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ORIGINAL ARTICLE

Determinants of Hospital Variation in Cardiac Rehabilitation Enrollment During Coronary Artery Disease Episodes of Care

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BACKGROUND: Cardiac rehabilitation (CR) is associated with improved outcomes for patients with coronary artery disease (CAD). However, CR enrollment remains low and there is a dearth of real-world data on hospital-level variation in CR enrollment. We sought to explore determinants of hospital variability in CR enrollment during CAD episodes of care: medical management of acute myocardial infarction (AMI-MM), percutaneous coronary intervention (PCI), and coronary artery bypass grafting (CABG).

METHODS: A cohort of 71 703 CAD episodes of care were identified from 33 hospitals in the Michigan Value Collaborative statewide multipayer registry (2015 to 2018). CR enrollment was defined using professional and facility claims and compared across treatment strategies: AMI-MM (n=18 678), PCI (n=41 986), and CABG (n=11 039). Hierarchical logistic regression was used to estimate effects of predictors and hospital risk-adjusted rates of CR enrollment.

RESULTS: Overall, 20 613 (28.8%) patients enrolled in CR, with significant differences by treatment strategy: AMI-MM=13.4%, PCI=29.0%, CABG=53.8% (P<0.001). There were significant differences in CR enrollment across age groups, comorbidity status, and payer status. At the hospital-level, there was over 5-fold variation in hospital risk-adjusted CR enrollment rates (9.8%–51.6%). Hospital-level CR enrollment rates were highly correlated across treatment strategy, with the strongest correlation between AMI-MM versus PCI (R^2=0.72), followed by PCI versus CABG (R^2=0.51) and AMI-MM versus CABG (R^2=0.46, all P<0.001).

CONCLUSIONS: Substantial variation exists in CR enrollment during CAD episodes of care across hospitals. However, within-hospital CR enrollment rates were significantly correlated across all treatment strategies. These findings suggest that CR enrollment during CAD episodes of care is the product of hospital-specific rather than treatment-specific practice patterns.

Key Words: cardiac rehabilitation ■ coronary artery disease ■ episode of care ■ hospital ■ quality of care

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WHAT IS KNOWN

- Cardiac rehabilitation (CR) confers significant benefit to patients hospitalized with coronary artery disease, including those receiving medical management for acute myocardial infarction, percutaneous coronary intervention, or coronary artery bypass grafting.
- Enrollment in CR remains low and variable across hospitals, but the underlying determinants of enrollment are not well known.

WHAT THE STUDY ADDS

- CR enrollment rates after coronary artery disease admissions varied by 5-fold across hospitals but within-hospital enrollment rates across treatment strategies were similar.
- The effect of payer and admitting hospital on CR enrollment was as large as or greater than patient demographic and clinical factors.
- Patients in high CR enrollment hospitals attended more sessions within 90 days of discharge with fewer days from discharge to first CR session.

Cardiac rehabilitation (CR) may confer significant clinical benefit for patients with coronary artery disease (CAD), including lower cardiovascular mortality, fewer readmissions, and improved quality of life.[1,2] Guidelines strongly recommend CR for patients who have undergone coronary artery bypass grafting (CABG) or percutaneous coronary intervention (PCI), as well as patients medically managed for acute myocardial infarction (AMI-MM).[3–6] While there has been considerable focus on increasing CR referral rates, wide geographic variability persists, and only 20% to 40% of eligible patients ultimately enroll in CR.[7,8]

Despite the demonstrated benefits of CR, few eligible patients receive a CR referral and even fewer patients ultimately enroll in a single CR session.[9–12] Improving CR enrollment during episodes of care for CAD at a hospital-level requires a better understanding of the variation and underlying determinants of enrollment. Prior studies have focused primarily on referral to CR and have shown wide variability in referral rates across hospitals.[9] However, referral rates are an inadequate proxy for enrollment, with reported referral rates >2-fold higher than enrollment.[8] Moreover, the extent to which variation in CR enrollment is a product of patient complexity or hospital-specific practice patterns is not known. Even less is known about CR enrollment across CAD treatment strategies, as clinical registries are often procedure-based or do not capture post-discharge CR enrollment.[13] Identifying determinants of CR enrollment variation may help to inform hospital-level quality improvement initiatives seeking to boost enrollment after CAD events.

In this context, we sought to explore hospital-level variation in CR enrollment during CAD episodes of care by leveraging a statewide, multipayer administrative claims registry in Michigan. Specifically, we sought to identify determinants of variation in CR enrollment across hospitals, the extent to which variation in risk-adjusted CR enrollment can be attributed to the hospital level, and within-hospital variation in CR enrollment by treatment strategy: AMI-MM, PCI, and CABG. We hypothesize that CR enrollment will vary widely across hospitals, with substantial variation in enrollment attributed to the hospital-level.

METHODS

This study was deemed exempt from human subjects' protections by the University of Michigan Institutional Review Board. Members of the study team (Dr Thompson, J.M. Yaser, J.D. Syrjamaki) had direct access to the data throughout the study and take responsibility for its integrity and the data analysis. Because of the sensitive nature of the data in this study, public access to the data will not be provided.

