HBCR	home-based cardiac rehabilitation
IPTW	inverse proportional treatment weighting
VA	Veterans Health Administration

10% of veterans participated in CR.¹⁰ Among CR-eligible Medicare beneficiaries in 2016, only 24% of patients participated in CR.⁶ Lack of access to CR programs and transportation issues are often the biggest barriers to enrolling in a CR program for eligible patients.¹¹ Additionally, significant disparities in CR enrollment by race, ethnicity, and geographical distribution have been demonstrated in prior studies.^{12–15} Most consistently, lower referral and participation rates have been found among women, racial and ethnic minority groups, and those with lower education levels. According to the Million Hearts CR Collaborative, increasing participation to 70% across the nation could save 25 000 lives and prevent 180 000 hospitalizations per year.¹⁶

In a recent scientific statement, the American Association of Cardiovascular and Pulmonary Rehabilitation, American College of Cardiology, and American Heart Association recommended home-based CR (HBCR) referrals for CR-eligible, low-to-medium risk, clinically stable patients who are unable to access center-based CR (CBCR).¹⁷ At its core, HBCR addresses 5 target health behaviors: medication adherence, physical activity, smoking cessation, healthy eating, and stress management. Several clinical trials and Cochrane reviews have shown HBCR to be equally effective to CBCR in terms of their benefits.^{18–20} The recent COVID-19 pandemic resulted in the temporary

closure of nearly 75% of traditional CBCR programs worldwide.²¹ This prompted several CR programs to transition to telehealth and offer HBCR as a means to maintain continuity of care during the pandemic.^{22–28} Particularly in the Veterans Health Administration (VA), a unique hub and spoke health care delivery model allowed for the expansion of HBCR programs to accommodate veterans who were unable to attend CBCR during this time.²³

Very limited literature exists on the effect of HBCR participation on patient outcomes in clinical settings. In an effort to increase participation in CR, the VA has established HBCR programs. The main objective of our research was to compare mortality outcomes between HBCR participants and nonparticipants at the San Francisco VA Medical Center.

METHODS

In order to minimize the possibility of unintentionally sharing information that can be used to reidentify private information, anonymized data that support the findings of this study are available from the corresponding author upon reasonable request.

The Healthy Heart Program

We conducted a retrospective cohort study using data that were collected to evaluate a quality improvement program. With funding from the VA Office of Rural Health, the Healthy Heart Program was established at the San Francisco VA in August 2013. Details of the program have been described previously.^{8,29,30} Briefly, patients hospitalized for MI, PCI, coronary artery bypass grafting, or valvular surgery at the San Francisco VA were referred to the CR team via an automated referral process. For each referred patient, the Healthy Heart Program nurse completed a detailed chart review and interview to assess patient needs and determine whether HBCR was indicated, feasible, and appropriate. For patients who underwent PCI, this interview typically occurred in the hours following their procedure; for the surgical patient, a bedside visit typically occurred on postoperative day 3 or 4.

Patients were not offered enrollment in HBCR if they were being discharged to a nursing facility, were planned for a staged PCI, did not have a telephone, had significant cognitive impairment or movement disorders that interfered with exercise training, or had cardiac conditions that were not optimized (uncontrolled hypertension, unstable angina, arrhythmias, decompensated heart failure, symptomatic valvular heart disease). All other patients who were eligible for Phase II CR were offered enrollment into the Healthy Heart HBCR program or referral to a (non-VA) facility-based CR program.

Intervention

Our approach was informed by 3 different theoretical models: Social Cognitive Theory, the Health Belief Model, and the Predisposing, Reinforcing, and Enabling Constructs in Educational Diagnosis and Evaluation-Policy, Regulatory, and Organizational Constructs in Educational and Environmental Development implementation planning model.^{31–33} According to social cognitive theory, 3 main factors affect the likelihood that an individual will change a health behavior: self-efficacy, goals, and outcome expectations. Self-efficacy is a critical component of CR participation, both for patients and providers. According to the health belief model, people's beliefs about their susceptibility to ischemic heart disease and their perceptions of the benefits of CR programs influence their willingness to participate. The 6 main constructs that influence people's health care decisions are perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy. The implementation planning model focuses on predisposing, enabling, and reinforcing factors associated with patient participation in CR. Predisposing factors to participation in CR included patient and provider knowledge about the benefits of CR. Enabling factors included available resources, streamlined (automated) referral, and care coordination. Reinforcing factors included social support, reassurance, and symptom relief.

