Relationship Between Cardiac Rehabilitation and Long-Term Risks of Death and Myocardial Infarction Among Elderly Medicare Beneficiaries

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Background**—**For patients with coronary heart disease, exercise-based cardiac rehabilitation improves survival rate and has beneficial effects on risk factors for coronary artery disease. The relationship between the number of sessions attended and long-term outcomes is unknown.

Methods and Results**—**In a national 5% sample of Medicare beneficiaries, we identified 30 161 elderly patients who attended at least 1 cardiac rehabilitation session between January 1, 2000, and December 31, 2005. We used a Cox proportional hazards model to estimate the relationship between the number of sessions attended and death and myocardial infarction (MI) at 4 years. The cumulative number of sessions was a time-dependent covariate. After adjustment for demographic characteristics, comorbid conditions, and subsequent hospitalization, patients who attended 36 sessions had a 14% lower risk of death (hazard ratio [HR], 0.86; 95% confidence interval [CI], 0.77 to 0.97) and a 12% lower risk of MI (HR, 0.88; 95% CI, 0.83 to 0.93) than those who attended 24 sessions; a 22% lower risk of death (HR, 0.78; 95% CI, 0.71 to 0.87) and a 23% lower risk of MI (HR, 0.77; 95% CI, 0.69 to 0.87) than those who attended 12 sessions; and a 47% lower risk of death (HR, 0.53; 95% CI, 0.48 to 0.59) and a 31% lower risk of MI (HR, 0.69; 95% CI, 0.58 to 0.81) than those who attended 1 session.

Conclusions**—**Among Medicare beneficiaries, a strong dose–response relationship existed between the number of cardiac rehabilitation sessions and long-term outcomes. Attending all 36 sessions reimbursed by Medicare was associated with lower risks of death and MI at 4 years compared with attending fewer sessions. **(*Circulation*. 2010;121:63-70.)**

Key Words: coronary disease ■ heart failure ■ mortality ■ myocardial infarction ■ rehabilitation

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Exercise-based cardiac rehabilitation is an important part of the long-term management of patients with chronic stable angina[1] and of patients who have had a myocardial infarction (MI)[2] or undergone coronary artery bypass grafting (CABG) surgery.[3] Medicare has long reimbursed for cardiac rehabilitation for these indications, and the list of eligible indications recently expanded to include percutaneous coronary intervention, heart transplantation, and cardiac valve replacement or repair.[4]

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Among patients with coronary heart disease, participation in cardiac rehabilitation, compared with nonparticipation, has been reported to have beneficial effects. In a meta-analysis of randomized controlled trials, participation in exercise-based cardiac rehabilitation improved both survival rate and risk factors associated with coronary artery disease.[5] An observational analysis of Medicare beneficiaries in 1997 also found a survival benefit associated with any participation in cardiac rehabilitation among patients hospitalized for coronary conditions.[6] Among patients with heart failure, results from Heart Failure: A Controlled Trial Investigating Outcomes of Exercise Training (HF-ACTION) suggested that exercise was efficacious.[7]

Among patients who participate in cardiac rehabilitation, evidence on the optimal "dose" of cardiac rehabilitation is limited.[5,6,8] It is not known whether attending more cardiac rehabilitation sessions is better than attending fewer or if there is a threshold number of sessions above which patients obtain less benefit. In the present study, we sought to characterize the dose–response relationship between the num-

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ber of cardiac rehabilitation sessions attended and the long-term risks of death and MI in a cohort of Medicare beneficiaries participating in cardiac rehabilitation.

Methods

Data Source

We obtained research-identifiable Medicare claims data from January 1, 1999, through December 31, 2006, for a national 5% sample of beneficiaries from the Centers for Medicare & Medicaid Services. The data include inpatient, outpatient, physician, and denominator files. The inpatient file contains claims for institutional inpatient services. The outpatient file contains claims for institutional outpatient services, including emergency department visits. The physician file contains claims for other noninstitutional physician services. The denominator file contains information on beneficiary eligibility and enrollment and demographic characteristics. The study population was limited to Medicare beneficiaries ≥65 years of age living in the United States. The analyses were limited to claims incurred during periods of fee-for-service coverage. The institutional review board of the Duke University Health System approved the study.

Patient Population

We identified all patients with at least 1 Medicare claim for early outpatient cardiac rehabilitation services with or without continuous ECG monitoring (*Current Procedural Terminology* codes 93797 and 93798) during the study period. The date of each patient's first cardiac rehabilitation claim served as the index date. To allow for determination of comorbid conditions present on the index date and determination of subsequent accrual of cardiac rehabilitation sessions and outcomes, we limited the analysis to patients whose index date was between January 1, 2000, and December 31, 2005. In addition, we required patients to have been enrolled in fee-for-service Medicare for the full year before the index date.

