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ORIGINAL ARTICLE

Hospital and Operator Variation in Cardiac Rehabilitation Referral and Participation After Percutaneous Coronary Intervention: Insights From Blue Cross Blue Shield of Michigan Cardiovascular Consortium

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BACKGROUND: Despite its established benefit and strong endorsement in international guidelines, cardiac rehabilitation (CR) use remains low. Identifying determinants of CR referral and use may help develop targeted policies and quality improvement efforts. We evaluated the variation in CR referral and use across percutaneous coronary intervention (PCI) hospitals and operators.

METHODS: We performed a retrospective observational cohort study of all patients who underwent PCI at 48 nonfederal Michigan hospitals between January 1, 2012 and March 31, 2018 and who had their PCI clinical registry record linked to administrative claims data. The primary outcomes included in-hospital CR referral and CR participation, defined as at least one outpatient CR visit within 90 days of discharge. Bayesian hierarchical regression models were fit to evaluate the association between PCI hospital and operator with CR referral and use after adjusting for patient characteristics.

RESULTS: Among 54 217 patients who underwent PCI, 76.3% received an in-hospital referral for CR, and 27.1% attended CR within 90 days after discharge. There was significant hospital and operator level variation in in-hospital CR referral with median odds ratios of 3.88 (95% credible interval [CI], 3.06–5.42) and 1.64 (95% CI, 1.55–1.75), respectively, and in CR participation with median odds ratios of 1.83 (95% CI, 1.63–2.15) and 1.40 (95% CI, 1.35–1.47), respectively. In-hospital CR referral was significantly associated with an increased likelihood of CR participation (adjusted odds ratio, 1.75 [95% CI, 1.52–2.01]), and this association varied by treating PCI hospital (odds ratio range, 0.92–3.75) and operator (odds ratio range, 1.26–2.82).

CONCLUSIONS: In-hospital CR referral and 90-day CR use after PCI varied significantly by hospital and operator. The association of in-hospital CR referral with downstream CR use also varied across hospitals and less so across operators suggesting that specific hospitals and operators may more effectively translate CR referrals into downstream use. Understanding the factors that explain this variation will be critical to developing strategies to improve CR participation overall.

Key Words: cardiac rehabilitation ■ hospitals ■ percutaneous coronary intervention ■ quality of health care ■ registries

Given its association with improvements in quality of life and reduced rates of readmission and cardiovascular mortality, cardiac rehabilitation is strongly recommended in international guidelines for patients with cardiovascular disease and especially those who have undergone percutaneous coronary intervention (PCI).[1–3] Nonetheless, rates of cardiac rehabilitation (CR) referral and downstream utilization remain low.[4–8]

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WHAT IS KNOWN

- Among patients with coronary artery disease, participation in cardiac rehabilitation is associated with significant health benefits including improved quality of life and decreased risks of readmission and mortality.
- Despite class I guideline recommendations, enrollment in cardiac rehabilitation remains low and highly variable. The effect of in-hospital cardiac rehabilitation (CR) referrals on downstream participation, and the amount of variability in CR referral and enrollment attributable to the hospital and provider are unknown.

WHAT THE STUDY ADDS

- In-hospital CR referral after percutaneous coronary intervention was significantly associated with downstream CR use within 90 days after percutaneous coronary intervention (adjusted odds ratio, 1.75 [95% credible interval, 1.52–2.01]), suggesting that this practice can improve rates of CR enrollment.
- There was significant hospital and percutaneous coronary intervention operator-level variation in rates of CR referral and CR participation after accounting for patient demographic, insurance, and clinical factors.
- There was substantial variation in the association of in-hospital CR referral with 90-day CR use by percutaneous coronary intervention hospitals and operators, suggesting that hospitals and physicians play an important role in translating CR referrals into CR utilization.

Nonstandard Abbreviations and Acronyms

BMC2	Blue Cross Blue Shield of Michigan Cardiovascular Consortium
CI	credible interval
CR	cardiac rehabilitation
MOR	median odds ratio
PCI	percutaneous coronary intervention

This remarkable gap in CR participation is likely related to numerous and complex factors that exist at the policy, hospital, provider, and patient levels including patient characteristics like comorbidities, insurance coverage, and socioeconomic status.[4,9,10] However, the magnitude of variation in CR referral and participation by hospital and operator remains incompletely understood and could help identify targets for quality improvement interventions.[5,7,11,12]

With increased emphasis on ensuring in-hospital referral to CR before discharge,[13] it remains unclear what impact the practice of in-hospital CR referral has on downstream CR participation, and whether the association between in-hospital CR referral and CR participation is modified by PCI hospital and operator after accounting for patient characteristics. In this context, we sought to describe (1) variation in 90-day CR participation by hospital and PCI operator and (2) whether the association of in-hospital CR referral on CR participation was modified by hospital and PCI operator.

METHODS

Data Sources

We linked 2 data sources for this study. The first was the Blue Cross Blue Shield of Michigan Cardiovascular Consortium (BMC2) clinical PCI registry, which includes all patients who underwent PCI in both inpatient and outpatient settings at 48 nonfederal PCI-capable hospitals in Michigan.