Data Source and Sample

Data from the Michigan Value Collaborative (MVC) administrative claims data registry were used for this study. The MVC is a statewide collaborative quality initiative representing 87 Michigan hospitals and 39 provider organizations supported by Blue Cross Blue Shield of Michigan (BCBSM) and Blue Care Network (BCN) with the goal of helping Michigan hospitals achieve the best possible outcomes at the lowest reasonable cost. The MVC registry contains facility and professional administrative claims data for all Michigan residents insured by BCBSM/BCN commercial plans, BCBSM/BCN Medicare Advantage plans and Medicare fee-for-service (FFS). Administrative claims are arranged into episodes of care, including all facility and professional claims provided during the index admission or procedure and within 90 days of discharge, which have been validated against external data sources.[14] Details on the construction and definitions of MVC registry episodes of care can be found in the Appendix.

The MVC registry contains episodes of care for AMI-MM, PCI, and CABG, which were defined using *International Classification of Diseases (ICD)* versions 9 and 10 diagnosis and procedure codes from facility claims and Current Procedure Terminology (CPT) codes from professional claims (Table I in the Data Supplement). We note that PCI episodes of care include both inpatient and outpatient procedures. Episodes from the MVC registry were eligible for inclusion in the study if they (1) had an index admission or procedure date between January 1, 2015 and December 31, 2018 and (2) were treated at one of the 33 Michigan hospitals that provide both PCI and CABG services. Patients were excluded if they died during the index admission or procedure, were discharged to hospice care, or had missing discharge disposition information.

CR Enrollment

Current procedural terminology (CPT) codes and health care common procedure codes were used to identify claims for CR in facility and professional claims (CPT: 93797 and 93798, health care common procedure codes: G0422 and G0423, revenue center code: 943).[15] A binary variable was created indicating any CR enrollment within 90 days of discharge (yes versus no). Secondary CR enrollment variables included the number of days from discharge to the first CR visit and the number of CR sessions attended within 90 days of discharge.

Covariates

Several patient covariates were included in the analysis, including demographics, clinical factors, and comorbidities. Demographics included patient age category (85+ years, 75–84 years, 65–74 years, 55–64 years, and <55 years), sex (male versus female), and payer type (BCBSM/BCN Commercial, BCBSM/BCN Medicare Advantage and Medicare FFS). Clinical factors included 6-month prior spending above the median for the sample, treatment strategy (AMI-MM, PCI, or CABG), and the presence of comorbidities within 6 months of admission. Comorbidities occurring in the 6 months before admissions were derived from administrative claims data

Table 1. Patient Characteristics by CR Enrollment Status

Patient characteristics	Overall	CR enrollment No	CR enrollment Yes	*P* value
Sample, n	71 703 (100)	51 090 (71)	20 613 (29)	…
Hospitals, N	33	33	33	…
Male, n (%)	45 696 (63.7)	31 352 (61.4)	14 344 (69.6)	<0.001
Age category, n (%)				
85+ y	7989 (11.1)	7126 (14.0)	863 (4.2)	<0.001
75–84 y	18 710 (26.1)	13 613 (26.7)	5097 (24.7)	…
65–74 y	26 092 (36.4)	17 525 (34.3)	8567 (41.6)	…
55–64 y	12 929 (18.0)	8741 (17.1)	4188 (20.3)	…
<55 y	5983 (8.3)	4085 (8.0)	1898 (9.2)	…
Large 6-mo prior spending, n (%)	35 371 (49.3)	26 288 (51.5)	9083 (44.1)	<0.001
Payer, n (%)				
Medicare FFS	42 547 (59.3)	31 694 (62.0)	10 853 (52.7)	<0.001
Medicare advantage	8336 (11.6)	6026 (11.8)	2310 (11.2)	…
Commercial	20 820 (29.0)	13 370 (26.2)	7450 (36.1)	…
Admission type, n (%)				
AMI-MM	18 678 (26.0)	16 167 (31.6)	2511 (12.2)	<0.001
PCI	41 986 (58.6)	29 817 (58.4)	12 169 (59.0)	…
CABG	11 039 (15.4)	5106 (10.0)	5933 (28.8)	…
Number of HCCs, mean (SD)				
Mean (SD)	5(3)	5 (3)	4 (2)	<0.001
Median (IQR)	4 (4)	4 (4)	3 (3)	
Major HCC categories, n (%)				
Diabetes	33 426 (46.6)	24 795 (48.5)	8631 (41.9)	<0.001
Congestive heart failure	27 217 (38.0)	21 812 (42.7)	5405 (26.2)	<0.001
Vascular disease	22 316 (31.1)	17 440 (34.1)	4876 (23.7)	<0.001
COPD	18 699 (26.1)	14 987 (29.3)	3712 (18.0)	<0.001
Cancer	7869 (11.0)	5747 (11.3)	2122 (10.3)	0.0002
Neurological disorders	5340 (7.5)	4313 (8.4)	1027 (5.0)	<0.001
Chronic kidney disease	4847 (6.8)	4261 (8.3)	586 (2.8)	<0.001
Psychiatric disorder	4542 (6.3)	3583 (7.0)	959 (4.7)	<0.001
Respiratory dysfunction	3297 (4.6)	2611 (5.1)	686 (3.3)	<0.001
Cerebrovascular disease	3134 (4.4)	2551 (5.0)	583 (2.8)	<0.001
Drug/alcohol disorders	1415 (2.0)	1135 (2.2)	280 (1.4)	<0.001
Chronic liver disease	1148 (1.6)	941 (1.8)	207 (1.0)	<0.001

AMI-MM indicates acute myocardial infarction medically managed; CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; CR, cardiac rehabilitation; FFS, fee-for-service; HCC, hierarchical condition category; IQR, interquartile range; and PCI, percutaneous coronary intervention.