As previously described,³⁰ patients who chose to enroll in HBCR received a workbook and DVD titled, "An Active Partnership for the Health of Your Heart." A personal health journal was provided for documenting vital signs, activity, and dietary intake. In addition, each participant received equipment on an as-needed basis, including resistance bands, a weight scale, a blood pressure cuff, a pedometer/heart rate monitoring device, an exercise peddler or stationary bike, and a dietary video. A nurse or exercise physiologist assisted the patient in formulating achievable goals using the specific, measurable, attainable, realistic, and time-related criteria.³⁴

The Healthy Heart program focused on 5 key health behaviors: physical activity, healthy eating, smoking cessation, medication adherence, and stress management. Aside from modifying these health behaviors, patients cannot directly control cardiovascular risk factors, such as blood pressure, lipid levels, blood sugar, or body weight. Participants who enrolled in the HBCR program received up to 9 video or telephonic coaching and motivational interviewing sessions over a period of 12 weeks (weekly for the first 6 weeks, then biweekly). At 3 and 6 months after completing the HBCR program, patients were offered follow-up phone calls to address any subsequent questions. A majority of visits were carried out telephonically, but occasional video

visits were used to demonstrate and supervise certain exercises. Patients were not required to have a smartphone for the sessions and were able to participate by means of a cellphone or landline.

The program staff and patients co-developed individualized treatment plans that were tailored to each patient's diagnosis, individual goals, and preferences. Clinicians taught participants how to self-monitor exercise, using the 6 to 20 Borg dyspnea rating scale.³⁵ Initially, moderate intensity exercise was prescribed with a target heart rate that was 60% to 75% of the 6-minute walk test peak heart rate and an initial Borg scale target (11–14 on 20-point scale). The program physician approved each treatment plan.

Study Sample

For the purposes of this study, we included all patients hospitalized for MI, PCI, coronary artery bypass grafting, or valvular surgery who were referred to and eligible for HBCR between August 1, 2013 and December 31, 2018. If a patient had multiple referrals during this time frame or enrolled in HBCR more than once during the 5 years, the first index event that was followed by enrollment in HBCR was selected for analysis. In order to compare outcomes between patients who underwent HBCR with those who did not have any CR, we excluded any patients who elected referral to facility-based CR programs from the analysis. We also excluded any patients who died within 30 days of the date of index event because they would not have had the opportunity to enroll in HBCR. The study was approved by the San Francisco VA institutional review board and all patients signed informed consent.

Data Collection

Data on patient demographics, comorbid conditions, and vital status were obtained from chart review and the VA Corporate Data Warehouse. Comorbid conditions were defined as the presence of 1 inpatient and/or 2 outpatient *International Classification of Diseases (ICD)* codes in the 1 year before hospitalization for an index event. Data on number of telephonic sessions attended were recorded on a REDCap database that was used to assess participant attendance. Patients were followed via the electronic health record system through June 30, 2021 for assessment of outcomes. There was no loss to follow up for the mortality outcomes because the government obtains information about mortality even for patients who are lost to follow-up.

Primary and Secondary Outcomes

The primary outcome of the study was 1-year mortality and the secondary outcome was mortality over the

entire study period. Data on patient-centered outcome measures such as quality of life, health behaviors, and functional capacity were not available for inclusion in the analysis.

Statistical Analysis

χ^2 and *t*-tests were used to examine differences in the distribution of baseline demographics and comorbid conditions between HBCR participants and nonparticipants. We created stabilized propensity weights for HBCR participants versus nonparticipants using data on patient demographics, rurality, marital status, indication for CR, and comorbid conditions (as listed in Table). A Cox proportional hazards model with inverse probability treatment weighting (IPTW) was used to compare mortality between the 2 groups. Given the fact this was not a randomized controlled trial, IPTW was an important measure to eliminate confounding by differences in baseline variables between the 2 groups while also preserving the sample size. Covariate balance was verified by comparing standardized differences between patients who underwent HBCR (versus those who did not) and by visually inspecting the distribution of continuous variables before versus after weighting.³⁶ Patients with any missing data on race, ethnicity, rurality, marital status, and comorbid conditions were eliminated from the Cox proportional hazards model. All statistical analyses were carried out using SAS Enterprise Guide (version 7.15 HF3, SAS Institute, Cary, NC) and STATA, version 15.1 (StataCorp, College, TX) statistical packages. This work was funded by the VA Health Services Research and Development Quality Enhancement Research Initiative (IP1 HX002002).