Cardiac Rehabilitation Dose

The exposure of interest was the number of cardiac rehabilitation sessions reimbursed by Medicare for each patient. We searched outpatient and physician claims for the dates of up to 36 cardiac rehabilitation sessions per patient in the 36 weeks after the index date. Although the Medicare national coverage determination specifies coverage for 36 sessions over 18 weeks, Medicare contractors have the discretion to cover additional sessions over 36 weeks.[4]

Outcomes

The primary outcome for this study was all-cause death, which we determined on the basis of death dates in the Medicare denominator files. We also examined subsequent MI, which we determined by searching for the first inpatient or emergency department claim with a primary diagnosis of a new MI (*International Classification of Diseases, Ninth Revision, Clinical Modification* [*ICD-9-CM*] code 410.x1) after the index date. We examined both outcomes through December 31, 2006. The length of follow-up used in the statistical models was 4 years after the index date.

Other Variables

Patient age, sex, and race were available in the denominator files. Comorbid conditions were based on the presence of relevant *ICD-9-CM* diagnosis codes on any inpatient, outpatient, or physician claim in the year before the index date. We used previously validated coding algorithms[9,10] to search for any diagnosis of cancer (140.x to 172.x, 174.x to 208.x, 238.6), cerebrovascular disease (362.34, 430.x to 438.x), chronic obstructive pulmonary disease (416.8, 416.9, 490.x to 505.x, 506.4, 508.1, 508.8), dementia (290.x, 294.1, 331.2), diabetes mellitus (250.x), heart failure (428.x, 398.91, 402.x1, 404.x1, 404.x3), hypertension (401.x to 405.x, 437.2), peptic ulcer disease (531.x to 534.x), peripheral vascular disease (093.0, 437.3, 440.x, 441.x, 443.1 to 443.9, 557.1, 557.9, V43.4), and renal disease (403.x1, 404.x2, 404.x3, 582.x, 583.0 to 583.7, 585.x, 586.x, 588.x, V42.0, V45.1, V56.x).

We searched inpatient claims for the date of each patient's first hospital admission, if any, after the index date. We searched all claims in the year before the index date for the indication that qualified the patient for cardiac rehabilitation coverage. Between 2000 and 2005, the covered indications included MI (*ICD-9-CM* diagnosis code 410.xx), CABG (procedure code 36.1x or diagnosis code V45.81), and stable angina (diagnosis code 413.x). For patients with multiple indications, we selected the qualifying indication using a hierarchy of CABG, MI, and angina, in that order.

Statistical Analysis

To describe characteristics of the study population at the index date, we present categorical variables as percentages and continuous variables as medians and interquartile ranges. We use a histogram to summarize the total number of cardiac rehabilitation sessions reimbursed by Medicare within 36 weeks of the index date for each patient.

To describe the observed mortality rate of the study population, we plotted cumulative incidence estimates based on a single Kaplan-Meier curve for all patients from the index date through 36 weeks, while rehabilitation sessions accrued, and separate Kaplan-Meier curves, conditional on survival to 36 weeks, from 36 weeks through 4 years for patients grouped by the total number of cardiac rehabilitation sessions. We tested for differences between the separate curves using a log-rank test. To describe the observed rate of MI while accounting for the competing risk of death, we plotted a single cumulative incidence curve[11] for all patients from the index date through 36 weeks and separate cumulative incidence curves, conditional on event-free survival to 36 weeks, from 36 weeks through 4 years for patients grouped by the total number of cardiac rehabilitation sessions. We tested for differences between the curves using Gray tests.[12]

We estimated the unadjusted and adjusted relationships between the number of cardiac rehabilitation sessions and each outcome by using Cox proportional hazards models. Treating the cumulative number of sessions as a time-dependent covariate, we first modeled its effect by using a restricted cubic spline with knots at 10, 16, 22, and 28 sessions. A restricted cubic spline function allowed us to estimate a smoothed nonlinear relationship between exposure and outcome in a regression model.[13] We assessed the nonlinear spline terms as a group using the Wald test. If this group test indicated that the terms added significant explanatory value to the model at $\alpha=0.10$, we retained the terms in the final model. If not, we omitted the terms from the final model, leaving only the linear term. The adjusted model also included demographic characteristics, comorbid conditions, and a time-dependent indicator for any hospitalization during the first 36 weeks after the first rehabilitation session to account for stops or delays in cardiac rehabilitation because of serious illness. We ran the models for all patients and by indication. If the relationship between an outcome and the number of sessions was estimated to be nonlinear, we plotted the hazard ratios (HRs) and 95% confidence intervals (CIs) for 36 sessions compared with each number of fewer sessions.