Because of the sensitive nature of the data in this study, public access to the data will not be provided. Briefly, BMC2 is a prospective, multicenter, statewide registry of patients who underwent PCI at all nonfederal hospitals in Michigan. The registry is based on the National Cardiovascular Data Registry CathPCI platform and enhanced by the inclusion of novel variables and rigorous auditing practices. A detailed description of the registry has been previously described.[14]

The second data source was the Michigan Value Collaborative, which has developed and maintains a validated claims-based registry with 90-day price-standardized episodes of care from Medicare fee-for-service, Blue Cross Blue Shield of Michigan preferred provider organization, and Blue Cross Network Health Maintenance Organization (BCN HMO) commercial and Medicare Advantage administrative claims.[15–17] All clinically related claims within 90 days after discharge from the index hospitalization or procedure were included in the episode. Of note, BCN HMO and Medicare Advantage administrative claims were available from 2014 onward. Dual-eligibility was defined as having Medicaid insurance as determined by the Medicaid insurance field in the clinical PCI registry in addition to their primary insurance coverage. The vast majority of dual eligible patients had Medicare fee-for-service and Medicaid coverage.

We linked the BMC2 clinical registry data to Michigan Value Collaborative's 90-day episodes of care where PCI occurred through indirect matching of the index PCI procedure using multiple variables including hospital and operator National Provider Identifier numbers; admission, discharge, and procedure dates for the index hospitalization; and patient sex and date of birth as previously described.[18,19] We excluded patients who died during the hospitalization, were deemed ineligible or were missing eligibility information for CR, were discharged to a location other than their home, left against medical advice, or were missing patient covariate data included in the regression models (Figure I in the Data Supplement). The University of Michigan Institutional Review Board approved the study and determined that it met the definition of research not requiring informed consent. The analytic and statistical methods are available through M.S. (mcseth@med.umich.edu) to other researchers for purposes of replicating the procedure.

However, the data used in this study cannot be shared because of our data use agreements.

Study Population

Using the linked dataset, we evaluated consecutive patients who underwent PCI, including both inpatient and outpatient PCI, between January 1, 2012 and March 31, 2018, at 48 PCI-capable hospitals in Michigan and were discharged home. We excluded patients who were deemed ineligible for CR referral as defined by the National Cardiovascular Data Registry CathPCI data dictionary v4.4 (Figure I in the Data Supplement). Specifically, patients could be considered ineligible based on patient, provider, and health care system-related factors.

Outcomes

Referral to CR before PCI discharge was obtained from the clinical PCI registry. CR referral included referral to traditional CR programs and training sessions as well as alternative options such as home-based CR. CR participation was defined as ≥1 administrative claim for outpatient CR within the 90 days following discharge based on the following coding: Current Procedural Terminology codes (93797 and 93798), Healthcare Common Procedure Coding System codes (G0422 and G0423), and revenue center code 943.[6,8,20]

Statistical Analysis

Baseline characteristics were compared between patients who attended at least one CR session within 90 days and those who did not. Absolute standardized differences >10% were considered to be an indicator of imbalance. To measure variation in CR referral and CR participation attributable to hospitals and PCI operators, we fit Bayesian hierarchical logistic regression models adjusting for covariates including patient characteristics and accounting for patient clustering by hospital and PCI operator with a binary outcome of CR referral (or CR participation). STAN software[21] was utilized for Markov chain Monte Carlo sampling through the RSTAN interface to the R programming software and environment.[22] The RSTANARM package was used to provide a standard R formula interface for the hierarchical model.[23] See Methods in the Data Supplement for more details on the implementation of Bayesian models. Patient characteristics including age, sex, race, diabetes, history of heart failure, prior myocardial infarction, history of peripheral artery disease, prior PCI, prior coronary artery bypass graft surgery, history of cerebrovascular disease, outpatient versus inpatient hospitalization, coronary artery disease presentation (asymptomatic, nonischemic symptoms, stable angina, unstable angina, non-ST-elevation myocardial infarction, or ST-elevation myocardial infarction), primary insurance coverage (Medicare fee-for- service, Blue Cross Blue Shield of Michigan preferred provider organization, BCN HMO, Medicare Advantage Blue Cross Blue Shield of Michigan preferred provider organization, Medicare Advantage BCN HMO, or BCN Other), and Medicaid as secondary payer coverage were incorporated as patient fixed effects. PCI hospitals and operators were incorporated as random intercepts.

Hospital risk standardized rates were calculated as the product of the overall average CR participation rate and a hospital-specific predicted-over-expected ratio which was derived using the posterior Markov chain Monte Carlo sample (see Methods in the Data Supplement for more details). We reported median odds ratios (MORs), which are estimated from the posterior distribution of the variance parameter for the hospital and provider level random intercepts,[24] and describe PCI hospital and operator level variation in CR referral and CR participation rates. MOR was estimated for each of the 7000 posterior draws, and median and 95% credible intervals (CIs) reported graphically for each site. MORs are always >1 and are a measure of variability between clusters in the likelihood of receiving a referral for CR (or CR participation) between 2 randomly selected hospitals (or providers within a hospital) for a patient that is otherwise identical.[24] In other words, a hospital-level MOR of 2.0 for the outcome of CR referral would mean that if 2 hospitals were randomly selected and treated the same hypothetical patient, and then this exercise was repeated over all possible pairs of hospitals, in half of the pairs the odds of receiving a CR referral at one hospital would be at least twice the odds compared with the other hospital. The greater the MOR, the greater the extent that differences between clusters account for variability in the outcome at the patient level. An advantage noted by Austin and Merlo[25] of the MOR is that it is on the same scale as estimates of patient (and cluster-level) fixed effect covariates on the odds of the outcome. Thus, one can compare the magnitude of the MOR with that of potentially modifiable patient variables on the odds of the outcome.