RESULTS

Study Population

Between August 2013 and December 2018, 1120 patients were referred to and found eligible for outpatient CR at the San Francisco VA. Of these, 98% were male, 76% White, and 88% of non-Hispanic ethnicity. A majority (68%) of patients lived in urban areas and half (50%) were hospitalized for a PCI before being referred to CR. Fifty-six percent of patients (630/1120) did not participate in CR whereas the remaining 490 patients (44%) enrolled in the San Francisco Healthy Heart HBCR program.

Nonparticipants were on average 2 years older than participants (Table). There were no statistically significant differences in the distribution of race, ethnicity, marital status, rurality, or comorbid conditions (except for heart failure) between HBCR participants and nonparticipants. A higher proportion of HBCR participants were hospitalized for coronary artery bypass grafting

in comparison to nonparticipants (24% versus 16%, $P<0.01$) whereas nonparticipants had a greater proportion of PCI admissions (54% versus 44%, $P<0.01$). On applying IPTW, the mean weight was 1.0 (minimum 0.49, Q1 0.77, median 0.9, Q3 1.14, maximum 3.22) with an SD of 0.35. The differences in the distribution of characteristics between the 2 groups were eliminated with insignificant *P* values for all tests of difference and standardized differences of <0.1 between the groups for all variables (Table).

Primary and Secondary Outcomes

Median follow-up time was 4.2 years for the cohort. The overall mortality rate was 3% (38/1120) over 1 year following index hospitalization and 17% (133/1120) over the entire follow up period. One-year mortality was 4% (28/630) among nonparticipants versus 2% (10/490) among HBCR participants (unadjusted $P=0.03$; IPTW-adjusted $P=0.31$). Mortality during the entire follow up period was 20% (128/630) among nonparticipants versus 12% (57/490) among HBCR participants (unadjusted $P<0.01$; IPTW-adjusted $P=0.01$; Figure 1).

A Cox proportional hazards model with IPTW suggested that HBCR was associated with a 33% lower hazard of 1-year mortality, but this was not statistically significant (hazard ratio [HR], 0.67 [95% CI, 0.31–1.45]; $P=0.31$; Figure 2A). During the entire follow-up period (median of 4.2 years), HBCR was significantly associated with a 36% lower hazard of mortality (HR, 0.64 [95% CI, 0.45–0.90]; $P=0.01$; Figure 2B).

Of the 490 participants, 209 patients (43%) completed 9 or more sessions of HBCR. The average number of sessions completed was 7.15 with an SD of 3.03. On examining the adjusted marginal probability of mortality by number of CR sessions attended over a median follow up of 4.2 years, we found an overall declining trend with increasing number of sessions attended (Figure 3).

DISCUSSION

In this large study of 1120 patients with ischemic heart disease who were offered HBCR, 490 (44%) agreed to participate following MI, revascularization, or hospitalization for valvular heart disease. During a median of 4.2 years follow up, one fifth of HBCR nonparticipants died. However, the hazard of mortality was 36% lower among patients who participated in HBCR. Although no observational study can eliminate the possibility that healthier patients were more likely to participate in HBCR, we rigorously adjusted for confounding using an inverse probability weighted Cox regression analysis with the goal of equalizing the samples across all variables other than exposure to HBCR. These results

Table. Characteristics of 1120 Patients With Ischemic Heart Disease by Participation in Home-Based Cardiac Rehabilitation