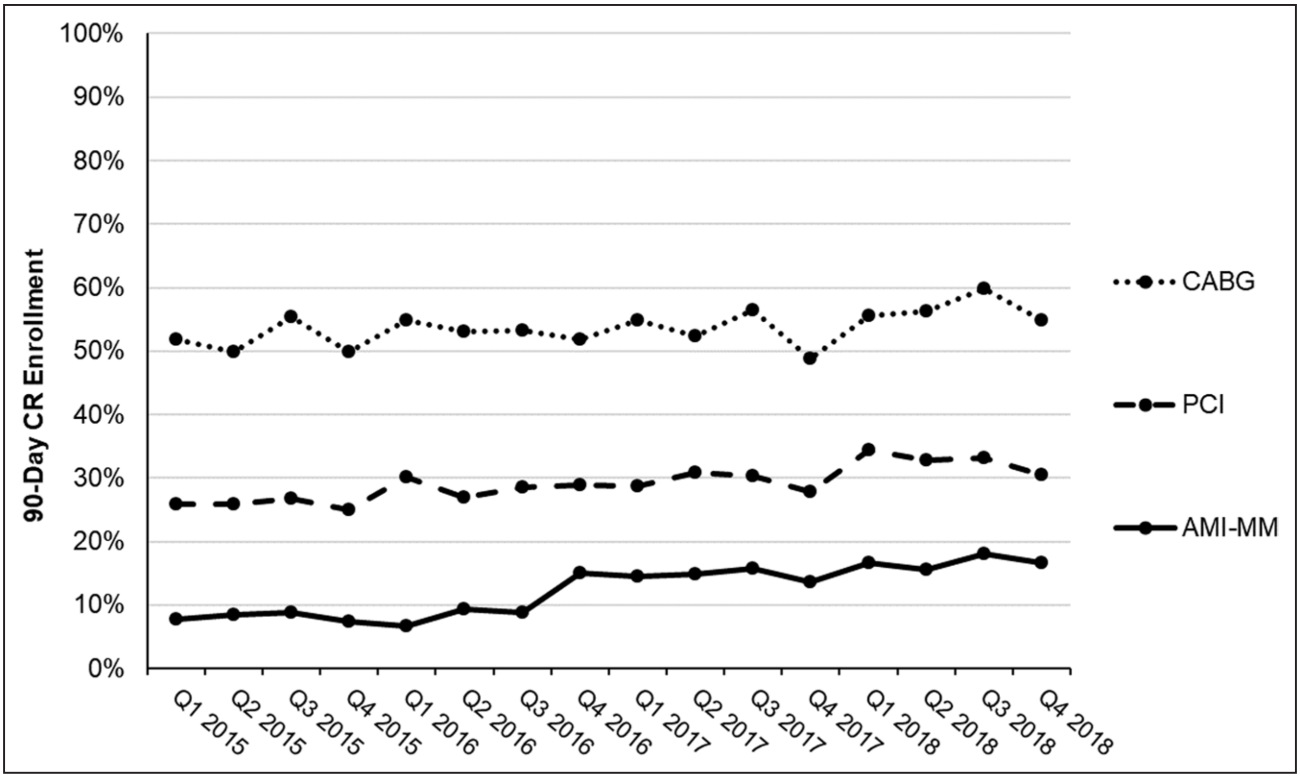

Figure 1. Quarterly trends in cardiac rehabilitation enrollment from 2015 to 2018 for medically managed acute myocardial infarction (AMI-MM), percutaneous coronary intervention (PCI), and coronary artery bypass grafting (CABG).
CR indicates cardiac rehabilitation.

using established methods to develop 79 hierarchical condition categories (HCCs), which were grouped into 12 major HCC categories for analysis (Table II in the Data Supplement).[16,17] The mean and SD number of comorbidities was estimated for each patient. Additionally, the presence of AMI (yes or no) was included as a covariate in the PCI and CABG episodes of care. Each patient was also attributed to its admitting hospital according to its national provider identifier.

Statistical Analysis

Significant differences in patient covariates across CR enrollment status were evaluated in bivariate analyses. Chi-square tests and ANOVA were used to test for differences in categorical and continuous patient covariates, respectively. Quarterly trends in CR enrollment were plotted over time, stratified by treatment strategy (AMI-MM, PCI, and CABG). Rates of CR enrollment were also compared across payers for all CAD events and by treatment strategy using χ^2 tests.