We performed a few sensitivity analyses. First, we ran the models on the subset of patients who had any diagnosis of heart failure in the previous 12 months because patients with heart failure are a population of interest for cardiac rehabilitation. Second, to address the bias that may arise when some patients drop out of cardiac rehabilitation early, we ran the models on patients who attended at least 6 sessions. Finally, if the nonlinear spline terms were deemed necessary, we altered the number and position of the knots to determine whether the specification of the spline function led to different results.

We also used a linear regression model to estimate the associations of demographic characteristics, comorbid conditions, qualifying indication, and subsequent hospitalization with the number of cardiac rehabilitation sessions patients attended. Only patients who survived until 36 weeks were included in this analysis.

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Table 1. Characteristics of Patients Who Attended at Least 1 Cardiac Rehabilitation Session

Characteristic	Patients (n=30 161)
Age, median (interquartile range), y	74.0 (70.0–78.0)
Male sex, n (%)	19 229 (63.8)
Race, n (%)	
Black	839 (2.8)
White	28 771 (95.4)
Other/unknown	551 (1.8)
Comorbid conditions, n (%)	
Cancer	4511 (15.0)
Cerebrovascular disease	9902 (32.9)
Chronic obstructive pulmonary disease	10 647 (35.4)
Dementia	400 (1.3)
Diabetes mellitus	10 790 (35.8)
Heart failure	11 955 (39.7)
Hypertension	26 045 (86.5)
Peptic ulcer disease	1200 (4.0)
Peripheral vascular disease	9251 (30.7)
Renal disease	2291 (7.6)
Qualifying indication for cardiac rehabilitation, n (%)*	
CABG	18 325 (60.8)
MI	6181 (20.5)
Stable angina	4484 (14.9)
Unknown	1171 (3.9)
Year of first cardiac rehabilitation session, n (%)	
2000	5262 (17.4)
2001	5150 (17.1)
2002	5335 (17.7)
2003	5167 (17.1)
2004	4802 (15.9)
2005	4445 (14.7)

*For patients with multiple indications, the qualifying indication was selected with the use of a hierarchy of CABG, MI, and stable angina, in that order.

Results

There were 30 161 Medicare beneficiaries in the national 5% sample who started cardiac rehabilitation between January 1, 2000, and December 31, 2005. Table 1 shows the characteristics of the study population at the index date. Most patients were men (64%), and 5% were nonwhite. The average age was 74 years. Forty percent had a diagnosis of congestive heart failure in the previous year, and 36% had diabetes mellitus. The most frequent qualifying indication was CABG (61%). The qualifying indication for 4% of the patients could not be determined.

Figure 1 shows the distribution of cardiac rehabilitation sessions for each patient within 36 weeks of the index date. The median number of sessions was 25 (interquartile range, 13 to 34). More than 40% of the patients attended ≥30 sessions, and 13% attended <6. We limited the number of cardiac rehabilitation sessions to 36 because not all Medicare carriers reimburse for additional sessions. This limitation affected 1225 patients (4%) who had >36 sessions recorded in the claims data. Nearly one third of the patients (n=8560) were hospitalized at some point during the 36 weeks after the index date. Among those hospitalized, 2676 (31%) resumed attending cardiac rehabilitation sessions after discharge.

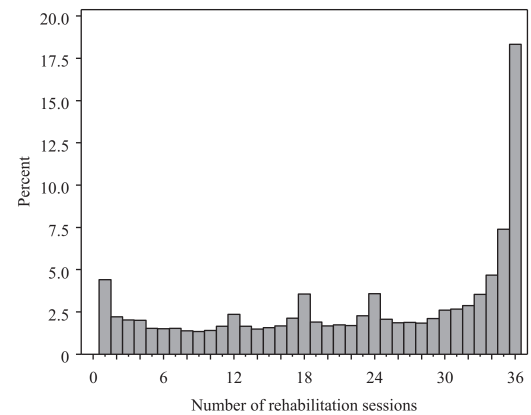

Figure 1. Histogram of cumulative cardiac rehabilitation sessions attended during the first 36 weeks after the index date.

The observed incidence of death is shown in Figure 2. Overall mortality rate during the first 36 weeks was 2.0% (n=605). From this point through the end of follow-up, mortality rates differed significantly by the total number of rehabilitation sessions attended (P<0.001). The mortality rate was consistently highest among patients who attended <12 sessions and lowest among patients who attended ≥36 sessions.

