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# Cardiac Rehabilitation Participation and Mortality After Percutaneous Coronary Intervention: Insights From the Veterans Affairs Clinical Assessment, Reporting, and Tracking Program

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**Background**—Cardiac rehabilitation (CR) is strongly recommended after percutaneous coronary intervention (PCI), but it is underused. We sought to evaluate CR participation variation after PCI and its association with mortality among veterans.

**Methods and Results**—Patients undergoing PCI between 2007 and 2011 were identified in the Veterans Affairs Clinical Assessment, Reporting, and Tracking database and followed up until January 25, 2017. We excluded patients who died within 30 days of PCI and calculated the percentage participating in  $\geq 1$  outpatient CR visits within 12 months after PCI. We constructed multivariable hierarchical logistic regression models for CR participation, clustered by facility. We estimated propensity scores for CR participation, matched participants and nonparticipants by propensity score, calculated mortality rates, and estimated the association with mortality using Cox proportional hazards models. Participation in CR after PCI was 6.9% (2986/43 319) and varied significantly by PCI facility (range, 0%–36%). After 6.1 years median follow-up, CR participants had a 33% lower mortality rate than all nonparticipants (3.8 versus 5.7 deaths/100 person-years; hazard ratio, 0.67; 95% confidence interval, 0.61–0.75;  $P < 0.001$ ) and a 26% lower mortality rate than 2986 propensity-matched nonparticipants (3.8 versus 5.1 deaths/100 person-years; hazard ratio, 0.74; 95% confidence interval, 0.65–0.84;  $P < 0.001$ ). Participants attending  $\geq 36$  sessions had the lowest mortality rate (2.4 deaths/100 person-years; hazard ratio, 0.47; 95% confidence interval, 0.36–0.60;  $P < 0.001$ ).

**Conclusions**—CR participation after PCI among veterans is low overall, with significant facility-level variation. CR participation is associated with lower mortality rates in veterans. Additional efforts are needed to promote CR participation after PCI among veterans. (*J Am Heart Assoc.* 2018;7:e010010. DOI: 10.1161/JAHA.118.010010.)

**Key Word:** cardiac rehabilitation • health services • percutaneous coronary intervention • quality and outcomes • secondary prevention

Cardiac rehabilitation (CR) is an evidence-based program of exercise training, risk factor modification, and psychosocial counseling.<sup>1,2</sup> Participation in CR is associated with lower cardiovascular mortality and fewer hospitalizations.<sup>3–9</sup> Although current professional society guidelines and performance measures strongly recommend CR after myocardial infarction or revascularization,<sup>10–16</sup> <20% of eligible patients participate in the United States.<sup>17,18</sup>

The Veterans Health Administration (VA) is a national healthcare system that provides both percutaneous coronary intervention (PCI) and CR services and may present an

opportunity for improving use of CR after PCI. However, a recent analysis demonstrated only 10% participation among VA patients after myocardial infarction, PCI, or coronary artery bypass surgery.<sup>18,19</sup> It has also been observed that there is significant variation in participation by hospital and region, but the reasons for this variation are not entirely understood.<sup>17–20</sup> Additionally, it is unknown whether participation in CR is associated with lower mortality among veterans.

Improved understanding of facility-level variation in CR participation could lead to targeted interventions to promote CR. Therefore, we used the VA Clinical Assessment, Reporting,

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## Clinical Perspective

### What Is New?

- Participation in cardiac rehabilitation after percutaneous coronary intervention is associated with a 26% lower mortality rate among veterans, but there is significant facility-level variation in participation (range, 0%–36%).

### What Are the Clinical Implications?

- There is opportunity for facilities to adopt new approaches to improve participation in cardiac rehabilitation.
- Increasing participation in cardiac rehabilitation may improve outcomes after percutaneous coronary intervention.

and Tracking (CART) database, linked with VA and non-VA healthcare data, to evaluate variation in CR participation after PCI at VA facilities and to estimate the association of CR participation with long-term mortality in veterans.