Patient characteristics	All patients	HBCR participants		Nonparticipants		P value		Standardized differences	
		(N=490)		(N=630)		Before IPTW	After IPTW	Before IPTW	After IPTW
Age, y±SD	68.2±8.3	67±7.9		69.2±8.4		<0.01	0.8	0.28	0.02
Sex (n, %)									
Male	1098	474	97%	624	99%	<0.01	0.93	0.28	0.02
Female	22	16	3%	6	1%				
Race*						0.23	0.99	0.17	0.00
White	854	371	76%	483	77%				
Black	77	38	8%	39	6%				
Other [§]	83	43	9%	40	6%				
Ethnicity [†]						0.32	0.9	0.12	0.00
Not Hispanic	987	430	88%	557	88%				
Hispanic	77	38	8%	39	6%				
Marital status [‡]						0.58	0.71	0.02	0.00
Married	552	246	50%	306	49%				
Single/separated/divorced/widowed	566	243	50%	323	51%				
Rurality						0.75	0.88	0.03	0.00
Urban	760	335	68%	425	67%				
Rural	360	155	32%	205	33%				
Year of admission for index event						<0.01	0.99	0.36	0.04
2013	65	36	7%	29	5%				
2014	255	118	24%	137	22%				
2015	251	139	28%	112	18%				
2016	267	107	22%	160	25%				
2017	165	45	9%	120	19%				
2018	117	45	9%	72	11%				
Indication for cardiac rehabilitation						<0.01	0.99	0.25	0.05
Percutaneous coronary intervention	556	215	44%	341	54%				
Coronary artery bypass grafting	215	116	24%	99	16%				
Myocardial infarction/angina	149	74	15%	75	12%				
Other [§]	200	85	17%	115	18%				
Comorbid conditions									
Hypertension	860	374	76%	486	77%	0.75	0.9	0.02	0.01
Dyslipidemia	794	345	70%	449	71%	0.75	0.93	0.02	0.01
Diabetes	454	186	38%	268	43%	0.12	0.88	0.09	0.01
Heart failure	248	94	19%	154	24%	0.03	0.91	0.13	0.01
Stroke	66	29	6%	37	6%	0.97	0.96	0.00	0.00
Peripheral vascular disease	157	69	14%	88	14%	0.96	0.8	0.00	0.02
Chronic obstructive lung disease	184	74	15%	110	17%	0.29	0.93	0.06	0.01
Chronic kidney disease	84	35	7%	49	8%	0.69	0.94	0.02	0.01
Valvular heart disease	249	102	21%	147	23%	0.31	0.87	0.06	0.01
Atrial fibrillation/flutter	204	81	17%	123	20%	0.2	0.97	0.08	0.00
Depression	111	50	10%	61	10%	0.77	0.95	0.02	0.00
Posttraumatic stress disorder	124	60	12%	64	10%	0.27	0.93	0.07	0.01

HBCR indicates home-based cardiac rehabilitation; and IPTW, Inverse probability of treatment weighting.

* Data on race were missing for 38 HBCR participants and 68 nonparticipants.

† Data on ethnicity were missing for 22 HBCR participants and 34 nonparticipants.

‡ Data on marital status were missing for 1 HBCR participant and 1 nonparticipant.

§ The category “other” includes the following race categories: American Indian or Alaska Native, Asian, and Native Hawaiian or Other Pacific Islander.

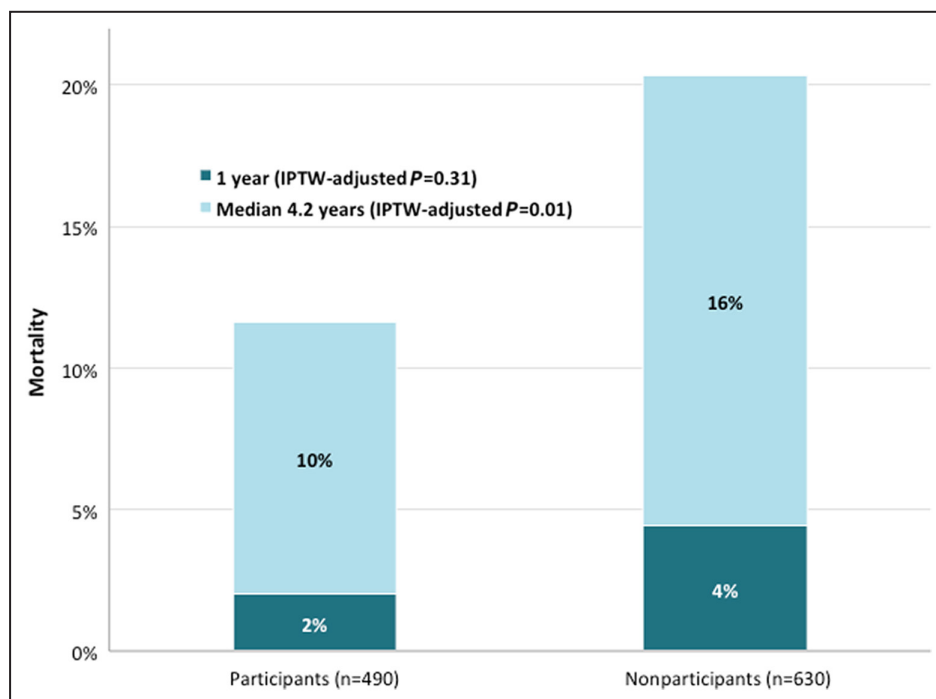


Figure 1. Mortality in home-based cardiac rehabilitation participants vs nonparticipants with inverse probability of treatment weighted P values.