Figure 3 shows a similar plot for incidence of new MI. The overall incidence of MI was 1.6% (n=464) during the first 36 weeks after the index date, with no noticeable early spike in events. After 36 weeks, there were statistically significant differences in the incidence of MI by the total number of cardiac rehabilitation sessions (P=0.002). Patients who attended ≥24 sessions had the lowest subsequent rate of MI, whereas patients who attended <12 sessions had the highest incidence of MI.

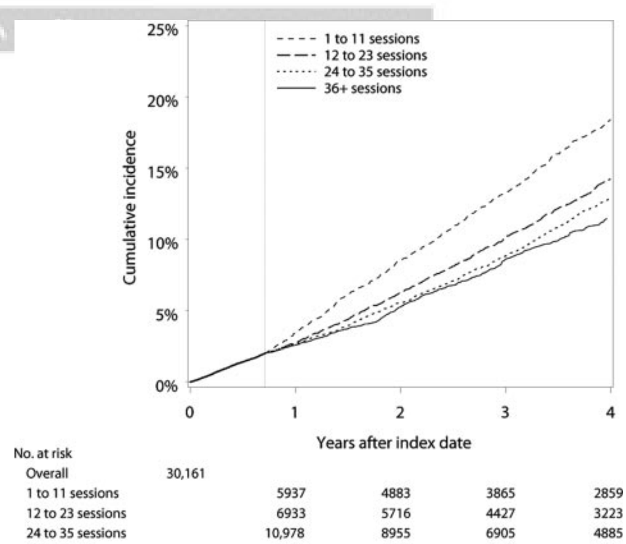

Figure 2. Cumulative incidence of death by number of cardiac rehabilitation sessions attended.

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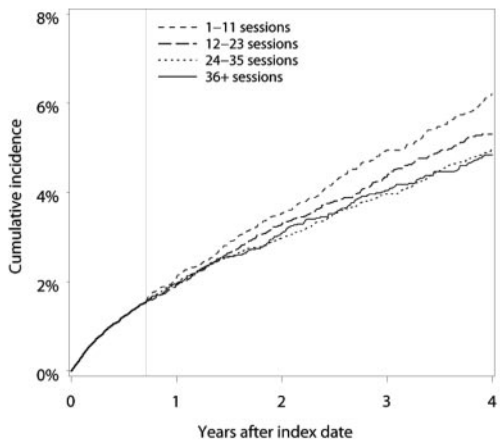

No. at risk					
Overall	30,161				
1 to 11 sessions		5693	4573	3572	2582
12 to 23 sessions		6695	5406	4113	2943
24 to 35 sessions		10,708	8546	6516	4514
36 sessions		5314	4286	3297	2271

Figure 3. Cumulative incidence of MI by number of cardiac rehabilitation sessions attended.

The initial model for mortality rate indicated that the nonlinear spline terms for the cumulative number of cardiac rehabilitation sessions were statistically significant (χ_2^2=15.6; P<0.001). Significant results were also obtained for all indications. Therefore, we retained these terms for all of the mortality rate models. The number and position of knots for the spline function in the mortality rate model did not change the results, and therefore we used the original specifications. The nonlinear spline terms were not statistically significant in the initial MI model (χ^2=1.0; P=0.61). These terms were insignificant for the indications, as well. Therefore, all MI models included only a linear term for the cumulative number of cardiac rehabilitation sessions.

In the unadjusted mortality rate model, the spline function estimated a substantial and statistically significant relationship between the number of cardiac rehabilitation sessions and the risk of death. For example, attending 36 sessions was associated with an 18% lower risk of death compared with attending 24 sessions (HR, 0.82; 95% CI, 0.73 to 0.92), a 29% lower risk compared with attending 12 sessions (HR, 0.71; 95% CI, 0.64 to 0.78), and a 58% lower risk compared with attending 1 session (HR, 0.42; 95% CI, 0.38 to 0.47). Results of the adjusted mortality rate model are shown in Table 2. The HRs remained highly significant but were moderated slightly after adjustment for demographic characteristics, comorbid conditions, and subsequent hospitalization. The full spline function of the adjusted HR for death for 36 sessions compared with fewer sessions is shown in Figure 4. Attending 36 cardiac rehabilitation sessions was associated with significantly lower risk of death compared with any other number of sessions, although the most substantial differences were seen in comparison with the first 12 to 18 sessions.