## Methods

The data, analytic methods, and study materials will not be made available to other researchers for purposes of reproducing the results or replicating the procedure because of policies for use of VA and Medicare data.

## Population

We used data from the VA CART database to identify patients undergoing PCI from January 1, 2007, to December 31, 2011. The VA CART program is a national quality program supporting all VA cardiac catheterization laboratories, where invasive cardiac procedures are performed. A key feature of the CART program is the CART software application, which is embedded in the VA electronic health record that systematically collects all procedural data on catheterization procedures, both diagnostic and interventional, performed in the VA system.<sup>21,22</sup> We excluded patients who died within 30 days of PCI. The University of California, San Francisco Committee on Human Research, San Francisco VA Medical Center Research and Development Committee, and VA Puget Sound Health Care System Institutional Review Board and Research and Development Committees approved the study and waived the requirement for informed consent.

## Outcomes

CR participation was defined as  $\geq 1$  encounters for CR (*Current Procedural Terminology* codes 93797, 93798, S9472, S9473, G0422, and G0423) within 1 year after discharge. We

determined CR participation from data on encounters from VA care, non-VA care purchased by VA, and Medicare. Mortality was determined from VA vital status files. The last date of follow-up was January 25, 2017.

## Patient Characteristics, Comorbidities, and Procedure Characteristics

Patient characteristics (age, sex, race/ethnicity, and insurance status) were obtained from VA electronic health record data. Comorbidities and procedural characteristics (procedure status and coronary anatomical characteristics) were entered into the CART application by clinical providers. When CART data were missing or unavailable, comorbidities were obtained from VA inpatient and outpatient data. A comorbid condition was considered present if it was listed as a diagnosis in 2 outpatient encounters or 1 inpatient encounter during the year before and including the index event. Procedure characteristics (procedure status, PCI, and extent of coronary disease) were coded by clinical providers in the CART application.

## Facility Characteristics

Geographic region was described on the basis of PCI facility location, categorized by US Census Regions (New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont; Mid Atlantic: New Jersey, New York, Pennsylvania; South Atlantic: Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia; East North Central: Indiana, Illinois, Michigan, Ohio, Wisconsin; East South Central: Alabama, Kentucky, Mississippi, Tennessee; West North Central: Iowa, Nebraska, Kansas, North Dakota, Minnesota, South Dakota, Missouri; West South Central: Arkansas, Louisiana, Oklahoma, Texas; Mountain: Arizona, Colorado, Idaho, New Mexico, Montana, Utah, Nevada, Wyoming; Pacific: Alaska, California, Hawaii, Oregon, Washington). PCI volume was determined from the CART database as the number of PCIs performed at each facility per year that PCIs were performed at the facility. Facility PCI volume was dichotomized at 200 procedures per year.<sup>23</sup> CR center status was determined from a 2011 survey of VA facilities.

## Statistical Analysis

Differences in patient characteristics by CR participation were compared using Wilcoxon rank-sum test for continuous variables and the  $\chi^2$  test for categorical variables. We described percentage of PCI patients participating in CR by facility. We constructed multivariable hierarchical logistic regression models for participation in CR, clustered by facility, using generalized estimating equation models with logit link. Variables included in the model were year of procedure and all

