CLINICAL RESEARCH STUDY

THE AMERICAN JOURNAL of MEDICINE®

Participation in Cardiac Rehabilitation, Readmissions, and Death After Acute Myocardial Infarction

Shannon M. Dunlay, MD, MS,[a,b] Quinn R. Pack, MD,[c] Randal J. Thomas, MD, MS,[a] Jill M. Killian, BS,[b] Véronique L. Roger, MD, MPH[a,b]

[a]Division of Cardiovascular Diseases and [b]Department of Health Sciences Research, Mayo Clinic, Rochester, Minn; [c]Division of Cardiology, Baystate Medical Center, Springfield, Mass.

ABSTRACT

BACKGROUND: Participation in cardiac rehabilitation has been shown to decrease mortality after acute myocardial infarction, but its impact on readmissions requires examination.

METHODS: We conducted a population-based surveillance study of residents discharged from the hospital after their first-ever myocardial infarction in Olmsted County, Minnesota, from January 1, 1987, to September 30, 2010. Patients were followed up through December 31, 2010. Participation in cardiac rehabilitation after myocardial infarction was determined using billing data. We used a landmark analysis approach (cardiac rehabilitation participant vs not determined by attendance in at least 1 session of cardiac rehabilitation at 90 days post-myocardial infarction discharge) to compare readmission and mortality risk between cardiac rehabilitation participants and nonparticipants accounting for propensity to participate using inverse probability treatment weighting.

RESULTS: Of 2991 patients with incident myocardial infarction, 1569 (52.5%) participated in cardiac rehabilitation after hospital discharge. The cardiac rehabilitation participation rate did not change during the study period, but increased in the elderly and decreased in men and younger patients. After adjustment, cardiac rehabilitation participants had lower all-cause readmission (hazard ratio [HR], 0.75; 95% confidence interval [CI], 0.65-0.87; $P < .001$), cardiovascular readmission (HR, 0.80; 95% CI, 0.65-0.99; $P = .037$), noncardiovascular readmission (HR, 0.72; 95% CI, 0.61-0.85; $P < .001$), and mortality (HR, 0.58; 95% CI, 0.49-0.68; $P < .001$) risk.

CONCLUSIONS: Cardiac rehabilitation participation is associated with a markedly reduced risk of readmission and death after incident myocardial infarction. Improving cardiac rehabilitation participation rates may have a large impact on post-myocardial infarction healthcare resource use and outcomes.

 • *The American Journal of Medicine (2014) 127, 538-546*

KEYWORDS: Cardiac rehabilitation; Epidemiology; Myocardial infarction; Readmission; Survival

Each year, an estimated 635,000 Americans will have a first acute myocardial infarction.[1] With advancement in therapies, in-hospital survival after myocardial infarction has dramatically improved.[2,3] Thus, a large number of incident myocardial infarction survivors are being dismissed from the hospital into the community and are at risk for readmission. In fact, effective October 1, 2012, readmissions occurring early after myocardial infarction hospital discharge are being used as a publicly reported measure of quality of healthcare delivery and as a determinant of reimbursement by the Centers for Medicare & Medicaid Services (CMS).[4]

Participation in a cardiac rehabilitation program after myocardial infarction has been shown to improve survival, decrease the risk of recurrent myocardial infarction, and improve exercise capacity.[5-8] However, its impact on

Funding: This study was supported by grants from the National Institutes of Health (K23 HL116643 [SMD] and RO1-HL59205 [VLR]), and was made possible by the Rochester Epidemiology Project (R01-AR30582 from the National Institute of Arthritis and Musculoskeletal and Skin Diseases).

Conflict of Interest: None.

Authorship: All authors had access to the data and played a role in writing this manuscript.

Requests for reprints should be addressed to Shannon M. Dunlay, MD, MS, Division of Cardiology, Mayo Clinic, 200 First St SW, Rochester, MN 55905.

E-mail address: dunlay.shannon@mayo.edu

0002-9343/$ -see front matter
http://dx.doi.org/10.1016/j.amjmed.2014.02.008

readmissions requires further investigation. Reports from the early 1990s suggested that cardiac rehabilitation participation may reduce costs in part through a reduction in readmissions,[9,10] but more focused contemporary data are needed. Despite its known benefits, cardiac rehabilitation remains underused by myocardial infarction survivors, with participation rates as low as 14% in some series.[11] Because referral to cardiac rehabilitation remains a large barrier to participation,[12] evidence that cardiac rehabilitation reduces readmission would provide an additional incentive for hospitals and providers to refer their patients to cardiac rehabilitation after myocardial infarction.

We aimed to examine the association between cardiac rehabilitation participation and outcomes, including readmissions and death after incident myocardial infarction, in our ongoing myocardial infarction surveillance study in Olmsted County, Minnesota. We are uniquely positioned to examine this issue because we identify all incident myocardial infarctions, and the entire health care experience from diagnosis to death is captured for these patients in a community setting.

CLINICAL SIGNIFICANCE

- Only half of community patients participate in cardiac rehabilitation after acute myocardial infarction.
- Participation in a cardiac rehabilitation program after myocardial infarction reduces the risk of long-term hospital readmission by 25% and death by 42%.
- Patients should be educated about the positive impact of cardiac rehabilitation participation on long-term outcomes after myocardial infarction.

