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Geographic Variation in Cardiac Rehabilitation Access

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Structured Abstract

Background: There is marked geographic variation in cardiac rehabilitation (CR) initiation, ranging from 10-40% of eligible patients at the state level. The potential causes of this variation, such as patient access to CR centers, are not well studied.

Objectives: The authors sought to determine how access to CR centers affects CR initiation in Medicare beneficiaries.

Methods: The authors used Medicare files to identify CR-eligible Medicare beneficiaries and calculate CR initiation rates at the hospital referral region (HRR) level. We used linear regression to evaluate the percent variation in CR initiation accounted for by CR access across HRRs. We then employed geospatial hotspot analysis to identify CR deserts, or counties in which patient load per CR center is disproportionately high.

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Results: A total of 1,269,147 Medicare beneficiaries were eligible for CR from 2014 to 2017, of whom 314,997 (25%) initiated CR. The West North Central Census Division had the highest adjusted CR initiation rate (37.0%) and the highest density of CR programs (5.89 per 1,000 CR-eligible Medicare beneficiaries). Density of CR programs accounted for 23.5% of geographic variation in CR initiation at the HRR level. A total of 39 largely urban counties comprising 13% of the United States population age ≥65 had disproportionately low CR access and were identified as CR deserts.

Conclusions: A substantial proportion of geographic variation in CR initiation was related to access to CR programs, with a significant amount of the U.S. population living in CR deserts. These data invite further study on interventions to increase CR access.

Condensed Abstract

There is marked geographic variation in cardiac rehabilitation (CR) initiation. We evaluated how access to CR centers affects this variation in Medicare beneficiaries. A total of 1,269,147 Medicare beneficiaries were CR-eligible from 2014-2017, of which 25% initiated CR. The West North Central Census Division had the highest adjusted CR initiation rate (37.0%). Density of CR programs accounted for 23.5% of geographic variation in CR initiation. A total of 39 urban counties comprising 13% of the United States population age ≥65 had disproportionately low CR access and were identified as CR deserts. These findings invite study on increasing CR access.

Tweet:

Participation in cardiac rehabilitation (CR), an important therapy for heart attack survivors, has wide regional variation in the United States. Access to CR drives much of this variation, with some areas (CR deserts) having little or no CR access. #CardiacRehab

Keywords

cardiac rehabilitation; geographic variation; access to care

Introduction

Cardiac rehabilitation (CR), a comprehensive group of services including exercise and cardiovascular risk factor management, is an important part of guideline-directed medical therapy for patients with cardiovascular disease.[1–3] Participation in CR programs increases quality of life and decreases mortality.[4] The relationship of CR with outcomes is dose-dependent[3]; thus CR utilization is generally characterized as initiation (attending at least 1 session) and adherence (number of sessions attended).[5] Multiple studies have demonstrated that Medicare patients initiating CR attend 24-26 sessions on average.[6,7] However, less than a quarter of eligible patients initiate CR in the United States,[8] suggesting that strategies to improve CR initiation may significantly improve cardiovascular outcomes. Prior work has shown wide geographic variation in CR initiation in the United States with states in the northern Midwest reaching CR initiation rates of 30-50% and many states in the Southeast having CR initiation of approximately 10%.[6,8–10] There is also significant variation in the geographic density of CR centers.[11,12] However, the relationship of geographic variation in CR utilization with access to CR centers is not well described. The objective of this study was to characterize geographic variation in CR initiation in the United States using geospatial and statistical methods with Medicare claims data from 2013-2018. We hypothesized that much of geographic variation was caused by regional differences in access to CR centers.

Methods

Data sources

We obtained data regarding CR eligibility, initiation and adherence from the 2013 to 2018 100% Limited Data Set files from the Centers for Medicare & Medicaid Services (CMS) and hospital characteristics and locations from the 2014 to 2018 American Hospital Association Annual Survey Database.[13] Density of CR centers was defined as the number of CR centers per 1,000 CR-eligible Medicare beneficiaries in each Hospital Referral Region (HRR).[14] We calculated a weighted average distance to the nearest CR center within each HRR using the number of residents age ≥65 (as a surrogate for Medicare beneficiaries) in each census tract from the Census 2010 Demographic Profile Summary File.[15] We geocoded each census tract centroid within an HRR and determined the distance in miles from the centroid to the nearest CR center. The average of these distances was proportionally weighted by the number of people age ≥65 years within each tract to account for the population distribution within the HRR.

We estimated patient income using the U.S. Census Bureau 2015 American Community Survey (ACS)[15] data. Percentages of county populations below the poverty line were obtained from the Census Bureau Small Area Income and Poverty Estimates for 2018.[16] CR patient loads per CR center were estimated using county population age ≥65 years from the 2018 ACS and 2016 to 2018 county-level coronary heart disease hospitalizations for patients age ≥65 years from the Centers for Disease Control and Prevention Interactive Atlas of Heart Disease and Stroke.[17] The analysis was conducted under the terms of a data use agreement with CMS, and the Institutional Review Board of Vanderbilt University Medical Center granted an exemption for the study.

Patient population

The study population included inpatient Medicare beneficiaries age ≥65 years who resided in the United States and had uninterrupted fee-for-service coverage until their death or for 1 year following discharge. Inclusion in the study was based on a diagnosis code (International Classification of Diseases −9th or −10th Revision code) or procedure (Current Procedure Terminology/Healthcare Common Procedure Coding System) code for a qualifying diagnosis between January 2014 and December 2017. Claims codes were adapted from the Million Hearts Outpatient Cardiac Rehabilitation Use Surveillance Methodology[18] and are displayed in Supplemental Table 1. Qualifying diagnoses included acute myocardial infarction, percutaneous coronary intervention, coronary artery bypass surgery, cardiac valve surgery, and heart or heart-lung transplant. Medicare beneficiaries with systolic heart failure were included in a sensitivity analysis. Further details are provided in the Supplemental Methods.