To evaluate the association of in-hospital CR referral on downstream CR participation, we added a CR referral fixed effect to the previously described Bayesian hierarchical model with an outcome of CR participation. We also included an interaction term between CR referral at the hospital and operator levels. This allowed us to evaluate whether the association between CR referral and CR participation varied by PCI hospital or operator. To examine the correlation between hospital and operator CR referral and participation rates, we reported an adjusted R^2 from a linear regression model adjusting for hospital and operator PCI volumes, respectively.

Finally, we stratified hospitals and operators into high and low performing sites based upon the posterior credible interval (CI) for the hospital (or operator) effect, so that for a site to be an outlier, the 95% CI for that hospital must be entirely above or below zero from the fitted model. We reported hospital characteristics from the 2018 American Hospital Association Annual Survey. We also reported measures of hospital quality derived from the publicly available Hospital Compare stars rating system and Hospital Consumer Assessment of Healthcare Providers and Systems patient survey results as of October, 2020.[26,27] We reported rates of medications at discharge for high and low CR use operators. All analyses were performed using R version 3.2.1.[28]

RESULTS

Of the 58 940 90-day PCI episodes between January 1, 2012 and March 31, 2018 that were linked between the BMC2 clinical registry and the Michigan Value Collaborative claims-based registry, a total of 4723 episodes were excluded leaving 54 217 episodes comprising the primary analytic cohort (Figure I in the

Data Supplement). Those who received an in-hospital referral to CR were more likely to be identified as White race, present with STEMI, and have fewer cardiovascular comorbidities (Table 1). Those who attended CR were more likely to be younger, present with STEMI, and have fewer cardiovascular comorbidities (Table 1). The overall rates of CR referral and participation during the study period were 76.3% and 27.1%, respectively. Between 2012 and 2018, rates of CR referral by quarter ranged between 68.5% and 85.7%. Contemporaneously, rates of CR participation increased from 21.0% in the first quarter of 2012 to 35.5%% in the first quarter of 2018 (Figure II in the Data Supplement).

Variation in CR Referral and Participation by PCI Hospital and Operator

After accounting for patient characteristics, insurance status, and clustering within operators and hospitals, there was substantial hospital-level variation in the risk-standardized rates of CR referral after PCI, ranging between 6.6% and 96.4%, with a median (interquartile range) of 73.7% (59.9%–90.2%; Figure 1A).

There was significant hospital and operator level variation in in-hospital CR referral after PCI with MORs of 3.88 (95% CI, 3.06–5.42) and 1.64 (95% CI, 1.55–1.75), respectively.

Table 1. Baseline Characteristics Stratified by Cardiac Rehabilitation Referral and Participation

	In-hospital CR referral (N=41 383)	No in-hospital CR referral (N=12 834)	*P* value	ASD, %	Any CR participation (N=14 676)	No CR participation (N=39 541)	*P* value	ASD, %
In-hospital CR referral	NA	NA	NA	NA	12 660 (86.3)	28 723 (72.6)	<0.001	34.20%
Any CR participation	12 660 (30.6)	2016 (15.7)	<0.001	35.80%	NA	NA	NA	NA
Age, mean (SD)	69.54 (10.55)	69.74 (10.57)	0.065	1.90%	68.79 (10.11)	69.88 (10.70)	<0.001	10.50%
Female sex	14 807 (35.8)	4774 (37.2)	0.004	2.90%	5096 (34.7)	14 485 (36.6)	<0.001	4.00%
Black race	3100 (7.5)	1890 (14.7)	<0.001	23.20%	1018 (6.9)	3972 (10.0)	<0.001	11.20%
White race	37 238 (90.0)	10 540 (82.1)	<0.001	22.80%	13 236 (90.2)	34 542 (87.4)	<0.001	9.00%
Insurance								
BCN other	215 (0.5)	75 (0.6)	<0.001	10.10%	106 (0.7)	186 (0.5)	<0.001	21.40%
Commercial BCBSM PPO	7359 (17.8)	2127 (16.6)			3356 (22.9)	6182 (15.6)		
Commercial BCN HMO	1808 (4.4)	491 (3.8)			782 (5.3)	1530 (3.9)		
Medicare FFS	3556 (8.6)	1471 (11.5)			9284 (63.3)	28 621 (72.4)		
Medicare advantage BCBSM PPO	25 251 (61.0)	7720 (60.2)			736 (5.0)	1934 (4.9)		
Medicare advantage BCN HMO	2052 (5.0)	611 (4.8)			412 (2.8)	1088 (2.8)		
Medicaid	1142 (2.8)	339 (2.6)			705 (4.8)	4322 (10.9)		
Comorbidities								
Prior heart failure	6429 (15.5)	2530 (19.7)	<0.001	11.00%	1538 (10.5)	7421 (18.8)	<0.001	23.60%
Prior myocardial infarction	12 935 (31.3)	4322 (33.7)	<0.001	5.20%	3465 (23.6)	13 792 (34.9)	<0.001	25.00%
Prior peripheral artery disease	6455 (15.6)	2524 (19.7)	<0.001	10.70%	1596 (10.9)	7383 (18.7)	<0.001	22.10%
Prior percutaneous coronary intervention	18 411 (44.5)	6478 (50.5)	<0.001	12.00%	4977 (33.9)	19 912 (50.4)	<0.001	33.80%
Prior CABG	7848 (19.0)	2426 (18.9)	0.887	0.20%	2112 (14.4)	8162 (20.6)	<0.001	16.50%
Prior cerebrovascular disease	6888 (16.6)	2224 (17.3)	0.072	1.80%	1817 (12.4)	7295 (18.4)	<0.001	16.90%
Diabetes	16 232 (39.2)	5301 (41.3)	<0.001	4.20%	5066 (34.5)	16 467 (41.6)	<0.001	14.70%
CAD presentation								
Asymptomatic	1221 (3.0)	391 (3.0)	<0.001	17.90%	301 (2.1)	1311 (3.3)	<0.001	30.10%
Nonischemic	986 (2.4)	362 (2.8)			271 (1.8)	1077 (2.7)		
Stable angina	4435 (10.7)	1367 (10.7)			1465 (10.0)	4337 (11.0)		
Unstable angina	18 522 (44.8)	6715 (52.3)			5813 (39.6)	19 424 (49.1)		
Non-STEMI	9963 (24.1)	2562 (20.0)			3748 (25.5)	8777 (22.2)		
STEMI	6256 (15.1)	1437 (11.2)			3078 (21.0)	4615 (11.7)		