**Table 1.** Characteristics of PCI Patients by CR Participation Status

Characteristics	All (N=43 319)	Participants (N=2986)	Nonparticipants (N=40 333)	P Value*
<b>Patient characteristics</b>				
Age, median (IQR), y	63 (59–70)	63 (59–68)	64 (59–71)	<0.001
Female sex, N (%)	704 (2)	54 (2)	650 (2)	0.41
<b>Race/ethnicity, N (%)</b>				
White	33 816 (78)	2334 (78)	31 482 (78)	0.04
Black	5088 (12)	376 (13)	4712 (12)	
Hispanic	1756 (4)	130 (4)	1626 (4)	
Asian/Pacific Islander/American Indian	667 (2)	41 (1)	626 (2)	
Unknown/missing	1992 (5)	105 (4)	1879 (5)	
Medicaid, N (%)	2561 (6)	169 (6)	2392 (6)	0.55
Current tobacco use, N (%)	9393 (22)	561 (19)	8832 (22)	<0.001
Hypertension, N (%)	37 400 (86)	2562 (86)	34 838 (86)	0.38
Hyperlipidemia, N (%)	37 030 (85)	2600 (87)	34 430 (85)	0.01
Diabetes mellitus type 2, N (%)	19 242 (44)	1354 (45)	17 888 (44)	0.29
Heart failure, N (%)	7990 (18)	472 (16)	7518 (19)	<0.001
Cerebrovascular disease, N (%)	5586 (13)	357 (12)	5229 (13)	0.11
Peripheral vascular disease, N (%)	7994 (18)	423 (14)	7571 (19)	<0.001
COPD, N (%)	9376 (22)	560 (19)	8816 (22)	<0.001
Chronic kidney disease, N (%)	6804 (16)	389 (13)	6415 (16)	<0.001
Hemodialysis, N (%)	767 (2)	22 (1)	745 (2)	<0.001
Depression, N (%)	7868 (18)	616 (21)	7252 (18)	<0.001
Valvular heart disease, N (%)	4249 (10)	316 (11)	3933 (10)	0.14
Arrhythmias, N (%)	7391 (17)	515 (17)	6876 (17)	0.78
Cancer, N (%)	6544 (15)	415 (14)	6129 (15)	0.06
Dementia, N (%)	221 (1)	(0) <sup>†</sup>	(1) <sup>†</sup>	0.01
<b>Status, N (%)</b>				
Elective	27 757 (64)	1742 (58)	26 015 (65)	<0.001
Urgent	11 882 (27)	855 (29)	11 027 (27)	
Emergent/salvage	2814 (7)	339 (11)	2475 (6)	
Unknown/missing	866 (2)	50 (2)	816 (2)	
Three-vessel disease, N (%)	11 430 (26)	828 (28)	10 602 (26)	0.08
<b>Facility characteristics</b>				
<b>Region, N (%)<sup>‡</sup></b>				
New England	736 (2)	76 (3)	660 (2)	<0.001
Mid Atlantic	2459 (6)	183 (6)	2276 (6)	
South Atlantic	9227 (21)	658 (22)	8569 (21)	
East North Central	4993 (12)	302 (10)	4691 (12)	
East South Central	4944 (11)	368 (12)	4576 (11)	
West North Central	5883 (14)	479 (16)	5404 (13)	
West South Central	7159 (17)	387 (13)	6772 (17)	
Mountain	3381 (8)	388 (13)	2993 (7)	

Continued

**Table 1.** Continued

Characteristics	All (N=43 319)	Participants (N=2986)	Nonparticipants (N=40 333)	P Value*
Pacific	4249 (10)	111 (4)	4138 (10)	
Puerto Rico	288 (1)	34 (1)	254 (1)	
PCI volume $\geq 200/y$ , N (%)	17 884 (41)	993 (33)	16 891 (42)	<0.001
On-site cardiac rehabilitation center, N (%)	16 793 (39)	1609 (54)	15 184 (38)	<0.001

COPD indicates chronic obstructive pulmonary disease; CR, cardiac rehabilitation; IQR, interquartile range; and PCI, percutaneous coronary intervention.

\*P value for comparison of participants and nonparticipants by Wilcoxon rank-sum test or  $\chi^2$ .

†Number suppressed because of corresponding cell size <10.