MATERIALS AND METHODS

Study Design and Setting

This study was conducted in Olmsted County, Minnesota. Population-based research is possible because there are few hospitals, namely, Olmsted Medical Center and Mayo Clinic. Medical records from all sources of care for residents are extensively indexed and linked via the Rochester Epidemiology Project.[13] Therefore, patient-level information can be obtained via the medical and administrative records. This study was approved by the Mayo Clinic and Olmsted Medical Center Institutional Review Boards.

Incident Myocardial Infarction Patient Identification and Validation

Olmsted County residents admitted with possible myocardial infarction to Olmsted County Hospitals from January 1, 1987, to September 30, 2010, were identified using International Classification of Diseases, 9th Revision (ICD-9) codes 410 and 411, as previously described.[3] Patients were excluded if they declined to provide Minnesota Research Authorization. Myocardial infarctions were validated using standard epidemiologic criteria.[3] Patients diagnosed with myocardial infarction before 1987 were excluded. The diagnosis of myocardial infarction was verified on the basis of the presence of cardiac pain, elevated biomarkers, and electrocardiogram changes.[3] The biomarkers creatine kinase and creatine kinase MB were used in clinical practice until 2000, and troponin was used thereafter. A review was done to ensure that alternative causes for elevations in biomarkers were considered. Troponin T, creatine kinase, and creatine kinase MB were measured with a sandwich electrochemiluminescence immunoassay on the Elecsys 2010 (Roche Diagnostics Corp, Indianapolis, Ind). The presence of ST elevation on the electrocardiogram was identified using the Minnesota code.[14] Reperfusion or revascularization during hospitalization was defined as having thrombolytic therapy or receiving coronary artery bypass grafting or percutaneous coronary intervention.

Participation in Cardiac Rehabilitation

Participation in cardiac rehabilitation was ascertained using administrative billing data. We relied on Current Procedural Terminology codes (93797, 93798, or 93799) with an associated numeric key specific for cardiac rehabilitation participation. Manual chart review was used to supplement billing data to ensure accuracy. The time to first cardiac rehabilitation participation was defined as the number of days after hospital discharge.

Additional Patient-Level Data

Baseline characteristics present at the time of myocardial infarction were obtained from the medical record. Clinical diagnosis was used to define hyperlipidemia, chronic obstructive pulmonary disease, cerebrovascular disease, and peripheral vascular disease. Smoking status was classified as current (if the patient smoked or quit within the last 6 months) or prior/never. Hypertension was defined by physician diagnosis, systolic blood pressure >140 mm Hg, or diastolic blood pressure >90 mm Hg. Diabetes mellitus was defined by blood glucose levels or use of diabetic medications. Anemia was defined as hemoglobin <13 mg/dL in men or <12 mg/dL in women. The Modification of Diet in Renal Disease equation[15] was used to estimate glomerular filtration rate. ZIP code of residence was used as a marker of socioeconomic status.

Study Outcomes

Data on all-cause hospitalizations after myocardial infarction from 1987 to 2010 were obtained through the Olmsted County Healthcare Expenditure and Utilization Database.[16-18] In-hospital transfers or between the Olmsted Medical Center and Mayo Clinic hospitals were considered a single hospitalization. Patients who died during their initial hospitalization were excluded. The principal

diagnosis for each hospitalization was assessed using the primary ICD-9 code, which reflects the main reason for admission. The primary reason for hospitalization was divided into cardiovascular (ICD-9 390-459) or non-cardiovascular (all other codes).

Death was ascertained from the medical record and through the follow-up infrastructure within the Rochester Epidemiology Project. In addition to deaths noted in clinical care, the Mayo Clinic registration office records obituaries and local death notices, and death data are obtained from the State of Minnesota Department of Vital and Health Statistics quarterly.

Statistical Analysis

Differences in baseline characteristics by cardiac rehabilitation participants and nonparticipants were tested using *t* tests for normally distributed continuous variables, the Wilcoxon rank-sum test for non-normally distributed variables, and chi-square for binary variables. Because cardiac rehabilitation is a nonrandomized intervention, we fitted a logistic regression model predicting cardiac rehabilitation participation. The model contained 20 variables (sex, age, hypertension, hyperlipidemia, smoking, diabetes, chronic obstructive pulmonary disease, cerebrovascular disease, body mass index, ST-elevation myocardial infarction, Killip class, glomerular filtration rate, anemia, reperfusion/revascularization, cardiologist care, receipt of beta-blocker and aspirin, length of stay, discharge to skilled nursing facility, and ZIP code). To examine the association between cardiac rehabilitation participation and readmission, we used Andersen-Gill models, which account for the repeated nature of hospitalizations.[19] Cox proportional hazard regression models were used to examine the association between cardiac rehabilitation participation and mortality.

The association of cardiac rehabilitation with outcomes was assessed using a landmark analysis in which all patients who died within 90 days of discharge after their myocardial infarction were excluded. The 90-day mark was considered day 0 for analysis, and patients were categorized as having attended cardiac rehabilitation (participants) or not (nonparticipants) by day 90 post-discharge. Three methods were used to account for differences in propensity to participate by cardiac rehabilitation participation status. First, the propensity score was adjusted for in the models. Second, we used the inverse probability of treatment weighting, which uses weights based on the propensity score to create a synthetic sample in which the distribution of measured baseline covariates is independent of treatment assignment.[20] A subject's weight is equal to the inverse of the probability of receiving the treatment that the subject received. Finally, we matched patients on the basis of the propensity to participate. A sensitivity analysis specifying 60 days post-discharge as day 0 for analysis yielded similar results (data not shown). Analyses were performed using Stata Version 13.0 (StataCorp LP, College Station, Tex) and SAS Version 9.3 (SAS Institute Inc, Cary, NC). A P value of $<.05$ was used as the level of significance.