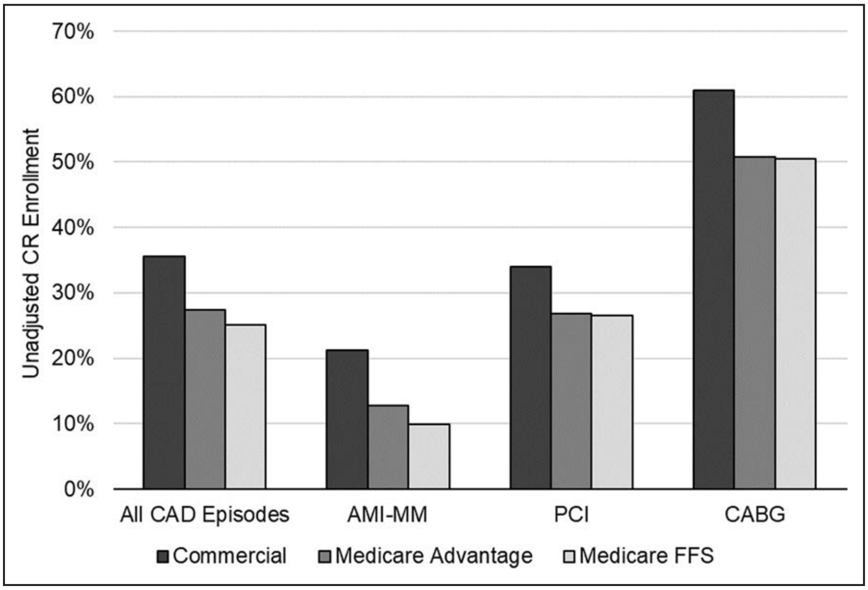

Figure 2. Ninety-day cardiac rehabilitation (CR) enrollment by payer and treatment strategy: medically managed acute myocardial infarction (AMI-MM), percutaneous coronary intervention (PCI), and coronary artery bypass grafting (CABG).
CAD indicates coronary artery disease; and FFS, fee-for-service.

Next, hierarchical logistic regression modeling was used to estimate the independent association between patient covariates and CR enrollment, and the model variance for hospital random effects. Four separate models of CR enrollment were created, including a model for all CAD episodes of care, and stratified by treatment strategy: AMI-MM, PCI, and CABG. All models were adjusted for sex, age category, large 6-month prior spending, payer, and major HCC categories. Additionally, the primary model for all CAD episodes of care adjusted for treatment strategy. In the models for PCI and CABG, additional adjustment included whether or not the patient was admitted with AMI (yes versus no).

From these models, the expected probability each patient received CR was estimated and then summed at the hospital level to sum the expected number of patients who received CR. The ratio of observed to expected (ie, the O/E ratio) number of patients receiving CR for each hospital was multiplied by the overall CR enrollment rate to calculate the hospital-level risk-adjusted CR enrollment rate. A dot plot was used to illustrate the variation in CR enrollment across hospitals for all CAD episodes of care, and by treatment strategy (AMI-MM, PCI, CABG). The hospital random effect variance was estimated from each hierarchical regression model and used to estimate the intraclass correlation coefficient (ICC) for the hospital. The ICC estimates the percent of the variation in CR enrollment that can be attributed to the hospital-level, adjusted for patient factors.[18] The hospital random effect variance was also used to estimate the median odds ratio (MOR), which is a measure of variation that expresses the relative odds of CR enrollment for 2 identical patients discharged from one randomly selected hospital to a second randomly selected hospital. As a sensitivity analysis, the analysis was repeated in only patients who were discharged to home (ie, excluding patients who were discharged to skilled nursing facilities, inpatient rehabilitation, or other extended care facilities).

To assess within-hospital CR enrollment across treatment strategy, scatter plots compared risk-adjusted CR enrollment with pairwise comparisons for AMI-MM, PCI, and CABG. The R^2 for each pairwise comparison was estimated to assess the extent to which variation in CR enrollment is explained across treatment strategies.

Finally, hospitals were placed into tertiles according to their rank-order in risk-adjusted CR enrollment for all CAD episodes of care, and by treatment strategy, representing low, moderate, and high CR enrollment. We compared the frequency and percent of any CR enrollment across tertiles, the mean (SD) number of sessions, and mean (SD) days to the first session among those who were enrolled in CR. Trends in these variables across hospital CR enrollment tertiles were tested using the Cochran-Armitage test for trend and for trends in mean number of sessions and days to first session across tertiles using ANOVA.

All analyses were performed using SAS 9.4 and Stata 15.1, and statistical tests were deemed significant at an alpha of 0.05 (2-sided).