The unadjusted linear relationship between the cumulative number of cardiac rehabilitation sessions and MI was statistically significant. Attending 36 sessions was associated with a 15% lower risk of death compared with attending 24 sessions (HR, 0.85; 95% CI, 0.81 to 0.90), a 28% lower risk compared with attending 12 sessions (HR, 0.72; 95% CI, 0.64 to 0.80), and a 38% lower risk compared with attending 1 session (HR, 0.62; 95% CI, 0.52 to 0.73). Statistical significance remained after adjustment, although the HRs were slightly moderated (Table 2). After adjustment, each case of an additional 6 cardiac rehabilitation sessions was associated with a 6% (HR, 0.94; P<0.001) lower risk of MI.

Table 2. Predictors of Death and MI Among Patients Undergoing Cardiac Rehabilitation

	HR (95% CI)	
Variable	Death	MI
No. of cardiac rehabilitation sessions*		
36 sessions vs 24 sessions	0.86 (0.77–0.97)	0.88 (0.83–0.93)
36 sessions vs 12 sessions	0.78 (0.71–0.86)	0.77 (0.69–0.86)
36 sessions vs 1 session	0.53 (0.47–0.59)	0.68 (0.58–0.81)
Subsequent hospitalization	2.68 (2.50–2.87)	1.55 (1.37–1.74)
Demographic characteristics		
Age (per 5 years)	1.35 (1.31–1.39)	1.18 (1.13–1.24)
Male sex	1.31 (1.21–1.40)	0.98 (0.88–1.10)
Nonwhite race	1.04 (0.89–1.22)	1.29 (1.03–1.62)
Comorbid conditions		
Cancer	1.43 (1.31–1.55)	0.93 (0.79–1.08)
Cerebrovascular disease	0.99 (0.92–1.06)	0.99 (0.88–1.11)
Chronic obstructive pulmonary disease	1.37 (1.27–1.46)	1.02 (0.91–1.14)
Dementia	1.84 (1.51–2.24)	1.41 (0.96–2.07)
Diabetes mellitus	1.21 (1.13–1.30)	1.41 (1.26–1.57)
Heart failure	1.84 (1.71–1.98)	1.29 (1.15–1.45)
Hypertension	0.87 (0.78–0.96)	1.05 (0.89–1.25)
Peripheral vascular disease	1.22 (1.14–1.31)	1.12 (1.00–1.26)
Peptic ulcer disease	1.17 (1.01–1.35)	0.99 (0.76–1.28)
Renal disease	1.35 (1.22–1.49)	1.32 (1.11–1.58)

*Estimates from the mortality model are based on a nonlinear spline function; estimates from the MI model are based on a linear function.

Specific results from the adjusted mortality rate model by cardiac rehabilitation indication are shown in Table 3, and the full estimated spline functions based on those models are shown in Figure 4. For patients who underwent CABG, there appears to have been a plateau at 24 cardiac rehabilitation sessions, beyond which no difference in estimated risk was observed compared with attending 36 sessions. On the basis of this model, attending 36 sessions was associated with significantly lower risk only compared with attending 15 sessions (HR, 0.86; 95% CI, 0.76 to 1.00) or fewer. For patients who had an MI, attending 36 sessions was associated with significantly lower risk of death compared with attending any lower number of sessions. For patients with a diagnosis of stable angina, there appears to have been a plateau at 18 sessions, beyond which no difference in estimated risk was observed, compared with attending 36 sessions. Attending 36 sessions compared with attending 9