RESULTS

Patient Characteristics

A total of 2991 patients were diagnosed with incident myocardial infarction from January 1, 1987, to September 30, 2010, and survived to hospital discharge. The characteristics of the study population are shown in **Table 1**. Cardiac rehabilitation participants were more likely to be obese, to smoke, to have hyperlipidemia, to be cared for by a cardiologist in the hospital, to receive reperfusion/revascularization, to be treated with beta-blockers and aspirin, and to have ST-elevation myocardial infarction. Nonparticipants had longer hospital length of stay, were more likely to be discharged to assisted and skilled care facilities, and had more comorbidity. Baseline characteristics of cardiac rehabilitation participants and nonparticipants stratified by propensity to participate quartiles are shown (**Table 2**). Patients were followed for an average of 7.6 years after myocardial infarction, and 1424 (47.6%) died.

Cardiac Rehabilitation Participation

Overall, 1569 patients (52.5%) participated in cardiac rehabilitation within 90 days of hospital discharge. Although there was no change in the overall cardiac rehabilitation participation over time ($P = .34$), there were changes by age and sex (**Figure 1**). Men ($P = .001$) and younger patients ($P < .001$) were less likely to participate in cardiac rehabilitation, whereas participation was stable among women ($P = .13$) and increased in the elderly ($P = .045$, age*year of diagnosis $P < .001$, sex*year of diagnosis $P = .001$). Most participants attended their first session early after discharge (median [25th, 75th percentile] 7 [5, 13] days) (**Figure 2**). Time to first participation was longer in elderly patients (median 9 vs 7 days for those aged $\geq$65 vs $<$65 years, $P < .001$) and those who had coronary artery bypass grafting (median 10 vs 7 days, $P < .001$). The number of sessions attended within 6 months after myocardial infarction varied widely. Although the median was 14 (8, 21) sessions, 204 patients (13.2%) participated in $<$5 sessions. Current smokers attended fewer sessions than nonsmokers (13 vs 17, $P < .001$).

Cardiac Rehabilitation Participation and Readmission

Most patients (n = 2265, 76%) were rehospitalized at least once. The primary reason for readmission was cardiovascular in 39.2% of cases and noncardiovascular in 60.8% of cases. The most common cardiovascular reasons were ischemic heart disease (ICD-9 428, 10.0%) and heart failure (ICD-9 428, 7.1%). The most common noncardiovascular reasons were respiratory/chest symptoms (ICD-9 786, 6.2%) and pneumonia (ICD-9, 3.4%). Cardiac rehabilitation participation was associated with markedly reduced all-cause readmission (**Table 3**, **Figure 3A**). All 3

Table 1 Patient Baseline Characteristics

Characteristic	Missing, n	Overall (n = 2991)	Cardiac Rehabilitation Status		P Value
			Nonparticipant (n = 1422)	Participant (n = 1569)	
Mean age at myocardial infarction (SD), y	0	67.3 (14.6)	73.2 (14.2)	62.0 (12.8)	<.001
Women, n (%)	0	1215 (40.6)	754 (53.0)	461 (29.4)	<.001
Risk factors and comorbid conditions, n (%)					
Hypertension	1	1827 (61.1)	993 (69.8)	834 (53.2)	<.001
Current smoker	5	738 (24.7)	302 (21.3)	436 (27.8)	<.001
Hyperlipidemia	2	1488 (49.8)	667 (46.9)	821 (52.4)	.003
Diabetes mellitus	1	654 (21.9)	392 (27.6)	262 (16.7)	<.001
Obese (BMI ≥30 kg/m^2)	4	989 (33.1)	431 (30.4)	558 (35.6)	.002
COPD	2	389 (13.0)	261 (18.4)	128 (8.2)	<.001
Cerebrovascular disease	3	424 (14.2)	306 (21.5)	118 (7.5)	<.001
Anemia (n, %)	32	804 (27.2)	533 (37.8)	271 (17.5)	<.001
Estimated GFR <60 mL/min, n, %)	17	1478 (49.7)	870 (61.5)	608 (39.0)	<.001
Incident MI characteristics					
Cardiology provider, n (%)	12	2638 (88.6)	1118 (79.0)	1520 (97.2)	<.001
ST-segment elevation, n (%)	38	922 (31.2)	346 (24.7)	576 (37.1)	<.001
Killip class 2-4, n (%)	16	827 (27.8)	498 (35.2)	329 (21.1)	<.001
Q waves, n (%)	203	1493 (53.5)	693 (52.9)	800 (54.1)	.53
Reperfusion/revascularization during hospitalization, n (%)	5	1911 (64.0)	610 (43.0)	1301 (83.0)	<.001
Fibrinolysis, n (%)*		261 (8.7)	71 (5.0)	190 (12.1)	—
Coronary artery bypass grafting, n (%)		280 (9.4)	85 (6.0)	195 (12.4)	—
PCI, n (%)		1526 (51.2)	480 (33.8)	1046 (66.7)	—
Medications during hospitalization	9				
Beta-blocker, n (%)		2595 (87.0)	1159 (81.8)	1436 (91.8)	<.001
ACE-I/ARB, n (%)		1559 (52.3)	755 (53.3)	804 (51.4)	.34
Aspirin, n (%)		2791 (93.6)	1278 (90.2)	1513 (96.7)	<.001
Hospital length of stay, d, median (25th, 75th percentile)	0	5 (3, 8)	6 (3, 10)	5 (3, 7)	<.001
Discharge to assisted or skilled care facility, n (%)	3	386 (12.9)	359 (25.3)	27 (1.7)	<.001