‡New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont; Mid Atlantic: New Jersey, New York, Pennsylvania; South Atlantic: Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia; East North Central: Indiana, Illinois, Michigan, Ohio, Wisconsin; East South Central: Alabama, Kentucky, Mississippi, Tennessee; West North Central: Iowa, Nebraska, Kansas, North Dakota, Minnesota, South Dakota, Missouri; West South Central: Arkansas, Louisiana, Oklahoma, Texas; Mountain: Arizona, Colorado, Idaho, New Mexico, Montana, Utah, Nevada, Wyoming; Pacific: Alaska, California, Hawaii, Oregon, Washington.

variables in Table 1. We also used this model to generate a propensity score from year of procedure and all variables in Table 1. We matched CR participants to CR nonparticipants in a 1:1 ratio by propensity score using nearest neighbor matching. We calculated mortality rates among those participating, those not participating, and propensity-matched nonparticipants and generated a cumulative hazard plot for propensity-matched participants and nonparticipants. These models included only CR participation status and death. We compared propensity-matched pairs using Cox proportional hazards, using the Stata option “vce cluster” by facility, which allows for intragroup correlation in estimating SEs. We used Cox proportional hazards models to estimate the association with number of CR sessions attended with mortality. These models included only number of CR sessions attended and death. All analyses were performed with Stata, version 15. Figures were created using Stata or Tableau. Dr Beatty had full access to all the data and takes responsibility for their integrity and the data analysis.

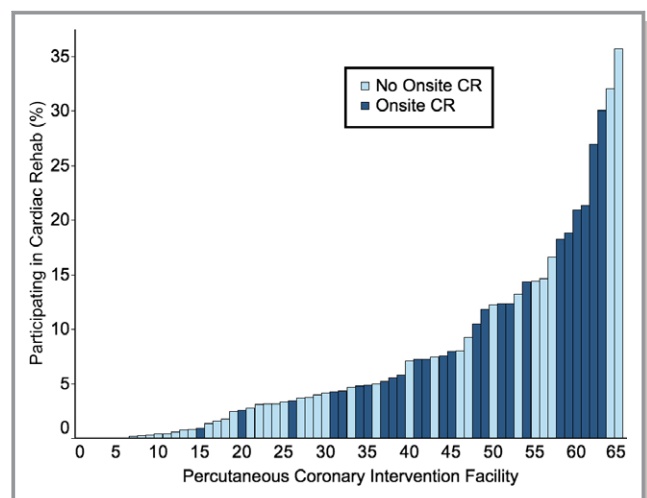
## Results

Between 2007 and 2011, there were 43 319 veterans who underwent PCI at a VA facility and survived at least 30 days. Of those veterans, 2986 (6.9%) participated in CR (Table 1), either at a VA facility or at another facility through care purchased by the VA or Medicare. There was substantial variation in participation in CR by facility, ranging from 0% to 36% participation (Figure 1). CR participation during the year after PCI increased between 2007 and 2011 (5.0%–8.3%;  $P<0.001$  for trend).

In an adjusted model including all variables from Table 1, older age, tobacco use, peripheral vascular disease, hemodialysis, and dementia were associated with decreased odds of participation in CR (Table 2). Black race, hyperlipidemia, depression, valvular heart disease, urgent/emergent procedure, and 3-vessel disease were associated with greater odds

of participation in CR (Table 2). There was regional variation, with significantly lower participation in the West South Central (Arkansas, Louisiana, Oklahoma, Texas) and Pacific (Alaska, California, Hawaii, Oregon, Washington) regions (Table 2). Other candidate factors from Table 1 were not significantly associated with CR participation ( $P>0.05$ ).