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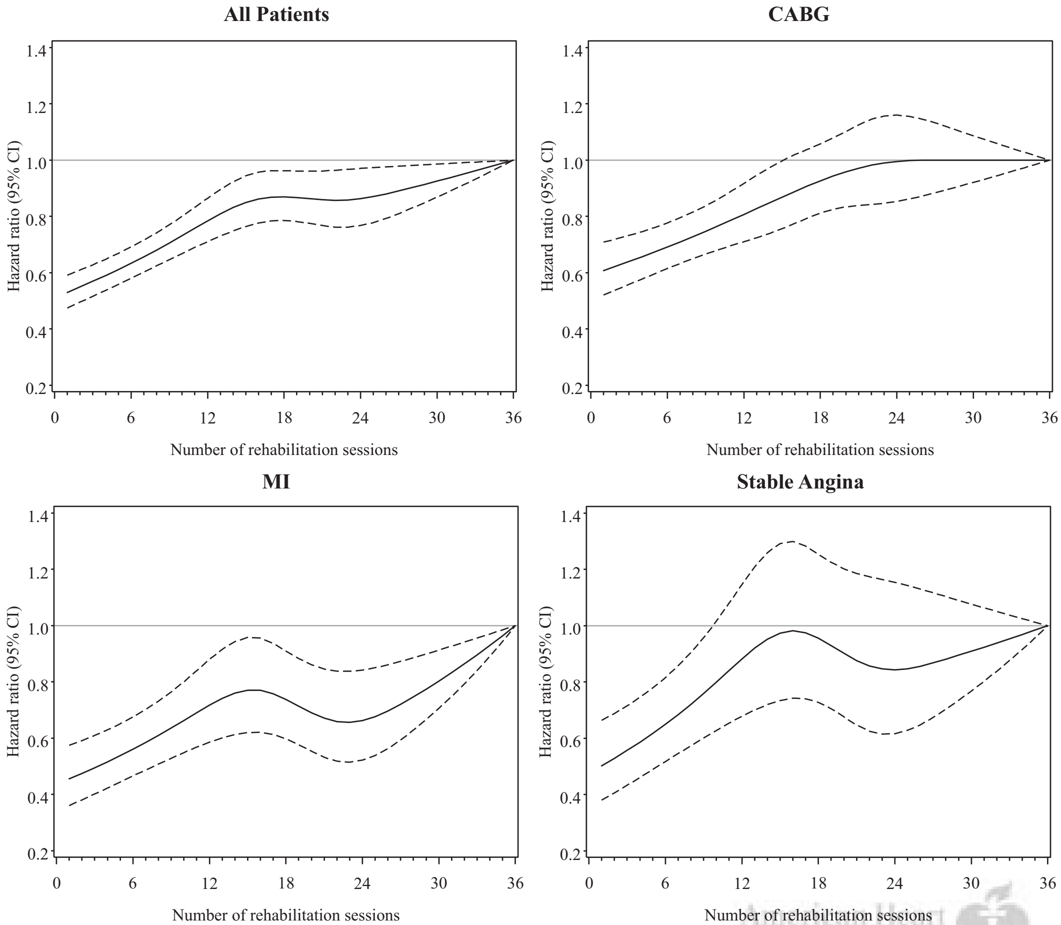

Figure 4. Adjusted relationships between the number of cardiac rehabilitation sessions attended and death, overall and by indication. HRs and 95% CIs are plotted on the *y* axes. Solid lines represent the estimated hazards of death or MI associated with attending 0 to 36 cardiac rehabilitation sessions vs attending 36 sessions. Dashed lines represent the 95% CIs around these estimates.

sessions (HR, 0.76; 95% CI, 0.60 to 0.96) or fewer was statistically significant in this group.

Specific results from the adjusted MI model by cardiac rehabilitation indication are shown in Table 3. For each indication, attending 36 sessions was significantly associated with a lower risk of MI compared with any lower number of sessions. After adjustment, each additional 6 cardiac rehabilitation sessions was associated with a 5% (HR, 0.95; $P=0.02$) lower risk of MI among patients who underwent CABG, a 6% (HR, 0.94; $P=0.03$) lower risk among patients with a previous MI, and an 11% (HR, 0.89; $P=0.001$) lower risk among patients with stable angina.

Among the 11 955 patients in the study population who had a diagnosis of heart failure, the distribution of qualifying indications was similar to the overall population. The adjusted relationship between the number of cardiac rehabilitation sessions and risk of death was similar in shape to the relationship found among all patients, although statistical significance was not achieved for all comparisons with 36 sessions. The linear relationship between the number of cardiac rehabilitation sessions and MI was significant. Attending 36 sessions was associated with lower risk of MI compared with attending any lower number of sessions. Table 3 shows other comparisons by the number of cumulative cardiac rehabilitation sessions based on the adjusted mortality rate and MI models.

Among the 26 497 patients who attended ≥6 cardiac rehabilitation sessions, the estimated relationship between the number of sessions attended and both death and MI was not substantially different from the results reported above for all patients. Compared with attending 36 sessions, attending any number of fewer sessions was associated with an increased risk of both death and MI. On the basis of regression models estimated within this subgroup, specific comparisons by number of cumulative sessions are shown in Table 3.

Table 4 shows predictors of the number of cumulative sessions attended. On average, patients who underwent CABG attended 0.5 more session than patients with an MI and 1 more session than patients with stable angina. Subsequent hospitalization led to patients attending almost 3 fewer sessions. Men attended slightly more sessions than women. Most comorbid conditions had only modest associations with the number of sessions attended. Overall, the model explained little of the variation in number of sessions attended ($R^2=0.05$).