ACE-I/ARB = angiotensin-converting enzyme inhibitor/angiotensin receptor blocker; BMI = body mass index; COPD = chronic obstructive pulmonary disease; GFR = glomerular filtration rate; PCI = percutaneous coronary intervention; SD = standard deviation.

methods of adjustment for propensity to participate used demonstrated a reduction in the risk of all-cause, cardiovascular, and noncardiovascular readmission in patients who attended cardiac rehabilitation compared with nonparticipants. The most conservative estimates were provided using the inverse probability treatment weighting approach, and these are highlighted in the "Abstract." The reduction in risk of readmission associated with cardiac rehabilitation participation was similar across all quartiles of propensity to participate. The impact of cardiac rehabilitation participation on readmission risk differed by type of myocardial infarction (*P* value for interaction = .022, Figure 4A). Participation in cardiac rehabilitation after non−ST-elevation myocardial infarction was associated with a marked reduction in the risk of readmission (hazard ratio [HR], 0.69; *P* < .001), but had no association with readmission after ST-elevation myocardial infarction (HR, 0.94; *P* = .60). Cardiac rehabilitation participation also had a trend toward less impact on smokers' readmission risk (*P* value for interaction with nonsmokers = .060).

Cardiac Rehabilitation Participation and Mortality

Cardiac rehabilitation participation was associated with markedly reduced mortality (Table 3). The 1-year Kaplan-Meier predicted mortality was 1.8% and 20.5% for participants and nonparticipants, respectively (Figure 3B). All 3 methods of adjustment for propensity to participate demonstrated a reduction in the risk of readmission in patients who attended cardiac rehabilitation compared with nonparticipants. The impact of cardiac rehabilitation participation on risk of death differed by smoking status (*P* value for interaction = .015, Figure 4B). Participation in cardiac rehabilitation in nonsmokers was associated with a more marked reduction in the risk of death (HR, 0.53; *P* < .001) compared with smokers (HR, 0.82; *P* = .23).

DISCUSSION

Among this community cohort, only half of patients participated in cardiac rehabilitation after myocardial infarction. Although age and gender disparities existed in

Table 2 Selected Baseline Characteristics of Cardiac Rehabilitation Participants and Nonparticipants by Propensity to Participate Quartiles

	Propensity to Participate in Cardiac Rehabilitation (Quartiles)							
	Lowest Quartile (n = 725)		Low Quartile (n = 724)		High Quartile (n = 724)		Highest Quartile (n = 725)	
Characteristic	Participants	Nonparticipants	Participants	Nonparticipants	Participants	Nonparticipants	Participants	Nonparticipant
Mean age, y	78	81	69	71	65	64	54	54
Women	65%	67%	48%	48%	37%	39%	8%	8%
Current smoker	18%	14%	30%	23%	30%	34%	25%	32%
Hyperlipidemia	58%	42%	44%	50%	49%	51%	59%	54%
Diabetes mellitus	42%	32%	25%	28%	19%	22%	7%	9%
Obese (BMI ≥30)	36%	23%	33%	36%	38%	38%	35%	39%
CVD	28%	33%	16%	19%	7%	5%	<1%	<1%
STEMI	17%	19%	23%	25%	37%	31%	48%	43%
Killip class 2-4	40%	49%	24%	29%	22%	22%	13%	8%
Anemia	46%	54%	31%	33%	18%	18%	5%	4%
Estimated GFR <60	78%	78%	50%	59%	42%	38%	26%	23%
Aspirin use	92%	85%	92%	92%	98%	98%	99%	100%
Median length of stay	8	7	5	5	5	5	4	3

All values shown are % unless otherwise noted.
BMI = body mass index; CVD = cerebrovascular disease; GFR = glomerular filtration rate; STEMI = ST-segment elevation myocardial infarction.

likelihood of participation, they narrowed over time. Participation in cardiac rehabilitation was associated with a lower post-myocardial infarction mortality and a reduced risk of cardiovascular and noncardiovascular readmissions.