Median follow-up time was 6.1 years (interquartile range, 4.9–7.5 years). There were 678 deaths among CR participants and 13 279 deaths among non-CR participants. There were 886 deaths among the 2986 non-CR participants who were 1:1 propensity matched with CR participants. CR participants had a 33% lower mortality rate than all nonparticipants (3.8 versus 5.7 deaths/100 person-years; hazard ratio, 0.67; 95% confidence interval, 0.61–0.75;  $P<0.001$ ) and a 26% lower mortality rate than 2986 propensity-matched nonparticipants (3.8 versus 5.1 deaths/100 person-years; hazard ratio, 0.74; 95% confidence interval, 0.65–0.84;  $P<0.001$ ) (Figure 2). For each 10 CR sessions attended, CR participants had 18% lower



**Figure 1.** Participation in cardiac rehabilitation (CR) by facility among veterans undergoing percutaneous coronary intervention from 2007 to 2011.

**Table 2.** Predictors of Participation in CR After PCI

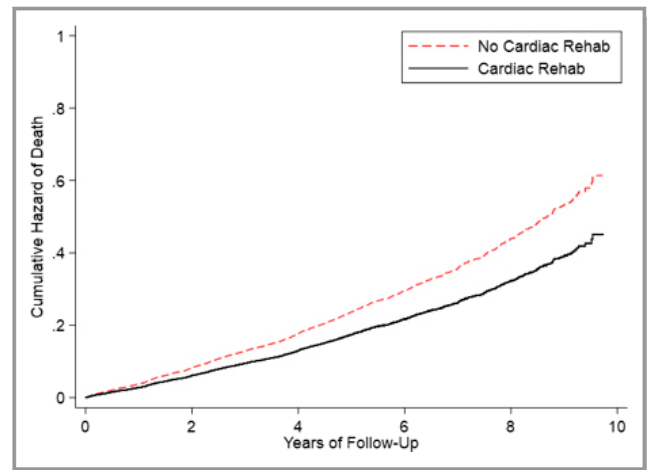
Characteristics	Adjusted Odds Ratio*	95% Confidence Interval	P Value
<b>Decreased odds of participation</b>			
Age (per 10-y increase)	0.83	0.80–0.88	<0.001
Current tobacco use	0.70	0.63–0.77	<0.001
Peripheral vascular disease	0.82	0.74–0.91	<0.001
Hemodialysis	0.47	0.32–0.70	<0.001
Dementia	0.39	0.18–0.85	0.01
<b>Region (vs New England)<sup>†</sup></b>			
Mid Atlantic	0.57	0.18–2.08	<0.001
South Atlantic	0.55	0.17–1.73	
East North Central	0.54	0.16–1.75	
East South Central	0.92	0.28–3.00	
West North Central	1.23	0.38–3.92	
West South Central	0.11	0.03–0.40	
Mountain	0.70	0.20–2.40	
Pacific	0.15	0.04–0.61	
Puerto Rico	0.92	0.15–5.29	
<b>Increased odds of participation</b>			
<b>Race/ethnicity (vs white)</b>			
Black	1.26	1.13–1.41	<0.001
Hispanic/Latino	1.20	0.98–1.47	
Asian/Pacific Islander/ American Indian	0.97	0.71–1.33	
Unknown/missing	0.85	0.70–1.04	
Hyperlipidemia	1.17	1.04–1.30	0.006
Depression	1.12	1.02–1.23	0.01
Valvular heart disease	1.22	1.08–1.38	0.001
<b>Status (vs elective)</b>			
Urgent	1.23	1.13–1.34	<0.001
Emergent/salvage	2.10	1.81–2.43	
Three-vessel disease	1.09	1.00–1.18	0.048
<b>Year of procedure (vs 2007)</b>			
2008	1.04	0.90–1.19	<0.001 <sup>‡</sup>
2009	1.33	1.16–2.53	
2010	1.66	1.44–1.92	
2011	1.73	1.49–2.00	

CR indicates cardiac rehabilitation; and PCI, percutaneous coronary intervention.

\*Adjusted for characteristics in Table 1 and year of procedure.