Discussion

In this analysis of elderly Medicare beneficiaries who participated in cardiac rehabilitation, we found significant dose–

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Table 3. Relationship Between the Number of Cardiac Rehabilitation Sessions Attended and Long-Term Outcomes by Subgroup

Indication and No. of Sessions Attended	HR (95% CI)*	
	Death	MI
Indication, CABG		
36 sessions vs 24 sessions	0.99 (0.85–1.16)	0.90 (0.83–0.98)
36 sessions vs 12 sessions	0.81 (0.71–0.92)	0.81 (0.69–0.96)
36 sessions vs 1 session	0.61 (0.52–0.71)	0.74 (0.58–0.95)
Indication, MI		
36 sessions vs 24 sessions	0.66 (0.52–0.84)	0.89 (0.80–0.99)
36 sessions vs 12 sessions	0.72 (0.59–0.88)	0.79 (0.64–0.97)
36 sessions vs 1 session	0.46 (0.36–0.57)	0.71 (0.52–0.96)
Indication, stable angina		
36 sessions vs 24 sessions	0.84 (0.62–1.15)	0.79 (0.69–0.91)
36 sessions vs 12 sessions	0.88 (0.68–1.15)	0.63 (0.47–0.83)
36 sessions vs 1 session	0.50 (0.38–0.66)	0.50 (0.33–0.76)
Heart failure		
36 sessions vs 24 sessions	0.88 (0.76–1.03)	0.91 (0.83–0.98)
36 sessions vs 12 sessions	0.81 (0.71–0.92)	0.82 (0.70–0.97)
36 sessions vs 1 session	0.54 (0.47–0.63)	0.75 (0.59–0.95)
Attended ≥6 sessions		
36 sessions vs 24 sessions	0.86 (0.76–0.97)	0.88 (0.82–0.95)
36 sessions vs 12 sessions	0.75 (0.68–0.83)	0.78 (0.67–0.91)
36 sessions vs 1 session	...	...

Estimates from the mortality model are based on a nonlinear spline function; estimates from the MI model are based on a linear function. Both models controlled for demographic characteristics, comorbid conditions, and subsequent hospitalization.

Table 4. Predictors of Cumulative Number of Cardiac Rehabilitation Sessions Attended

Variable	Estimate (SE)	*P*
Intercept	23.1 (0.3)	<0.001
Qualifying indication for cardiac rehabilitation		
CABG	(Reference)	
MI	−0.5 (0.2)	0.002
Stable angina	−1.0 (0.2)	<0.001
Unknown	−9.8 (0.4)	<0.001
Subsequent hospitalization	−2.7 (0.2)	<0.001
Demographic characteristics		
Age (per 5 years >65 y)	−0.1 (0.1)	0.03
Male sex	1.2 (0.1)	<0.001
Nonwhite race	−0.8 (0.3)	0.02
Comorbid conditions		
Cancer	0.4 (0.2)	0.05
Cerebrovascular disease	0.4 (0.1)	0.004
Chronic obstructive pulmonary disease	−0.5 (0.1)	<0.001
Dementia	−1.7 (0.6)	0.005
Diabetes mellitus	−0.0 (0.1)	0.88
Heart failure	0.3 (0.1)	0.08
Hypertension	1.3 (0.2)	<0.001
Peripheral vascular disease	−0.0 (0.2)	0.75
Peptic ulcer disease	−0.8 (0.3)	0.02
Renal disease	−0.2 (0.3)	0.39
R^2	0.05	

response relationships between the number of cardiac rehabilitation sessions attended and the risk of death and MI at 4 years. For both outcomes, attending the maximum of 36 sessions was associated with lower risk compared with any lower number of sessions. The relationship with survival was found to be nonlinear, with greater differences in survival rate associated with attending the first 18 sessions compared with later sessions. The relationship with MI was found to be linear.

Previous evidence on the dose–response relationship between cardiac rehabilitation and survival rate among patients with coronary heart disease is mixed. A review of 14 published randomized controlled trials did not find a dose–response relationship.[5] Most of these trials were published before 2000. A recent analysis of Medicare beneficiaries hospitalized in 1997 did find a dose–response relationship.[6] Both studies relied on a dichotomous measure of dose. Our work updates and expands on these analyses. First, we use data on patients who attended their first cardiac rehabilitation session between 2000 and 2005. Second, instead of using a dichotomous measure of dose, we explored dose as a continuous measure, which gave us greater statistical power to detect a relationship between dose and long-term outcomes. Using a continuous measure of dose also allowed us to determine the shape of the relationship.