Cardiac Rehabilitation Participation

As did the study by Williams et al,[21] the current study found that women and the elderly receive equal benefit from cardiac rehabilitation participation compared with their younger male counterparts. However, they are less likely to be referred and attend cardiac rehabilitation after myocardial infarction.[5,11,22] Although the average participation rate remained at approximately 52% over the last 3 decades, the age/gender gap narrowed over time, as cardiac rehabilitation participation increased among the elderly and declined among men and younger individuals. This decline in participation among men and younger people is concerning, and improved participation among all ages and genders is needed. It is notable that most patients began participating in cardiac rehabilitation early after hospital discharge with a median discharge-to-participation time of only 7 days. Early cardiac rehabilitation participation has been the standard of care at our institution for several decades, and patients are enrolled in cardiac rehabilitation while still hospitalized, and their first appointment is usually set up early post-discharge. The early enrollment in cardiac rehabilitation in our program is unique and in alignment with the guidelines, although nationally, time to enrollment averages 4 to 6 weeks.[23]

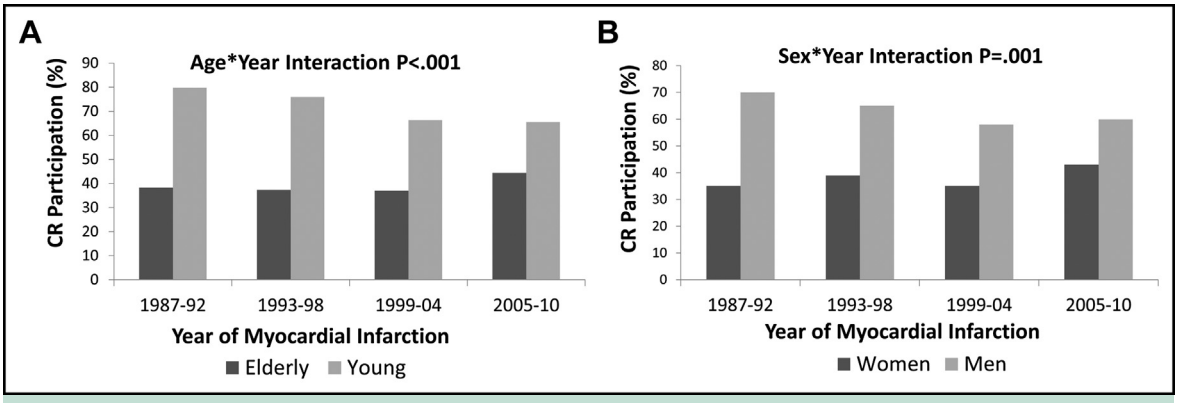

Figure 1 Cardiac rehabilitation participation according to age and sex. The proportion of patients participating in cardiac rehabilitation by year of myocardial infarction diagnosis according to age (**A**, elderly if age ≥65 years) and sex (**B**) is shown.

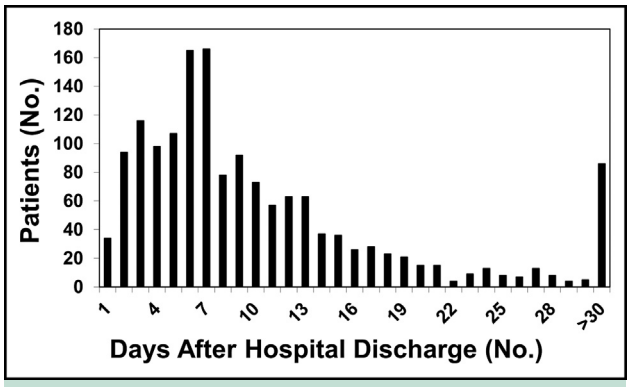

Figure 2 Timing of participation in cardiac rehabilitation. The number of days after incident myocardial infarction hospital discharge that patients attended their first session of cardiac rehabilitation is shown. CR = cardiac rehabilitation.

Early cardiac rehabilitation participation has been shown to be safe[24] and effective,[25] and to increase participation rates.[26]

Cardiac Rehabilitation and Mortality After Myocardial Infarction

Meta-analyses of randomized controlled trials and observational studies[5,7,27-30] have demonstrated a reduction in mortality after myocardial infarction associated with cardiac rehabilitation participation. Crude differences in mortality in observational studies are of greater magnitude than those observed in randomized controlled trials.[5,31] In part, this can be attributed to the nonrandomized nature of the intervention, whereby older, sicker patients are less likely to be referred and participate in cardiac rehabilitation, but more likely to experience adverse outcomes. However, examination of mortality differences in real-world populations is of great importance, because trial populations are highly selected.[32] The elderly patient with comorbidities who is commonly encountered in clinical practice would generally be excluded from trial enrollment, and their response to interventions such as cardiac rehabilitation may differ. We found that participation in cardiac rehabilitation post-myocardial infarction was associated with a 42% reduction in mortality over an average of 7.6 years. Furthermore, the mortality reduction persisted across the range of propensities to participate in cardiac rehabilitation, indicating that even the highest-risk incident myocardial infarction survivors participating in cardiac rehabilitation have lower mortality compared with those who do not participate. Current smokers were the sole subgroup who did not experience reduced mortality, although they attended fewer cardiac rehabilitation sessions, which could have affected their benefit.