IPTW indicates inverse probability of treatment weighting.

suggest that participation in HBCR contributed to lower mortality among patients referred to CR.

Ours is the first observational study to show a mortality benefit with HBCR. Prior literature has focused on comparing HBCR with CBCR programs in clinical trials^{18–20,37} Although multiple studies have demonstrated similar mortality in patients undergoing HBCR versus CBCR, efficacy in clinical trials does not always translate to effectiveness in real-world clinical practice. Our pragmatic study showed that patients enrolled in HBCR had lower mortality than those not enrolled in CR. Because the San Francisco VA Healthy Heart program's development in 2013, and during its evolution over the subsequent 5 years, several hundred veterans benefitted from participation. Additionally, our program was entirely remote and consisted only of motivational telephonic encounters with occasional video visits if needed. Despite real-world challenges such as technical issues, missed sessions, staffing issues, etc., the results of the intervention are promising and in alignment with a more regimented clinical trial. Therefore, our findings are an important addition to the current literature on HBCR programs.

To our knowledge, this is the first published study examining the survival benefits of HBCR among US veterans. Coronary atherosclerosis, heart failure, and MI account for the top 3 causes of cardiovascular hospitalization,³⁸ and cardiovascular disease is the leading cause of hospitalization among US veterans.³⁹ All

patients hospitalized for these conditions should ideally undergo CR after discharge barring any clinical contraindications. In case of barriers such as transportation issues or lack of access to a CBCR program, access to a HBCR program becomes critical in bridging the gap in access to CR and improving survival after hospitalization for serious cardiovascular illness. We hope that the pragmatic evidence from our study will encourage the development of more HBCR programs to help address this gap.

Our findings are especially relevant in light of the COVID-19 pandemic, which has caused many CBCR programs to offer HBCR as a temporizing measure.^{22–28} Providing HBCR in such situations allows for continued clinical care while maintaining safety and lowering exposure. As CBCR centers reopen, continuing to offer HBCR or hybrid programs to participants may be an innovative and equally effective method to deliver CR while maintaining social distance requirements.

A distinct advantage of HBCR is that time from index event to enrollment is significantly shorter than for CBCR (25 versus 77 days in a recent study).⁴⁰ Moreover, HBCR offers motivational training for the adoption of a new lifestyle within a patient's own environment, thus creating a sustainable lifestyle change. This is likely the most important factor attributable to the long-term success of HBCR programs, which may also be associated with higher completion than CBCR.⁴¹ Notably, 1 prior study comparing HBCR (9–12