RESULTS

A total of 71 703 discrete CAD episodes of care were identified between January 2015 and December 2018, including 18 678 AMI-MM episodes, 41 986 PCI episodes, and 11 039 CABG episodes. A total of 20 613 (28.8%) of episodes had any CR enrollment within 90-days of hospital discharge. CR enrollment significantly varied by treatment strategy: CABG (53.8%), PCI (29.0%), AMI-MM (13.4%), P<0.001. Among all episodes, patients enrolled in CR were significantly different with respect to sex, age, prior spending, payer, admission status, and comorbidities (Table 1). Quarterly trends in CR enrollment for all CAD episodes of care, and by treatment strategy are displayed in Figure 1. There were significant differences in CR enrollment across payers, with commercial beneficiaries having the highest enrollment rates across all CAD events (35.8%),

Table 2. Multivariable Model of Patient Characteristics Associated With CR Enrollment During CAD Episodes of Care

Patient characteristic	Odds ratio (95% CI)	*P* value
Female vs male	0.93 (0.90–0.97)	0.0004
Age		
85+	0.50 (0.45–0.55)	<0.001
75–84	1.15 (1.07–1.24)	0.0002
65–74	1.35 (1.26–1.45)	<0.001
55–64	1.08 (1.01–1.16)	0.027
<55	1 (Ref)	…
Large 6-mo prior spending	1.06 (1.02–1.10)	0.004
Payer		
Medicare FFS	0.70 (0.67–0.73)	<0.001
Medicare advantage	0.70 (0.66–0.75)	<0.001
Commercial	1 (Ref)	…
Treatment strategy, n (%)		
AMI-MM	0.47 (0.45–0.49)	<0.001
PCI	1 (Ref)	…
CABG	2.74 (2.62–2.87)	<0.001
Major HCC categories		
Cancer	1.05 (0.99–1.11)	0.130
Cerebrovascular disease	0.81 (0.73–0.90)	<0.001
Chronic kidney disease	0.50 (0.46–0.56)	<0.001
Chronic liver disease	0.70 (0.59–0.82)	<0.001
COPD	0.68 (0.65–0.71)	<0.001
Congestive heart failure	0.72 (0.69–0.75)	<0.001
Diabetes	0.83 (0.80–0.87)	<0.001
Drug/alcohol disorders	0.67 (0.58–0.78)	<0.001
Neurological disorders	0.81 (0.75–0.88)	<0.001
Psychiatric disorder	0.86 (0.80–0.94)	0.0004
Respiratory dysfunction	1.01 (0.92–1.12)	0.79
Vascular disease	0.77 (0.73–0.80)	<0.001

AMI-MM indicates acute myocardial infarction medically managed; CABG, coronary artery bypass grafting; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; CR, cardiac rehabilitation; FFS, fee-for-service; HCC, hierarchical condition category; and PCI, percutaneous coronary intervention.

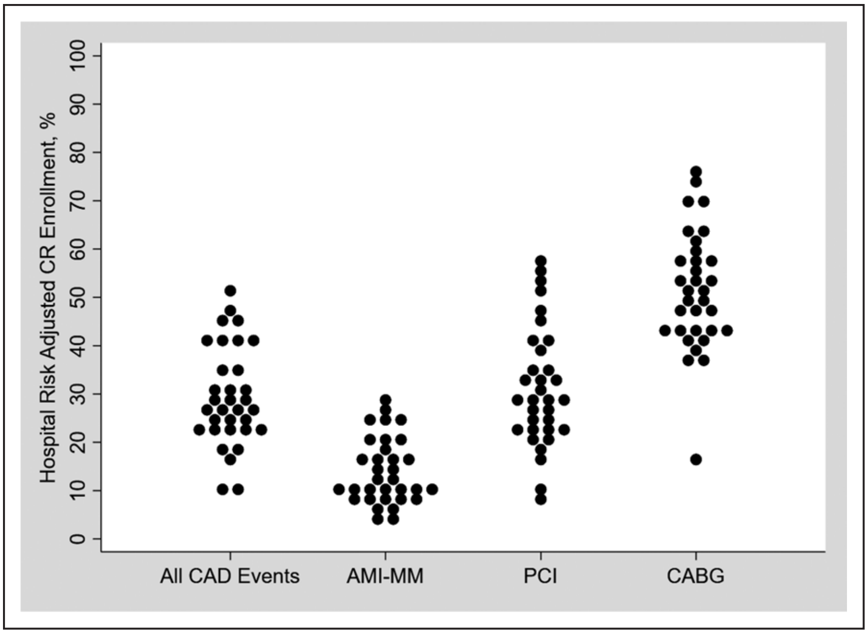

Figure 3. Hospital variation in cardiac rehabilitation (CR) enrollment during coronary artery disease (CAD) episodes of care and by treatment strategy: medically managed acute myocardial infarction (AMI-MM), percutaneous coronary intervention (PCI), and coronary artery bypass grafting (CABG).

followed by Medicare Advantage (27.7%) and Medicare FFS (25.5%; *P*<0.001; Figure 2). Significant differences in CR enrollment across payers was also found across treatment strategy (all *P*<0.001), with commercial beneficiaries consistently having the highest CR enrollment rates.

Predictors of CR Enrollment

In all CAD episodes of care, CR enrollment was significantly lower among females versus males (adjusted odds ratio [aOR], 0.93 [95% CI, 0.90–0.97], *P*<0.001), for Medicare FFS (aOR, 0.70 [95% CI, 0.67–0.73]; *P*<0.001) and Medicare Advantage (aOR, 0.70 [95% CI, 0.66–0.75]; *P*<0.001) versus commercial payers. Patients with several present comorbidities were also less likely to enroll in CR, including those with cerebrovascular disease, chronic kidney disease, chronic liver disease, chronic obstructive pulmonary disease, congestive heart failure, diabetes, drug/alcohol disorders, neurological disorders, psychiatric disorders, and vascular disease (Table 2). These patterns were similar across treatment strategies (Table III in the Data Supplement). Additionally, patients undergoing PCI with AMI versus without AMI were more likely to have enrolled in CR (aOR, 1.42 [95% CI, 1.39–1.49]; *P*<0.001), while CABG episodes with AMI versus without AMI were less likely to have enrolled in CR (aOR, 0.76 [95% CI, 0.69–0.83]; *P*<0.001). These findings were similar when limiting the analysis to patients who were discharged home (Table IV in the Data Supplement).