All categorical variables are represented as N (%) unless otherwise specified. ASD indicates absolute standardized difference; BCBSM, Blue Cross Blue Shield of Michigan; BCN, Blue Cross Network; CABG, coronary artery bypass grafting; CAD, coronary artery disease; CR, cardiac rehabilitation; FFS, fee-for-service; HMO, Health Maintenance Organization; NA, nonapplicable; PPO, Preferred Provider Organization; and STEMI, ST-elevation myocardial infarction.

Hospital risk-standardized rates of CR participation ranged between 5.7% and 53.1%, with a median (interquartile range) of 27.6% (21.1%–35.4%; Figure 1B). Similar to the pattern noted for CR referral, there was significant, albeit attenuated, hospital and operator level variation in CR participation with MORs of 1.83 (95% CI, 1.63–2.15) and 1.40 (95% CI, 1.35–1.47), respectively. Hospital as well as operator CR referral and 90-day CR participation rates were significantly correlated (hospital adjusted R^2: 0.29; $P<0.001$; operator adjusted R^2: 0.31; $P<0.001$; Figure 2).

With respect to 90-day risk-standardized rates of CR participation, high-performing hospitals were more likely to have higher Hospital Compare Star ratings, have better communication about postdischarge recovery, and were more likely to be recommended by patients compared with low-performing hospitals (Table 2). With respect to 90-day CR participation, high-performing PCI operators had a higher rate of in-hospital CR referral and higher rates of prescribing cardiovascular medical therapies including ACE-inhibitors, beta-blockers, and statins compared with low-performing operators (Table I in the Data Supplement).

Effect of In-Hospital CR Referral on Downstream CR Participation

In-hospital CR referral was significantly associated with downstream CR use within 90 days after PCI (adjusted odds ratio, 1.75 [95% CI, 1.52–2.01]). The association between in-hospital CR referral and downstream CR participation varied by hospital with odds ratios (site/operator posterior median and 95% CI) for the effect of referral on use ranging between 0.92 (95% CI, 0.65–1.31) and 3.75 (95% CI, 2.30–6.16) with a median (interquartile range) of 1.70 (1.48–1.99). The association between CR referral and use also varied by PCI operator with odds ratios for the effect of referral on use at the operator level ranging between 1.26 (95% CI, 0.73–2.05) and 2.82 (95% CI, 1.74–4.97) with a median (interquartile range) of 1.76 (1.63–1.87) (Figure 3).

DISCUSSION

Our study has 3 major findings. First, post-PCI in-hospital CR referral was associated with a significantly higher likelihood of CR participation supporting the practice of in-hospital CR referral for improving downstream participation. Second, there was significant variation in the rates of CR referral and CR participation across PCI hospitals and operators. Moreover, high-performing hospitals with respect to 90-day CR use had evidence of higher care quality based on Hospital Compare Star ratings and Hospital Consumer Assessment of Healthcare Providers and Systems survey results compared with low-performing hospitals. Third, the association of in-hospital CR referral with downstream CR participation varied substantially across hospitals and operators. These findings confirm that hospital and physician factors play an important role in translating in-hospital CR referrals into downstream CR use and are important targets for interventions to improve CR use after PCI.