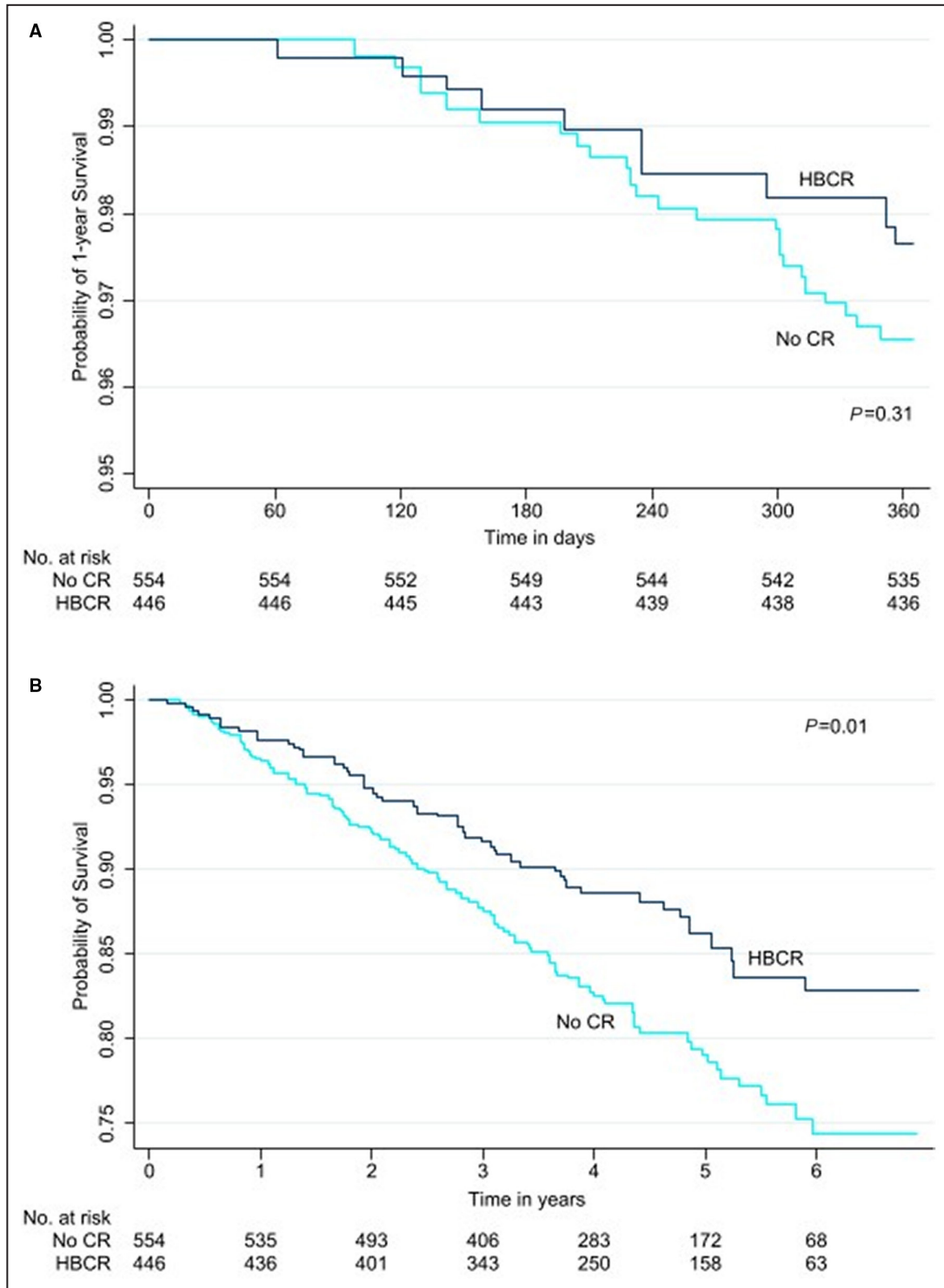


Figure 2. Survival in home-based cardiac rehabilitation participants and nonparticipants at 1 year (A) and up to 6 years (B).

CR indicates cardiac rehabilitation; and HBCR, home-based cardiac rehabilitation.

sessions) and CBCR (12–36 sessions) showed similar gains in 6-minute walk time among patients with ischemic heart disease.⁴⁰ Another study found that patients enrolled in HBCR had lower odds of hospitalization

than those enrolled in CBCR.⁴² Of course, HBCR is not without its challenges. Patient participation and adherence require a lot of self-motivation. Despite these challenges, HBCR has been found to be associated with