Hospital Variation in CR Enrollment

Adjusting for patient factors, rates of CR enrollment varied from 9.8% to 51.6% across 33 hospitals following all CAD episodes of care (Figure 3). From the hierarchical logistic regression model, 9.3% of the variation was attributed to the hospital level, with a MOR of 1.73 (95% CI, 1.48–1.96; Table 3). In other words, the median relative odds in CR enrollment between 2 randomly chosen hospitals was 1.73.

Across treatment strategies, CR enrollment varied from 4.6% to 29.7% in AMI-MM episodes, from 7.5% to 58.5% in PCI episodes, and from 16.8% to 76.3% in CABG episodes (Figure 3). The ICC and MOR estimates of hospital variation were the greatest for PCI (ICC=10.7%, MOR=1.82), followed by AMI-MM (ICC=10.0%, MOR=1.78) and CABG (ICC=6.6%, MOR=1.58; Table 3). Within hospitals, CR enrollment by treatment strategy was highly correlated, with the strongest correlation between AMI-MM versus PCI (R^2=0.72, *P*<0.001), followed by PCI versus

Table 3. Hospital Variance Estimates for CR Enrollment During CAD Episodes of Care and by Treatment Strategy

Hospital variance estimates	All CAD events	AMI-MM	PCI	CABG
Risk-adjusted CR use, mean (range)	29.8% (9.8%–51.6%)	14.7% (4.6%–29.7%)	31.5 (7.5%–58.4%)	51.6 (16.8%–76.3%)
Hospital random effect variance (SE)	0.33 (0.09)	0.37 (0.10)	0.39 (0.10)	0.23 (0.07)
Intraclass correlation coefficient (95% CI)	9.1% (4.5%–13.3%)	10.1% (5.0%–14.7%)	10.6% (5.6%–15.2%)	6.5% (2.7%–10.0%)
Median odds ratio (95% CI)	1.73 (1.45–1.97)	1.78 (1.49–2.04)	1.81 (1.52–2.07)	1.58 (1.34–1.78)

AMI-MM indicates acute myocardial infarction medically managed; CABG, coronary artery bypass grafting; CAD, coronary artery disease; CR, cardiac rehabilitation, and PCI, percutaneous coronary intervention.

CABG (R^2=0.51, P<0.001) and AMI-MM versus CABG (R^2=0.46, P<0.001; Figure 4). We do note that hospitals with relatively low CR enrollment rates for AMI had higher rates of enrollment for PCI and CABG.

Table 4 shows CR enrollment, number of CR sessions attended, and the number of days to the first CR session during the 90-day CAD episodes of care by the tertile of risk-adjusted CR enrollment rate. CR enrollment increased significantly across tertiles: low=18.2%, moderate=27.1% and high=40.9% (P-trend<0.001). Among patients enrolled in CR, there were increasing trends in the mean number of CR sessions attended within 90 days of discharge (low=11.3 sessions, moderate=12.1 sessions, high=12.7 sessions, P-trend<0.001), and decreasing trend in the mean days to first session (low=44 days, moderate=40 days, high=34 days, P-trend<0.001). These patterns were similar across treatment strategies.

DISCUSSION

In this analysis of 71 703 episodes of CAD at 33 hospitals in a statewide, multipayer claims registry, we report 4 major findings. First, there was over 5-fold variation in CR enrollment across hospitals during CAD episodes of care. Second, CR enrollment within a hospital was similar across CAD treatment strategies, suggesting hospital-specific, rather than treatment-specific, practice patterns. Third, the effect of payer and admitting hospital on CR enrollment was as large as or greater than patient demographic and clinical factors. Finally, patients in high CR enrollment hospitals had on average more CR sessions within 90 days of discharge and fewer days from discharge to first CR session.

Findings from this study have important implications for providers and policymakers seeking to improve CR enrollment. This study is among the first to highlight variation in hospital-level CR enrollment across multiple payers and CAD admission types. Importantly, prior studies have reported similar hospital-level variation and MORs for CR enrollment among Medicare beneficiaries and Veterans Affairs hospitals.[19] Moreover, a significant amount of the variation in CR enrollment was attributed to the hospital level, with similar enrollment rates across CAD patient cohorts receiving different treatments at the same hospital. Together, these findings suggest that hospitals may have specific practice patterns that may contribute to variation in CR enrollment. These findings differ from current literature, which demonstrates variation in CR enrollment at a regional level.[7] The underlying reasons for this variation may be a product of hospital-level practices, such as standardized referral protocols, affiliations with CR facilities, and physician endorsement, in addition to patient and local socioeconomic factors.[20–23] Nevertheless, several strategies have been shown to improve CR enrollment across hospital systems. The Million Hearts Initiative provides a