We report a CR referral rate after PCI that is modestly higher than contemporary estimates among similar patients. For instance, Beatty et al reported that among patients who underwent PCI between 2010 and 2015 in the state of Washington, 48% received a referral for CR.[7] Similarly, using the National Cardiovascular Data Registry CathPCI registry, Aragam et al demonstrated that 59.2% of patients who underwent PCI nationally

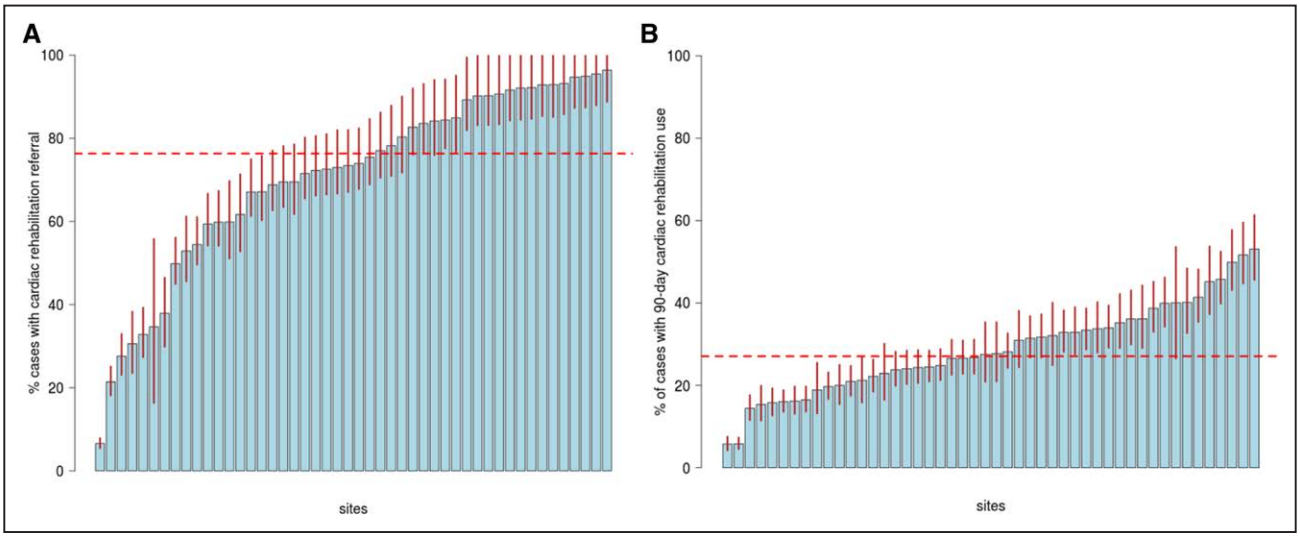

Figure 1. Risk-standardized rates of cardiac rehabilitation in-hospital referral and 90-day participation by hospital.
Risk-standardized rates of cardiac rehabilitation in-hospital referral by hospital (**A**) and cardiac rehabilitation use within 90 days among referred patients by hospital (**B**). Of note, hospital rates were sorted in ascending order for each graph; therefore, "site 1" in **A** may not be the same hospital as "site 1" in **B**.