Cardiac Rehabilitation and Readmission After Myocardial Infarction

Little is known about the association between cardiac rehabilitation participation and readmissions. In the early 1990s, patients participating in cardiac rehabilitation had lower readmission charges post-myocardial infarction compared with nonparticipants, because of lower incidence of hospitalizations and lower charges per hospitalization.[9] Although a randomized controlled trial would be the most definitive way to examine the impact of cardiac rehabilitation participation on readmissions, no such trial exists. In our well-defined community cohort of patients with incident myocardial infarction, we found that cardiac rehabilitation participation was associated with a 25% reduction in long-term readmission risk. These findings were robust to multiple statistical techniques used to account for differences in propensity to participate in cardiac rehabilitation. There are several potential reasons that cardiac rehabilitation participation may reduce the risk of both cardiovascular and noncardiovascular readmissions. First, cardiac rehabilitation participation is known to reduce the risk of reinfarction and to improve functional status, and it has favorable effects on cardiovascular risk factors, such as smoking and blood pressure.[8] Furthermore, cardiac rehabilitation programs offer not only secondary prevention therapies and regular repeated interactions and assessments by a multidisciplinary team but also an avenue for continued education and counseling of

Table 3 Participation in Cardiac Rehabilitation, Readmissions, and Mortality

	Risk of Participants vs Nonparticipants Hazard Ratio (95% CI), *P* value			
All-Cause Readmission	Unadjusted	Adjusted (Method 1)*	Adjusted (Method 2)†	Adjusted (Method 3)‡
Long-term				
All-cause	0.52 (0.47-0.57), <.001	0.72 (0.64-0.81), <.001	0.75 (0.65-0.87), <.001	0.61 (0.55-0.67), <.001
Cardiovascular	0.59 (0.52-0.67), <.001	0.77 (0.66-0.89), <.001	0.80 (0.65-0.99), .037	0.64 (0.56-0.74), <.001
Noncardiovascular	0.48 (0.43-0.53), <.001	0.69 (0.60-0.79), <.001	0.72 (0.61-0.85), <.001	0.59 (0.52-0.66), <.001
Death				
All-cause	0.24 (0.22-0.27), <.001	0.55 (0.48-0.64), <.001	0.58 (0.49-0.68), <.001	0.46 (0.39-0.54), <.001

CI = confidence interval.
*Method 1 is adjusted for propensity to participate.
†Method 2 used inverse probability treatment weighting, which generates weights based on the propensity score.
‡Method 3 matches based on propensity score (maximum matched pair difference in propensity = 0.10). This resulted in 804 matched pairs.

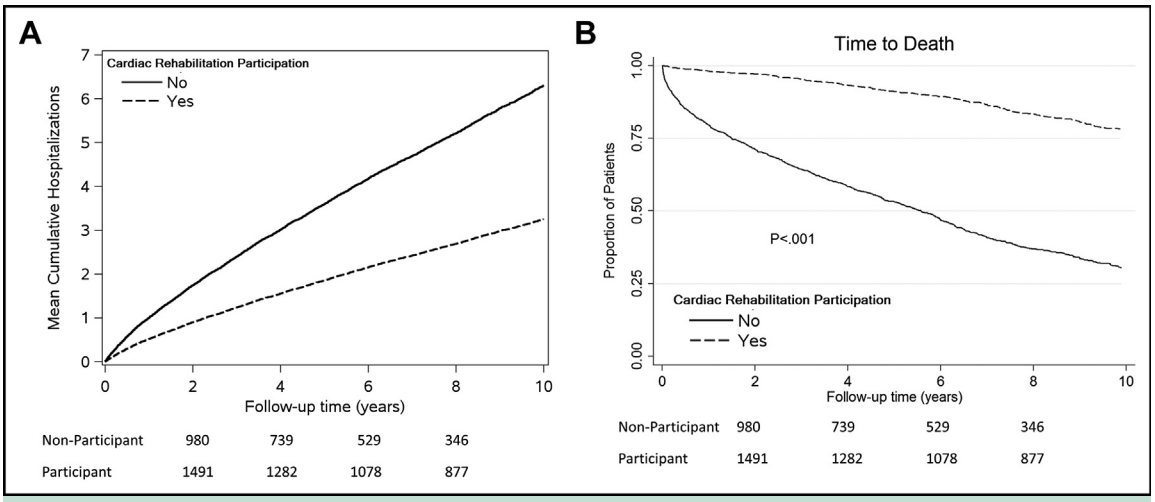

Figure 3 Readmission and mortality after myocardial infarction for cardiac rehabilitation. Participants and nonparticipants. The estimated mean number of readmissions over time (**A**) and Kaplan-Meier curves demonstrating time to death (**B**) after myocardial infarction are shown for cardiac rehabilitation participants and nonparticipants. The number of patients at risk is shown below the figures.

patients during the vulnerable period after acute myocardial infarction.

Public Health Implications

The association among cardiac rehabilitation participation, readmissions, and mortality is important in targeting public health efforts. Despite the fact that participation in cardiac rehabilitation has received a class I recommendation in the American College of Cardiology Foundation/American Heart Association guidelines after acute myocardial infarction, both referral and participation rates remain low.[11,12] Because there is a tremendous impetus to implement strategies to reduce readmissions, improving cardiac rehabilitation participation rates may represent a high-yield area to focus improvement efforts. Several key recommendations toward improving cardiac rehabilitation participation rates include educating patients and providers about the benefits of cardiac rehabilitation, implementing system-based approaches such as automating cardiac rehabilitation referrals, and improving accessibility and insurance coverage of cardiac rehabilitation programs.[33,34] The American College of Cardiology Foundation, American Heart Association, and American Association of Cardiovascular and Pulmonary Rehabilitation have developed, tested, and implemented cardiac rehabilitation performance measures,[35] which are included in the Physician Quality Reporting System, and will be audited by the CMS starting this year.