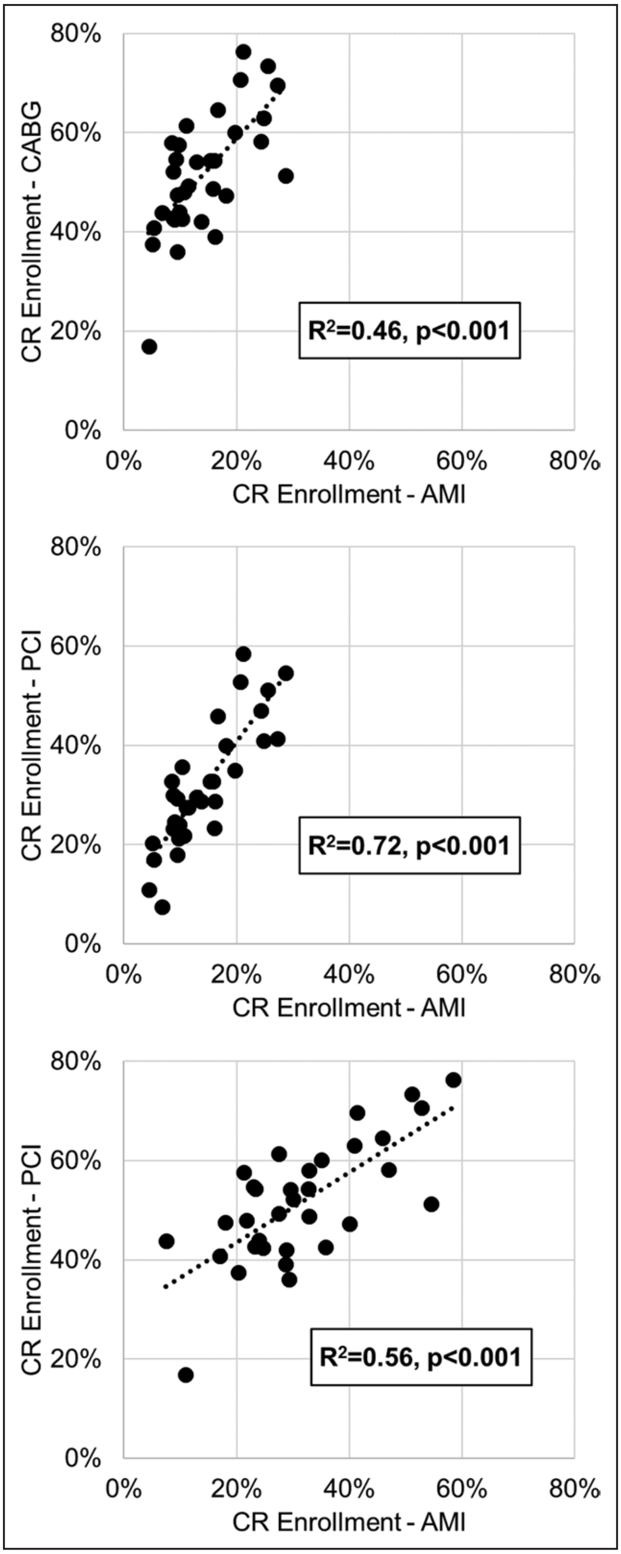

Figure 4. Within-hospital correlation in risk-adjusted cardiac rehabilitation (CR) enrollment rates during coronary artery disease episodes of care (medically managed acute myocardial infarction [AMI-MM], percutaneous coronary intervention [PCI], and coronary artery bypass grafting [CABG]).

framework for improving CR enrollment at the system level, which includes enhanced patient education, improving the process of enrolling patients into CR after

Table 4. Number of CR Claims and Days to First Claim Within 90 d of Discharge by Tertile of Risk-Adjusted CR Use

CR utilization	Tertile of risk-adjusted CR enrolment			*P*-trend
	Low	Moderate	High	
All CAD events (n=71 703)				
Patients, n	22 413	26 324	22 966	…
Any use, n (%)	4088 (18.2)	7131 (27.1)	9394 (40.9)	<0.0001
No. of claims, mean (SD)	11.3 (7.4)	12.1 (8.0)	12.7 (8.3)	<0.0001
Days to first claim, mean (SD)	44 (19)	40 (20)	34 (19)	<0.0001
Enrollment within 21 d, n (%)	440 (2.0)	1259 (4.8)	2774 (12.1)	<0.0001
AMI-MM (n=18 678)				
Patients, n	5312	7491	5875	…
Any use, n (%)	347 (6.5)	843 (11.3)	1321 (22.5)	<0.0001
No. of claims, mean (SD)	11.6 (8.0)	11.0 (7.7)	12.0 (8.6)	0.029
Days to first claim, mean (SD)	42 (20)	42 (21)	35 (21)	<0.0001
Enrollment within 21 d, n (%)	52 (1.0)	159 (2.1)	451 (7.7)	<0.0001
PCI (n=41 986)				
Patients, n	14 316	16 955	10 715	…
Any use, n (%)	2504 (17.5)	4819 (28.4)	4846 (45.2)	<0.0001
No. of claims, mean (SD)	11.8 (7.8)	12.5 (8.2)	13.1 (8.6)	<0.0001
Days to first claim, mean (SD)	40 (20)	38 (19)	30 (18)	<0.0001
Enrollment within 21 d, n (%)	438 (3.1)	1079 (6.4)	2044 (19.1)	<0.0001
CABG (n=11 039)				
Patients, n	2861	3851	4327	…
Any use, n (%)	1174 (41.0)	1970 (51.2)	2789 (64.5)	<0.0001
No. of claims, mean (SD)	10.4 (6.6)	11.4 (7.2)	12.6 (7.4)	<0.0001
Days to first claim, mean (SD)	53 (16)	46 (17)	41 (15)	<0.0001
Enrollment within 21 d, n (%)	11 (0.4)	77 (2.0)	162 (3.7)	<0.0001