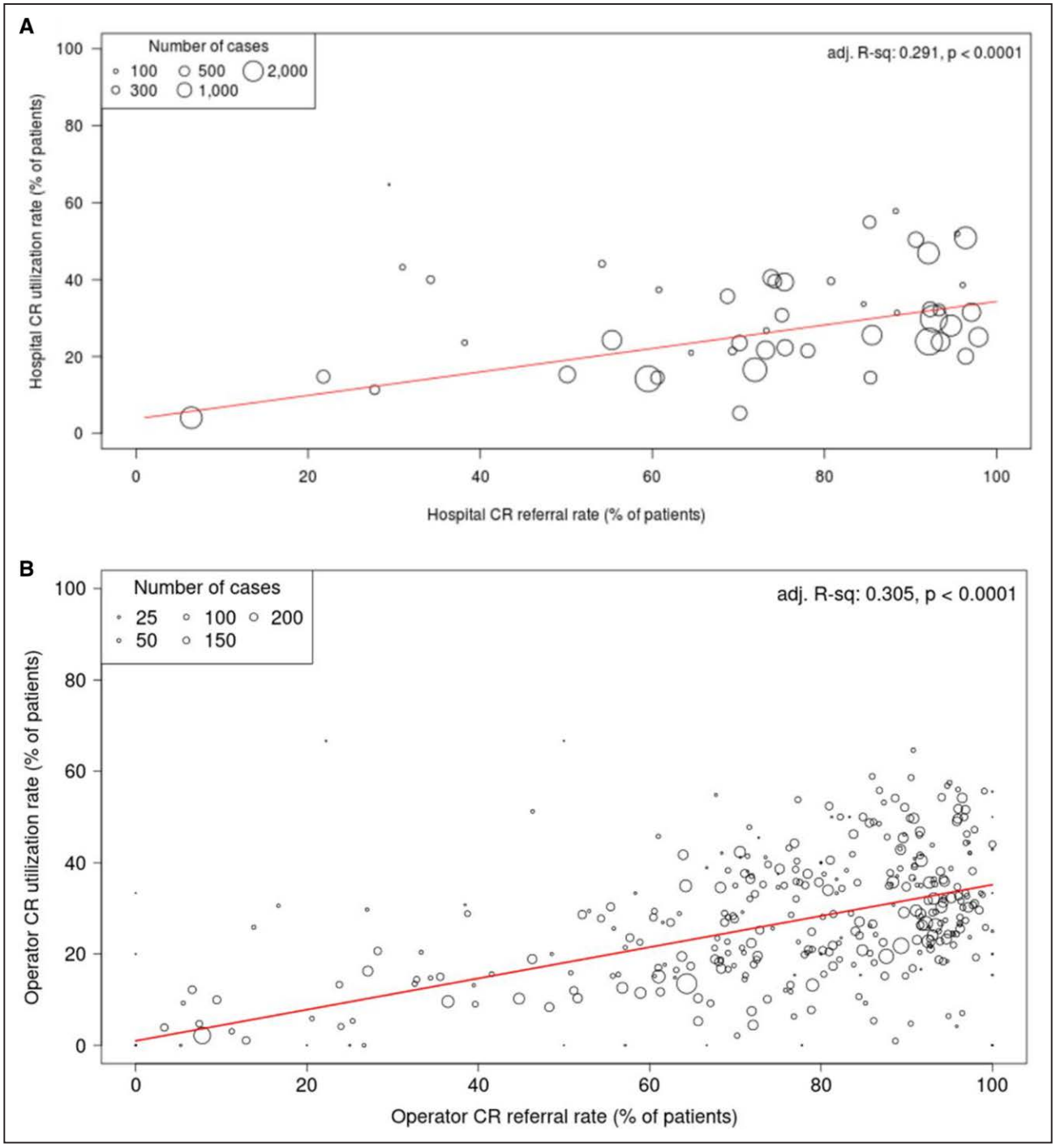

Figure 2. Correlation between rates of in-hospital cardiac rehabilitation referral and 90-day cardiac rehabilitation participation by hospital and operator.

The relationship between rates of in-hospital cardiac rehabilitation referral and 90-day cardiac rehabilitation participation is graphically depicted for hospitals (**A**) and operators (**B**). The R^2 measure of correlation is weighted for the percutaneous coronary intervention volume of hospitals (**A**) and operators (**B**). CR indicates cardiac rehabilitation.

received a referral for CR between 2009 and 2012.[5] Compared with prior findings from Michigan, we report an overall CR referral rate of 76.3%, which is >10 percentage points higher than the CR referral rate in Michigan between 2003 and 2008.[29] The relatively high and improved referral rates across Michigan may be related to targeted efforts by the BMC2 PCI quality collaborative aimed at improving rates of CR referral after PCI.

However, only a third of patients who received a referral for CR after PCI attended at least one session—an estimate that is consistent with prior research.[6] This gap highlights the need for novel

Table 2. Characteristics of Hospitals Stratified by High and Low Performance on 90-Day Cardiac Rehabilitation Use

	High CR use (12 hospitals)	Low CR use (12 hospitals)	*P* value	ASD, %
Bed size, %			0.41	0.89
100–199 beds	1 (8.3)	3 (25.0)		
200–299 beds	4 (33.3)	3 (25.0)		
300–399 beds	1 (8.3)	3 (25.0)		
400–499 beds	4 (33.3)	1 (8.3)		
500 or more beds	2 (16.7)	2 (16.7)		
Teaching hospital	11 (91.7)	11 (91.7)	1.00	<0.001
Hospital compare star rating				
1 star	0 (0.0)	1 (8.3)	0.041	168.7%
2 stars	2 (16.7)	7 (58.3)		
3 stars	2 (16.7)	3 (25.0)		
4 stars	3 (25.0)	1 (8.3)		
5 stars	5 (41.7)	0 (0.0)		
HCAHPS responses, percentage (SD)				
Room and bathroom were clean.				
Always	68.9% (5.2%)	67.3% (4.7%)	0.418	33.7%
Sometimes or never	9.4% (2.5%)	11.6% (4.1%)	0.134	63.5%
Usually	21.7% (3.20)	21.2% (2.5%)	0.673	17.5%
Nurses communicated well.				
Always	79.3% (2.5%)	77.8% (2.9%)	0.187	55.6%
Sometimes or never	3.7% (1.2%)	5.3% (2.4%)	0.055	82.6%
Usually	17.0% (1.5%)	16.9% (1.5%)	0.894	5.5%
Doctors communicated well.				
Always	78.5% (1.8%)	77.2% (2.7%)	0.167	58.4%
Sometimes or never	4.4% (0.9%)	5.8% (1.8%)	0.029	95.2%
Usually	17.1% (1.3%)	17.1% (1.9%)	1.00	<0.01%
Patients received help as soon as they wanted.				
Always	64.8% (5.3%)	63.3% (3.8%)	0.459	30.8%
Sometimes or never	8.6% (2.2%)	10.8% (4.3%)	0.122	65.6%
Usually	26.7% (3.8%)	25.8% (2.0%)	0.51	27.3%
Pain was well controlled.				
Always	68.8% (2.4%)	67.5% (2.4%)	0.216	52.0%
Sometimes or never	7.1% (1.2%)	9.0% (2.8%)	0.041	88.6%
Usually	24.2% (1.8%)	23.5% (1.5%)	0.328	40.8%
Staff explained about medicines before giving it to them.				
Always	62.1% (3.4%)	61.1% (3.2%)	0.466	30.3%
Sometimes or never	19.0% (2.6%)	21.3% (2.9%)	0.057	81.8%
Usually	18.9% (1.4%)	17.7% (1.6%)	0.049	85.0%
Communication regarding recovery after discharge.				
No, they were not given information about what to do during their recovery at home.	11.6% (1.4%)	13.7% (1.9%)	0.007	122.5%
Yes, they were given information about what to do during their recovery at home	88.4% (1.4%)	86.3% (1.9%)	0.007	122.5%
Patient understood post-discharge care.				
Strongly agree	52.2% (3.6%)	46.3% (4.2%)	0.001	149.2%
Agree	42.7% (3.3%)	46.9% (3.6%)	0.006	124.7%
Disagree or strongly disagree	5.2% (1.1%)	6.8% (2.0%)	0.024	99.3%