Study Limitations and Strengths

Some limitations should be acknowledged when interpreting these results. We captured readmissions occurring at Olmsted County facilities. However, among CMS-eligible Olmsted County residents, only 1% of 30-day readmissions and 5% of all hospitalizations in 2005 were to

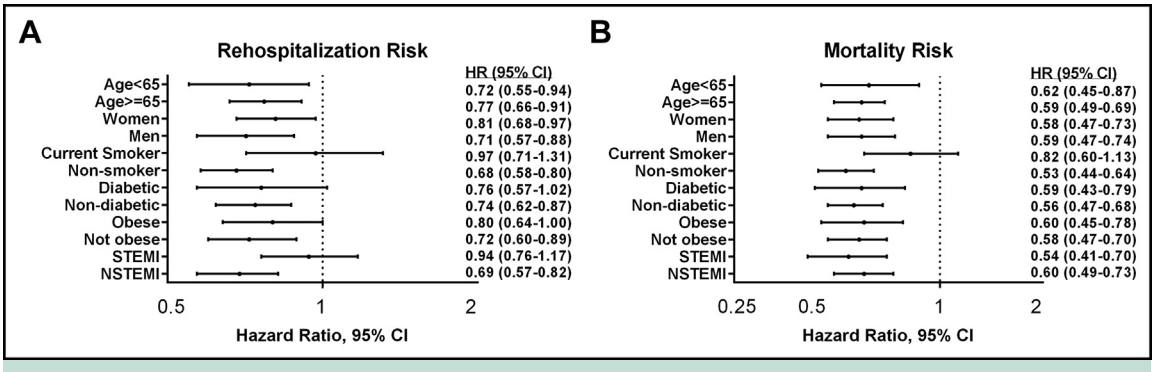

Figure 4 Risk of readmission and death according to baseline characteristics. The HRs (95% CIs) for readmission (**A**) and death (**B**) according to patient baseline characteristics are shown. CI = confidence interval; HR = hazard ratio; NSTEMI = non−ST-elevation myocardial infarction; STEMI = ST-elevation myocardial infarction.

facilities outside of Olmsted County. Therefore, the impact of hospitalizations at outside facilities on results is likely negligible. We rigorously accounted for differences in propensity to participate in cardiac rehabilitation, but cannot eliminate the possibility that residual confounding may exist. At our institution, we are not allowed to include insurance status in any modeling. However, the proportion of uninsured patients was low (1.7%), and lack of insurance coverage for cardiac rehabilitation attendance after myocardial infarction is likely rare. We were limited in our ability to assess the impact that cardiac rehabilitation participation has on readmissions early after hospital discharge, because patients were just beginning to participate in cardiac rehabilitation during that time. Finally, this reflects the experience of a single community, and results may differ in other settings. Despite these potential limitations, our study has several unique strengths, including the rigorous myocardial infarction definition applied to an entire community population and the extensive longitudinal follow-up with detailed information about patient characteristics and clinical outcomes.

CONCLUSIONS

Despite the clear benefits of participation in cardiac rehabilitation, it remains underused after acute myocardial infarction. In this community cohort, although only half of patients attended cardiac rehabilitation, participation was associated with marked reductions in hospital readmissions and mortality. Increasing participation in cardiac rehabilitation after myocardial infarction should be considered as part of a strategy to reduce readmissions.