Patients with heart failure benefited from attending more cardiac rehabilitation sessions. The dose–response relationship for both death and MI among patients with heart failure was similar to the relationship observed among all patients. During the study period, cardiac rehabilitation was only reimbursed by Medicare for diagnoses or events related to ischemic heart disease. Therefore, it is not known whether patients with nonischemic heart failure would have the same benefit we observed. Recently reported results from HF-ACTION indicate that exercise-based cardiac rehabilitation may be beneficial in this group.[7] An additional analysis of the HF-ACTION cohort participating in the exercise intervention identified a dose response of exercise intensity, in terms of metabolic equivalent hours per week, in predicting the primary outcome of the trial, all-cause death or all-cause hospitalization.[8]

Cardiac rehabilitation is underused in the indicated populations. Previous research suggests that <20% of eligible Medicare beneficiaries participate in cardiac rehabilitation.[14] We found that even among patients who attended any rehabilitation sessions, only 18% attended the full 36 sessions that Medicare reimburses. Given our finding that 36 sessions of rehabilitation is significantly associated with lower long-term risk of death and MI compared with fewer sessions, it may be worthwhile to investigate the reasons for lack of adherence to a full course of cardiac rehabilitation. Demographic characteristics and comorbid conditions were not strong predictors of adherence in this population.

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The effects of cardiac rehabilitation among elderly patients are not well characterized. In this study, we used a large national sample of elderly Medicare beneficiaries to demonstrate a dose–response relationship between cardiac rehabilitation and long-term outcomes. Similar to findings among patients of all ages,[15] there did not appear to be a safety signal with respect to early MI in this population.

Our study has some limitations. First, because the study population consists of Medicare fee-for-service beneficiaries, the results may not be applicable to beneficiaries enrolled in a Medicare managed care program or to younger patients. Second, it is not possible to state definitively that more frequent attendance at cardiac rehabilitation sessions is the sole mechanism of reducing the risks of long-term mortality and morbidity in this population. Adherence to early cardiac rehabilitation may be a proxy for other factors, such as a patient's general activity level, long-term exercise adherence, medication adherence, socioeconomic characteristics, and smoking status,[16] all of which directly affect adverse outcomes. To the extent that patients who are more adherent to cardiac rehabilitation have a more favorable profile for these other factors, it is possible that we overestimated the observed relationships. We did not have the data to explore these possible explanations. Third, there is a potential for bias due to the unmeasured underlying health status of patients in this study. We based the analysis on patients who attended at least 1 cardiac rehabilitation session because these patients are generally healthier than patients who do not participate in cardiac rehabilitation.[13] Nevertheless, there may be residual confounding by health status even among these patients, although it is unclear in which direction this might have biased the results. Healthier patients may not feel the need to attend cardiac rehabilitation and may be more likely to attend fewer sessions. It is also possible that less healthy patients cannot tolerate cardiac rehabilitation and thus attend fewer sessions. We tried to address this concern in a sensitivity analysis by only including patients who attended ≥6 sessions. The significant dose–effect relationship remained in this subset of the study population.

Conclusion

Among Medicare beneficiaries, a significant dose–response relationship exists between the number of cardiac rehabilitation sessions attended and long-term outcomes. Attending all 36 sessions that Medicare reimburses was associated with a lower risk of death and MI in the 4 years after the initiation of cardiac rehabilitation compared with attending fewer sessions. However, only 18% of patients who attended any cardiac rehabilitation sessions attended all 36 sessions. Our findings suggest that physicians should promote greater use of cardiac rehabilitation services and should strive to understand the barriers that prevent patients from attending the sessions to which they are entitled.

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Disclosures

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CLINICAL PERSPECTIVE

Exercise-based cardiac rehabilitation is recognized as an important part of the long-term management of coronary artery disease. It is associated with improved survival rate and beneficial changes in risk factors associated with coronary artery disease. However, the relationship between the dose of early outpatient cardiac rehabilitation and long-term outcomes is unknown. Using a large national sample of Medicare beneficiaries who attended any cardiac rehabilitation, we found that there was a strong dose–response relationship between the number of sessions attended and long-term risks of death and myocardial infarction. Attending all 36 sessions reimbursed by Medicare was associated with substantially lower risks of death and myocardial infarction at 4 years compared with attending any number of fewer sessions. However, only 18% of patients who attended any cardiac rehabilitation sessions attended all 36 sessions. Combined with the fact that a minority of eligible patients attends any cardiac rehabilitation in the first place, the proportion of patients who attend all of the sessions to which they are entitled is small. Our findings suggest that physicians should promote greater use of cardiac rehabilitation services and should strive to understand the barriers that prevent patients from completing a full course of early outpatient cardiac rehabilitation.

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Relationship Between Cardiac Rehabilitation and Long-Term Risks of Death and Myocardial Infarction Among Elderly Medicare Beneficiaries

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