<sup>†</sup>New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont; Mid Atlantic: New Jersey, New York, Pennsylvania; South Atlantic: Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia; East North Central: Indiana, Illinois, Michigan, Ohio, Wisconsin; East South Central: Alabama, Kentucky, Mississippi, Tennessee; West North Central: Iowa, Nebraska, Kansas, North Dakota, Minnesota, South Dakota, Missouri; West South Central: Arkansas, Louisiana, Oklahoma, Texas; Mountain: Arizona, Colorado, Idaho, New Mexico, Montana, Utah, Nevada, Wyoming; Pacific: Alaska, California, Hawaii, Oregon, Washington.

<sup>‡</sup>P value for linear trend by year.



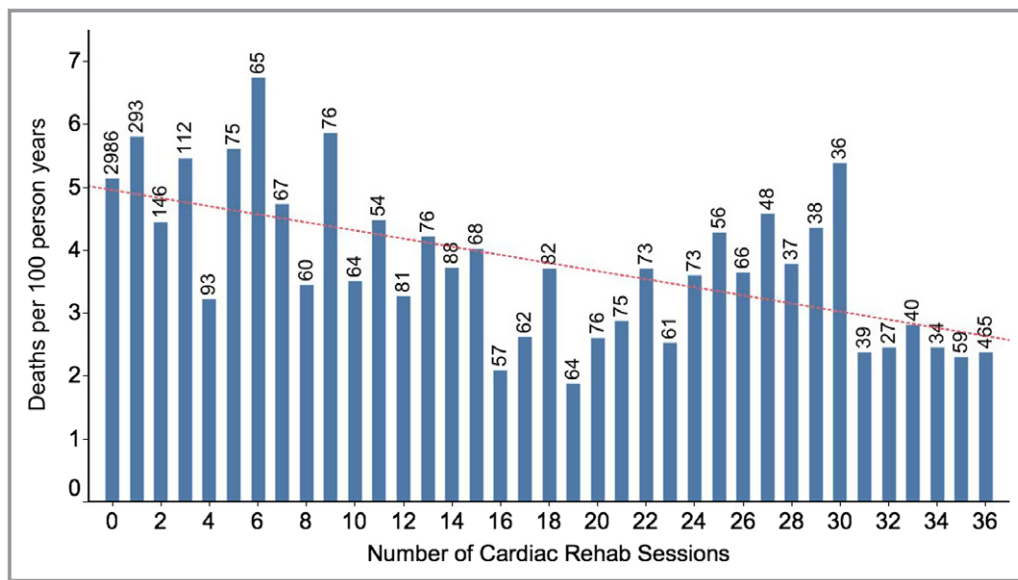
**Figure 2.** Cumulative hazard of death after percutaneous coronary intervention by participation in cardiac rehabilitation among propensity-matched pairs.

mortality (hazard ratio, 0.82; 95% confidence interval, 0.79–0.85;  $P<0.001$ ) (Figure 3). There were 465 patients who attended a complete course of at least 36 CR sessions, of whom only 69 died (2.4 deaths/100 person-years; hazard ratio, 0.47; 95% confidence interval, 0.36–0.60;  $P<0.001$  versus propensity-matched nonparticipants).

## Discussion

This research aimed to evaluate variation in CR participation after PCI among veterans and estimate the association of CR participation with long-term mortality. There was significant facility-level variation in CR participation within the VA healthcare system, ranging from 0% to 36%. Veterans who participated in CR had a significantly lower mortality rate than nonparticipants after accounting for patient and facility characteristics. Attending a greater number of CR sessions was associated with a lower mortality rate.