References

1. Go AS, Mozaffarian D, Roger VL, et al. Executive summary: heart disease and stroke statistics—2013 update: a report from the American Heart Association. *Circulation*. 2013;127:143-152.
2. Kostis WJ, Deng Y, Pantazopoulos JS, et al. Trends in mortality of acute myocardial infarction after discharge from the hospital. *Circ Cardiovasc Qual Outcomes*. 2010;3:581-589.
3. Roger VL, Weston SA, Gerber Y, et al. Trends in incidence, severity, and outcome of hospitalized myocardial infarction. *Circulation*. 2010;121:863-869.
4. Hospital Readmissions Reduction Program. Affordable Care Act., Subpart 1 of 42 CRT part 412. Sect. 1886(q) (2012).
5. Witt BJ, Jacobsen SJ, Weston SA, et al. Cardiac rehabilitation after myocardial infarction in the community. *J Am Coll Cardiol*. 2004;44:988-996.
6. Ades PA. Cardiac rehabilitation and secondary prevention of coronary heart disease. *N Engl J Med*. 2001;345:892-902.
7. Jolliffe JA, Rees K, Taylor RS, et al. Exercise-based rehabilitation for coronary heart disease. *Cochrane Database Syst Rev*. 2001:CD001800.
8. Lawler PR, Filion KB, Eisenberg MJ. Efficacy of exercise-based cardiac rehabilitation post-myocardial infarction: a systematic review and meta-analysis of randomized controlled trials. *Am Heart J*. 2011;162:571-584 e2.
9. Ades PA, Huang D, Weaver SO. Cardiac rehabilitation participation predicts lower rehospitalization costs. *Am Heart J*. 1992;123(4 Pt 1):916-921.
10. Ades PA, Pashkow FJ, Nestor JR. Cost-effectiveness of cardiac rehabilitation after myocardial infarction. *J Cardiopulm Rehabil*. 1997;17:222-231.
11. Suaya JA, Shepard DS, Normand SL, et al. Use of cardiac rehabilitation by Medicare beneficiaries after myocardial infarction or coronary bypass surgery. *Circulation*. 2007;116:1653-1662.
12. Brown TM, Hernandez AF, Bittner V, et al. Predictors of cardiac rehabilitation referral in coronary artery disease patients: findings from the American Heart Association's Get With The Guidelines Program. *J Am Coll Cardiol*. 2009;54:515-521.
13. Melton LJ 3rd. History of the Rochester Epidemiology Project. *Mayo Clin Proc*. 1996;71:266-274.
14. Kors JA, Crow RS, Hannan PJ, et al. Comparison of computer-assigned Minnesota Codes with the visual standard method for new coronary heart disease events. *Am J Epidemiol*. 2000;151:790-797.
15. Levey AS, Coresh J, Greene T, et al. Using standardized serum creatinine values in the modification of diet in renal disease study equation for estimating glomerular filtration rate. *Ann Intern Med*. 2006;145:247-254.
16. Dunlay SM, Redfield MM, Weston SA, et al. Hospitalizations after heart failure diagnosis a community perspective. *J Am Coll Cardiol*. 2009;54:1695-1702.
17. Dunlay SM, Shah ND, Shi Q, et al. Lifetime costs of medical care after heart failure diagnosis. *Circ Cardiovasc Qual Outcomes*. 2011;4:68-75.
18. Leibson CL, Katusic SK, Barbaresi WJ, et al. Use and costs of medical care for children and adolescents with and without attention-deficit/hyperactivity disorder. *JAMA*. 2001;285:60-66.
19. Andersen PK, Gill RD. Cox's regression model for counting processes: a large sample study. *Ann Stat*. 1982;10:1100-1120.
20. Rosenbaum PR. Propensity score. In: Armitage P, Colton T, eds. *Encyclopedia of Biostatistics*. New York: Wiley; 1998:3551-3555.
21. Williams MA, Ades PA, Hamm LF, et al. Clinical evidence for a health benefit from cardiac rehabilitation: an update. *Am Heart J*. 2006;152:835-841.
22. Dunlay SM, Witt BJ, Allison TG, et al. Barriers to participation in cardiac rehabilitation. *Am Heart J*. 2009;158:852-859.
23. Zullo MD, Jackson LW, Whalen CC, Dolansky MA. Evaluation of the recommended core components of cardiac rehabilitation practice: an opportunity for quality improvement. *J Cardiopulm Rehabil Prev*. 2012;32:32-40.
24. Soga Y, Yokoi H, Ando K, et al. Safety of early exercise training after elective coronary stenting in patients with stable coronary artery disease. *Eur J Cardiovasc Prev Rehabil*. 2010;17:230-234.
25. Haykowsky M, Scott J, Esch B, et al. A meta-analysis of the effects of exercise training on left ventricular remodeling following myocardial infarction: start early and go longer for greatest exercise benefits on remodeling. *Trials*. 2011;12:92.
26. Pack QR, Mansour M, Barboza JS, et al. An early appointment to outpatient cardiac rehabilitation at hospital discharge improves attendance at orientation: a randomized, single-blind, controlled trial. *Circulation*. 2013;127:349-355.
27. Oldridge NB, Guyatt GH, Fischer ME, Rimm AA. Cardiac rehabilitation after myocardial infarction. Combined experience of randomized clinical trials. *JAMA*. 1988;260:945-950.
28. Taylor RS, Brown A, Ebrahim S, et al. Exercise-based rehabilitation for patients with coronary heart disease: systematic review and meta-analysis of randomized controlled trials. *Am J Med*. 2004;116:682-692.
29. Pack QR, Goel K, Lahr BD, et al. Participation in cardiac rehabilitation and survival after coronary artery bypass graft surgery: a community-based study. *Circulation*. 2013;128:590-597.
30. Suaya JA, Stason WB, Ades PA, et al. Cardiac rehabilitation and survival in older coronary patients. *J Am Coll Cardiol*. 2009;54:25-33.
31. Beauchamp A, Worcester M, Ng A, et al. Attendance at cardiac rehabilitation is associated with lower all-cause mortality after 14 years of follow-up. *Heart*. 2012;99:620-625.
32. Lee PY, Alexander KP, Hammill BG, et al. Representation of elderly persons and women in published randomized trials of acute coronary syndromes. *JAMA*. 2001;286:708-713.

33. Arena R, Williams M, Forman DE, et al. Increasing referral and participation rates to outpatient cardiac rehabilitation: the valuable role of healthcare professionals in the inpatient and home health settings: a science advisory from the American Heart Association. *Circulation*. 2012;125:1321-1329.
34. Balady GJ, Ades PA, Bittner VA, et al. Referral, enrollment, and delivery of cardiac rehabilitation/secondary prevention programs at clinical centers and beyond: a presidential advisory from the American Heart Association. *Circulation*. 2012;124:2951-2960.
35. Thomas RJ, King M, Lui K, et al. AACVPR/ACCF/AHA 2010 Update: Performance measures on cardiac rehabilitation for referral to cardiac rehabilitation/secondary prevention services: a report of the American Association of Cardiovascular and Pulmonary Rehabilitation and the American College of Cardiology Foundation/American Heart Association Task Force on Performance Measures (Writing Committee to Develop Clinical Performance Measures for Cardiac Rehabilitation). *J Cardiopulm Rehabil Prev*. 2010;30:279-288.