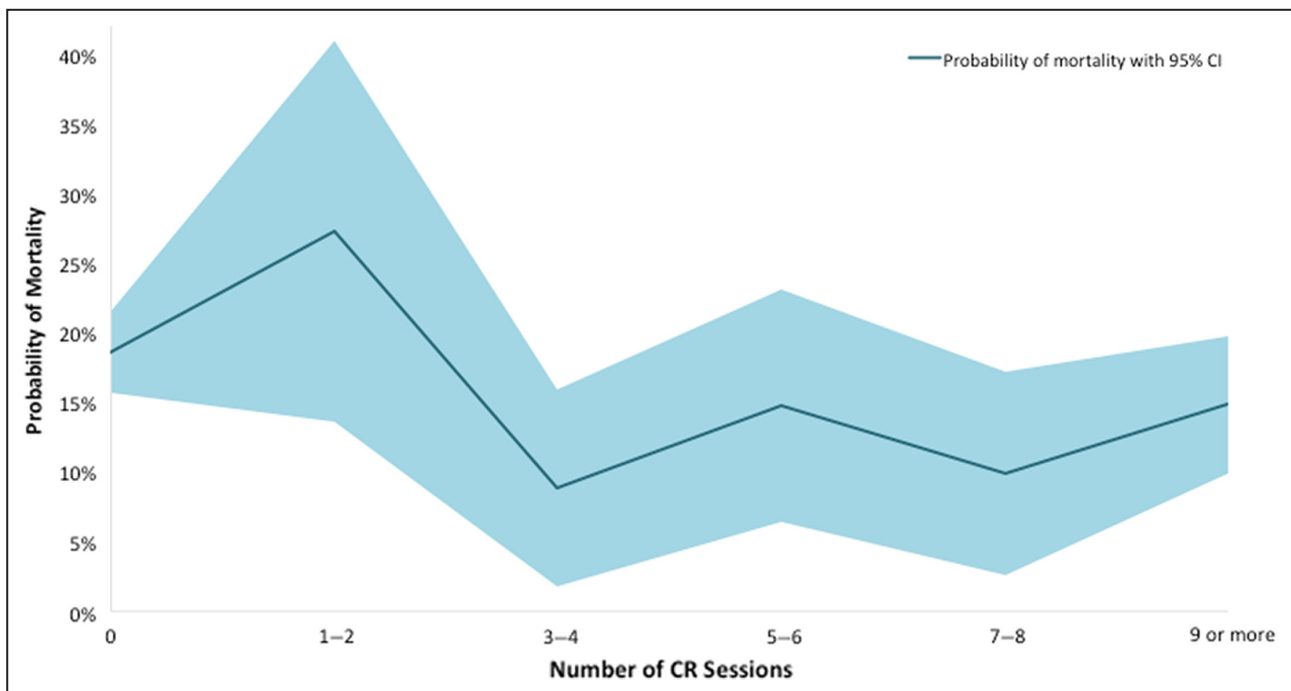


Figure 3. Probability of mortality during a median of 4.2 years follow-up by number of home-based cardiac rehabilitation sessions attended.

CR indicates cardiac rehabilitation.

increase in participation and adherence rates.^{8,29,43,44} Additionally, patients who are not adept with technology might find telemedicine onerous.

As technology grows, HBCR and virtual CR may implement new technological modalities that might potentially create inequalities between those who are able to understand and access this technology and those that are not. Prior studies have shown lower CR use by female, Black, and older patients.^{45,46} Moreover, a study found that despite making technology available to these populations, there was a persistence of the digital divide suggesting that additional interventions might be required to address it.⁴⁷ In an effort to reach people that are unable to access CR, HBCR should be wary of not exacerbating this digital divide and furthering inequalities in access and care.

Given that HBCR is still an emerging field, there is no standardized approach for HBCR delivery in the United States. This makes it difficult to compare programs and generalize outcomes. However, the latest joint statement on HBCR by the American Association of Cardiovascular and Pulmonary Rehabilitation, the American Heart Association, and the American College of Cardiology has delineated a skeletal structure for HBCR delivery that can be built on and individualized.¹⁷ In addition the Million Hearts Cardiac Rehab Collaborative⁴⁸ and the TakeHeart Initiative⁴⁹ have outlined key components of successful programs, including automated referral and care coordination

before enrollment. Another barrier is the lack of reimbursement for HBCR by the Centers for Medicare and Medicaid Services.²³ Further evidence and discussions with policymakers will be essential for the expansion of HBCR programs.

Our study has several limitations. Given the observational nature of our study design and lack of ability to randomize, causal inference is challenging. Although there is no way to completely eliminate unmeasured confounding and we were unable to account for health behaviors, we performed an IPTW analysis to account for all practically feasible confounders and still found a significant mortality benefit. Because the majority of our patients were English-speaking, older men, it is unclear whether HBCR would be associated with similar benefits in women or non-English speaking patients. Finally, because the San Francisco VA does not have a CBCR program, we were unable to compare HBCR to CBCR. However, we have previously demonstrated that patients undergoing HBCR experience similar functional outcomes and shorter wait times between index event and enrollment than patients undergoing CBCR.⁴⁰

CONCLUSIONS

In conclusion, although it is impossible to completely eliminate confounding in an observational study, our study provides pragmatic evidence that HBCR could

be associated with a survival benefit among select patients with cardiovascular disease. Our findings provide an impetus to further expand HBCR to deliver CR to those who are unable to access CBCR programs.

ARTICLE INFORMATION

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None.

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