AMI-MM indicates acute myocardial infarction medically managed; CABG, coronary artery bypass grafting; CAD, coronary artery disease; CR, cardiac rehabilitation; and PCI, percutaneous coronary intervention.

discharge, or tailoring CR programs to meet patient needs.[24] A systematic review of the literature showed that CR enrollment can be improved through both face-to-face delivery of CR with health care providers as well as offering unsupervised options.[25] Identifying and implementing interventions that are sensitive to the local resources of the center will increase the effectiveness of CR improvement efforts.

This study also adds to the growing body of literature demonstrating low rates of CR enrollment during CAD episodes of care. Over the 4 years in the study, there were only modest changes in CR enrollment, suggesting little progress has been made to improve enrollment. When examining CR enrollment across treatment strategies, our findings confirmed recent research demonstrating that medically managed AMI patients had lower rates of CR enrollment compared with those receiving revascularization procedures, such as PCI and CABG.[7,26] Enrollment rates in this study were also much lower than previously reported rates of referral to CR, highlighting the significant disparity between CR referral and enrollment. For example, reported rates of referral to CR for PCI patients have exceeded 50% of patients,[9,27] yet we found less than a third of PCI recipients enrolled in a single session. Referral to CR is a quality measure endorsed by the National Quality Forum and recommended by the American College of Cardiology and American Heart Association.[3] While possibly easier to capture in real time, referral rates may be an insufficient proxy for enrollment.

Finally, we identify important patient-level factors associated with CR enrollment across CAD treatment strategies. This study confirms other reports that suggest age, female sex, and the presence of comorbidities are significant predictors of CR enrollment.[7,15,26,28–30] The findings also confirm that patients undergoing PCI with AMI are more likely to enroll in CR after discharge, while CABG patients with AMI are less likely to enroll in CR.[7,8] Moreover, we add to the literature on patient determinants of CR enrollment by highlighting differences across payers. Specifically, we found that CR enrollment was the greatest among the commercially insured population compared with Medicare FFS or Medicare Advantage, independent of the treatment strategy chosen. We do note that differences across payers may be partly explained by socioeconomic factors not included in our data. Prior studies have shown socioeconomic indicators to be linked to CR referral and enrollment.[7,31,32] To improve CR enrollment, more work is needed to understand barriers related to insurance coverage and cost-sharing, which could inform public and private payer benefit designs.

These findings should be interpreted with several limitations in mind. First, data used in this study are limited to CAD episodes of care in Michigan and to beneficiaries with Medicare FFS and BCBSM/BCN commercial and Medicare Advantage plans, which may not be generalizable to all CAD episodes of care. However, this study expands upon existing literature that often focus solely on Medicare FFS beneficiaries by including beneficiaries from other payers.[7,26,32] Second, we only captured CR enrollment within 90 days of discharge, which likely underestimates overall enrollment rates and the number of CR sessions attended. Thus, longer time to enrollment may result in fewer CR sessions within the 90-day period. Third, there are limitations to claims data vis-à-vis missing data. Claims data lack clinically relevant and validated measures of disease severity, clinical status, and procedural information that might be important determinants of CR enrollment. Information may also be missing if it is irrelevant to medical billing practices, which may differ across hospitals. Future work should incorporate clinical registries into claims data to address these missing data issues. Fourth, administrative data also lack information on CR referral, which is an important predictor of enrollment and may explain variation in enrollment across hospitals.[8,15] Fifth, we do not include clustering or analysis of variation at the physician level. Grace et al[21] identified that physician endorsement of CR was a significant determinant of enrollment, which may be a contributing factor to variation across hospitals that was not available in our data.[33] Sixth, we were not able to separate out individuals with type II non-ST elevated myocardial infarction, which have historically lower rates of CR enrollment.[34] Finally, episodes of care in this study do not include patients with stable CAD, heart failure, valve repair/replacement, or heart transplant, who are also eligible for CR enrollment.

CONCLUSIONS

Enrollment in CR during CAD episodes of care varies from 10% to 50% across hospitals and treatment strategy. While several patient demographics, clinical, and insurance factors predicted eventual enrollment in CR, 10% of the variation in enrollment was attributed to the hospital-level. Future work should seek to identify and implement hospital-specific practices associated with higher CR enrollment and address nonhospital barriers to enrollment to facilitate national efforts supported by federal agencies and payers.

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Supplemental Material

Tables I–IV

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