(*Continued*)

Table 2. Continued

	High CR use (12 hospitals)	Low CR use (12 hospitals)	*P* value	ASD, %
Hospital rating on a scale from 0 (lowest) to 10 (highest).				
Rating of 6 or lower	7.1% (2.4%)	10.3% (3.0%)	0.007	120.7%
Rating of 7 or 8	19.8% (4.8%)	24.6% (2.6%)	0.005	126.1%
Rating of 9 or 10	73.2% (6.8%)	65.1% (5.0%)	0.003	135.2%
Area around their room was quiet at night.				
Always	53.9% (8.5%)	54.6% (4.8%)	0.815	9.7%
Sometimes or never	33.5% (4.0%)	31.2% (4.1%)	0.172	57.6%
Usually	12.6% (4.8%)	14.3% (3.0%)	0.318	41.7%
Would the patient recommend the hospital?				
Yes, they would definitely recommend the hospital	74.8% (8.1%)	62.4% (7.3%)	0.001	161.4%
Yes, they would probably recommend the hospital	20.8% (6.3%)	30.6% (5.4%)	0.001	166.0%
No, they would probably not or definitely not recommend the hospital	4.3% (2.2%)	7.0% (3.1%)	0.024	99.3%

The HCAHPS measures were obtained from the October 2020 Hospital Compare Files.[27] Data are presented as N (%) unless otherwise specified. HCAHPS indicates Hospital Consumer Assessment of Healthcare Providers and Systems.

quality improvement initiatives focused on CR participation even after in-hospital referrals are placed. Extending upon prior work, we not only found significant hospital-level variation in rates of CR referral[5,7] but we also found significant hospital-level variation in downstream CR participation. Moreover, we found a significant association between physicians performing PCI and both CR referral and downstream CR use. This finding underscores the importance of the PCI operator in not only ensuring that CR referrals are promptly placed after PCI and before discharge but also suggests that providers may affect downstream CR participation.

We also found substantial variation in the association of in-hospital CR referral with CR use by PCI hospital and less so, by operator. This finding illustrates the important role that hospitals and physicians play in translating CR referrals into downstream use. For instance, some hospitals may process CR referrals to ensure that their patients have a CR appointment within 10 days of discharge, a proven strategy to improve CR attendance.[30] Other hospital-based strategies shown to be effective to improve referral to and/or enrollment into early outpatient CR include (1) the use of a default opt-out decision pathway for CR in the electronic medical record[31]; (2) the use of a liaison-facilitated bedside meeting before hospital discharge, during which a CR staff person describes CR and schedules the patient's first outpatient CR appointment[32]; and (3) providers more strongly endorsing the importance of CR to their patients, thus increasing the likelihood of downstream participation.[10,11] Concerning the latter, some providers may more strongly endorse the importance of CR to their patients, thus increasing the likelihood of downstream participation.[11,12,33] Indeed, prior work has demonstrated that provider endorsement and physician attitudes toward CR are associated with CR participation.[11] This finding is also consistent with recent work by our group demonstrating that CR participation within 90-day episodes of care after PCI, coronary artery bypass surgery, and medically managed acute myocardial infarction varied substantially across hospitals but was significantly correlated within hospitals, suggesting that CR participation is a product of hospital-specific rather than treatment-specific practices.[34] This is further supported by the fact that we found that hospitals with the highest rates of post-discharge CR use after PCI were also better at communicating post-discharge recovery plans compared with low-performing hospitals. Finally, this variation in the relationship between in-hospital CR referral and 90-day CR use may also be related to the fact that some providers and hospitals may be better at ordering post-discharge CR referrals and promoting CR use among patients who did not receive an in-hospital CR referral.

Limitations

Our findings should be considered in the context of important limitations. First, although we attempted to adjust for granular patient demographic and clinical factors, consistent with the observational nature of the study, our findings may be affected by unmeasured confounding. For instance, although we included patient's dual eligibility status, a marker of poverty, in our regression models, there are likely other socioeconomic factors that play an important role in whether a patient participates in CR after PCI. Second, due to the