This is the first study to report CR participation by facility, which enables this study to more closely examine factors such as the availability of on-site CR. Facilities with on-site CR had a higher percentage of patients participating in CR, but this study demonstrates that having an on-site CR center is neither necessary nor sufficient for achieving high rates of participation.<sup>19</sup> Indeed, the 2 top-performing sites do not have on-site CR. Previous research suggests that important factors for high participation are strong healthcare professional endorsement and an organizational climate that values CR and has systematic processes for CR referral and enrollment.<sup>24</sup> For example, one of the top performing facilities without on-site CR initiates CR referrals at a standard posthospitalization clinic visit within 2 to 4 weeks of hospital discharge, with CR “highly encouraged” by providers, and



**Figure 3.** Mortality rate after percutaneous coronary intervention by number of sessions of cardiac rehabilitation attended among propensity-matched patients. The dotted red line represents the linear trend in mortality by number of sessions. The numbers above each bar represent the number of patients attending each number of sessions.

coordination of CR referrals is performed by a nurse case manager. Strategies used at other top performing facilities also include strong provider endorsement, automatic referral via electronic order sets, and contact by a CR liaison either in person in the hospital or within 1 week of referral by telephone.

Similar to prior research in other populations of patients with coronary heart disease,<sup>4–8</sup> veterans who participated in CR had lower mortality rates than veterans who did not participate in CR. The magnitude of the relative risk reduction observed in this study (27% lower risk) was comparable to previous studies (13%–47% lower risk).<sup>4,5,7–9</sup> Although people who participate in CR may be healthier than nonparticipants in ways that cannot be accounted for with analyses using coded encounter data, it is notable that the finding that CR participation is associated with lower mortality is consistently observed across different populations and analyses. In addition, we observed that participating in a greater number of CR sessions was associated with a lower mortality rate, consistent with previous studies.<sup>6</sup>

These data reveal several opportunities for improvement among some groups of patients undergoing PCI. Patients undergoing elective PCI had lower rates of participation in CR than those undergoing urgent or emergent procedures. Improving referral and promoting enrollment among patients undergoing elective PCI may be a potential strategy for improving participation. Additionally, we observed that patients with peripheral vascular disease had lower rates of participation. It is known that patients with peripheral vascular disease<sup>25</sup> benefit from supervised

exercise therapy and are recommended to receive exercise training. Targeting populations with multiple indications for secondary prevention interventions may be especially beneficial.

This study highlights the potential benefits that may arise from improving the system of delivery of CR. The Million Hearts Initiative Cardiac Rehabilitation Collaborative has identified increasing participation in CR as a strategy for reducing cardiovascular events nationwide by 2022 and has estimated that increasing CR participation to 70% would save 25 000 lives annually in the United States.<sup>26</sup> Similarly, our findings suggest that increasing participation in CR among veterans will save veteran lives.

Strategies that have been shown to be effective for increasing CR referral and participation rates include the following: automatic referral of all eligible patients at discharge, strong provider recommendation of participation in CR, structured staff contacts to encourage participation in CR, and early enrollment in CR.<sup>2,27–29</sup> Novel delivery strategies, such as telehealth-delivered home-based CR, have similar efficacy and may improve overall participation rates and access to CR.<sup>16,30,31,32</sup> Because the VA is an integrated health system, it offers a unique opportunity to implement strategies for improving CR participation and measuring the impact of these efforts. Indeed, the VA began instituting home-based CR in 2010. Although participation in CR has increased at sites with home-based CR, participation rates remain <25%.<sup>19</sup> Future studies should focus on the implementation and effectiveness of evidence-based strategies to improve participation in CR.

Several limitations to these findings should be noted. First, this study relied on coded encounter data to determine the denominator of potentially eligible patients. Some patients deemed ineligible for CR by their providers are included within our denominator. However, other analyses have demonstrated rates of ineligibility of <10%.<sup>33</sup> Second, because coded encounter data were used for this analysis, we cannot account for all potentially important factors that could contribute to likelihood of attending CR. Third, our study has limited generalizability to women, nonveterans, and uninsured populations. Finally, this study included only patients undergoing PCI, and findings may not be generalizable to other populations of patients eligible for CR.

## Conclusions

CR participation after PCI among veterans is low overall, with significant facility-level variation. CR participation is associated with lower long-term mortality rates. Additional efforts are needed to promote CR participation after PCI among veterans.

## Sources of Funding

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## Disclosures

None.

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