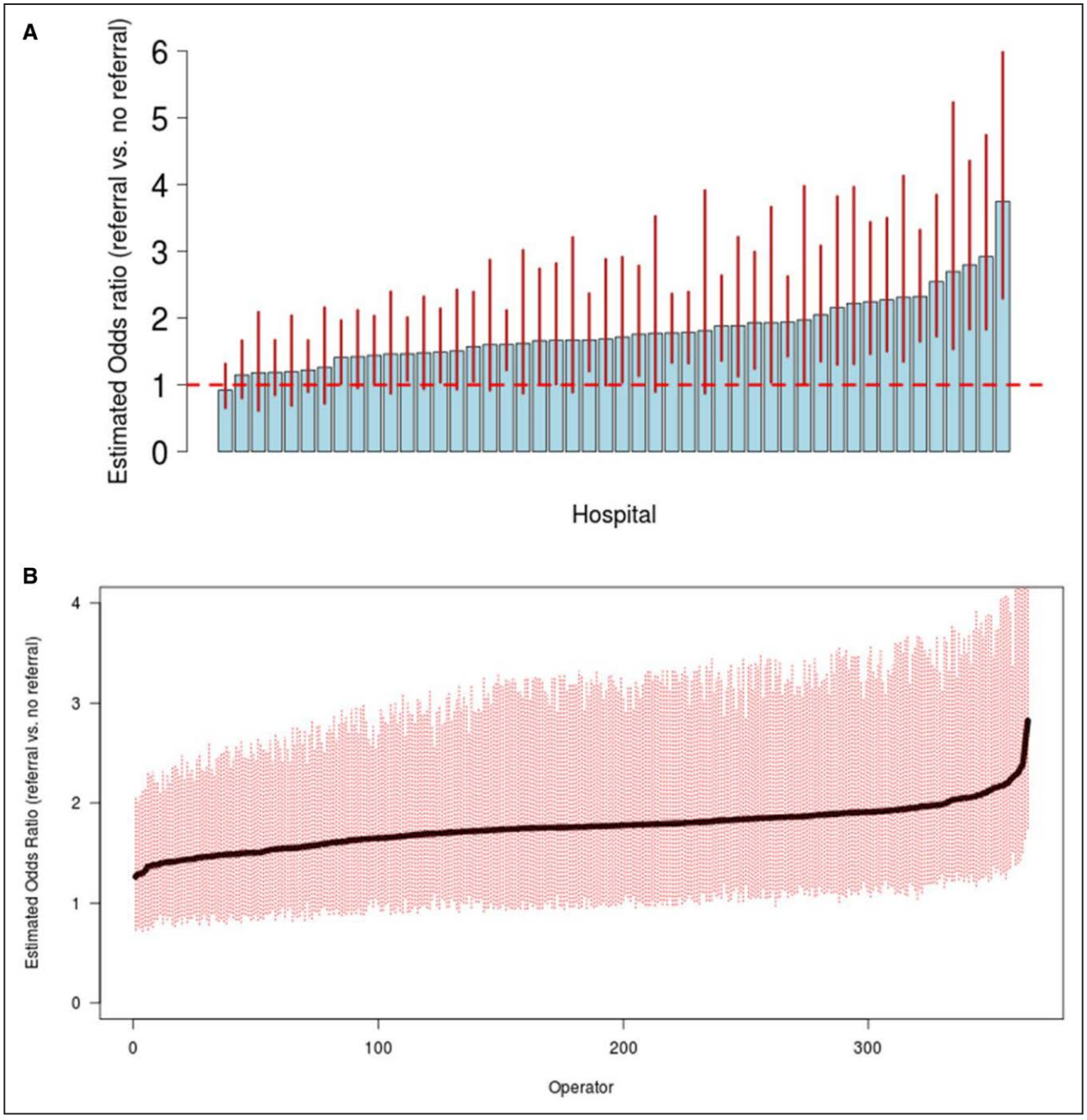

Figure 3. Estimated association of in-hospital cardiac rehabilitation (CR) referral on 90-day cardiac rehabilitation participation by hospital and percutaneous coronary intervention operator.

Estimated odds ratios for the effect of in-hospital CR referral on 90-day cardiac rehabilitation participation by hospital (**A**) and operator (**B**) for a medicare fee-for-service patient. The effects were derived from the inclusion of a random slope for in-hospital cardiac rehabilitation referral at the hospital and operator levels. In **A**, the odds ratio of 1 is depicted by the dashed red horizontal line. In **B**, the median OR (referral vs no-referral), black curve, and 95% credible intervals (vertical dashed lines) for the 365 operators in the dataset are presented.

structure of the administrative claims-based episodes of care from Michigan Value Collaborative, we were limited to evaluating CR participation within 90 days after PCI discharge—a relatively short time frame. However, the impact of this limitation is likely modest given that among patients who attend CR within 1 year after PCI discharge, over 90% attend their first CR session within 90 days of discharge.[8] Third, we did not capture CR referrals made outside the index PCI stay, which explains how a modest fraction of patients without a CR referral during the index PCI stay participated in CR within 90 days after PCI. Fourth, our findings were limited to a single state with a long-standing quality improvement program with focused initiatives aimed at improving CR referral, thus limiting the generalizability of our findings to other states.[35]

CONCLUSIONS

We found significant hospital and provider level variation in rates of in-hospital CR referral and downstream CR use. Thus, strategies including interventions aimed at both hospitals and providers may be most successful in improving CR participation. The association of in-hospital CR referral with downstream CR use varied across hospitals and PCI operators, suggesting that CR referrals in some hospitals or by some PCI operators were more likely to result in downstream CR participation compared with other hospitals or operators. Future research aimed at understanding the contextual factors that explain why CR referral has a differential effect on CR participation by hospital and operator will be critical to developing and implementing novel strategies to improve CR participation.

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Supplemental Materials

Methods.
Figures I and II.
Table I.

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