Outcomes

CR initiation (binary indicator of ≥1 outpatient claim for CR) was the primary outcome. We queried the Medicare outpatient Limited Data Set files for CR claims (Current Procedure Terminology/Healthcare Common Procedure Coding System codes 93797, 93798, G0422, G0423, or S9472) occurring in the year following the index discharge date. The secondary outcome was CR adherence, defined as the number of sessions attended.

Other variables

We obtained demographic characteristics, including age, sex, race/ethnicity, Medicaid eligibility, and geographic census region from the Limited Data Set files. We characterized the burden of comorbidities using the Elixhauser comorbidity score,[19] which incorporated diagnosis codes present during the index hospitalization and those documented in hospitalizations within the year before the index hospitalization. We obtained the county-level Social Deprivation Index[20] linked to 2015 to 2019 ACS data from the Robert Graham Center.[21] Hospital characteristics including presence of an inpatient or outpatient CR program, bed size, ownership, critical access status, presence of a cardiac catheterization lab, and presence of a cardiac surgery program, were obtained from the 2014 to 2018 American Hospital Association Annual Survey Database.[13]

Statistical analysis

Summary statistics were calculated as count and percentage for each variable in the full sample. We calculated the median (25th and 75th percentiles) of days between hospital discharge and CR initiation (wait time) as well as the mean and SD number of CR sessions attended. We used multivariable adjusted logistic regression to evaluate the effect of demographic, socioeconomic and clinical covariates on CR initiation with a compound symmetry correlation structure to account for correlation among patients at the same facility. We used linear regression to assess predictors of CR adherence (number of CR sessions attended) including a random intercept for hospital to account for correlation among patients at the same facility. We then performed a correlation analysis at the county-level to determine whether median wait time among CR attenders was associated with proportion of CR-eligible patients who initiated CR.

Using a negative binomial model and data at the HRR level, we determined the proportion of CR initiation in each Census Division, adjusted for age, sex, race/ethnicity, eligibility diagnosis, comorbidities, Medicaid eligibility, median county income, county-level social deprivation index, and hospital characteristics. Next, we calculated the number (density) of CR programs per 1,000 CR-eligible Medicare beneficiaries in each Census Division. Then, using the U.S. population ≥65 years of age as a surrogate for all Medicare beneficiaries, we calculated the driving distance from the centroid of each census tract to the nearest CR center, using the latitude and longitude coordinates of CR centers from the American Hospital Association Annual Survey of Hospitals. From these data, we reported the median (Q1, Q3) driving distance to the nearest CR center in each Census Division, weighted by the population of Medicare beneficiaries in each region.

We constructed a multivariable-adjusted negative binomial model with density of CR centers, average distance to nearest CR center, and patient characteristics within each HRR as the independent variables and proportion of eligible patients attending CR as the dependent variable. We used this model to calculate the adjusted proportion of eligible patients enrolling in CR within each Census Division and plot the proportion of CR-eligible Medicare beneficiaries initiating CR at the HRR level by the following: (1) density of CR centers per 1000 CR-eligible Medicare beneficiaries; and (2) average driving distance to the nearest CR center. The percent variance in CR utilization at the HRR level explained by demographic, socioeconomic and clinical characteristics was calculated by partial R-square statistics from a multivariable linear regression model with CR initiation percentage as the dependent variable.[22,23] Statistical analyses used SAS version 9.4[24] and R version 4.0.1.[25]

Geospatial analysis

Geospatial analyses used ArcGIS Pro version 2.8.[26] CR centers were geolocated, and an average patient load per center was calculated at the county level using Centers for Disease Control and Prevention coronary heart disease hospitalization rates and county ACS population estimates of age ≥65. We used hotspot analysis[27] (Getis-Ord Gi*) to identify CR patient load hotspots (CR deserts) based on average estimated facility patient load per county. Getis-Ord Gi* is an iterative statistic that compares a measure associated with each feature (in this case, CR patient load per county) and those of its neighboring features (which comprise a “neighborhood”) against the feature values in the rest of the map. Given the wide variation in county sizes, we set the neighborhood parameter using inverse distance weighted squared approach rather than a fixed distance band. A false discovery rate correction was used to account for spatial autocorrelation.[28] Getis-Ord Gi* returns a statistically significant z-score for a given county if its neighborhood has significantly high or low patient loads compared with a null hypothesis of random distribution of points of the same sample size and values. Identification of a hotspot indicates that a county and its surrounding counties have significantly high patient loads. CR deserts were conservatively defined as statistically significant hotspots based on CR patient load per facility with a CI of 95% and above.

Sensitivity Analyses

Patients with systolic heart failure comprised a significant portion of the CR-eligible population (n=606,571) and had a very low CR initiation rate (4%). The large number of systolic heart failure patients coupled with very low CR initiation rates for this diagnosis could disproportionately lower CR initiation and mask geographic variation signal for the other eligibility diagnoses. To maintain sensitivity for all other eligibility diagnoses and minimize homogeneity among geographic areas, we excluded systolic heart failure patients from the main analyses but performed sensitivity analyses analogous to those described in the previous text that included Medicare beneficiaries with systolic heart failure.

Results

Cohort derivation

A total of 1,729,671 Medicare fee-for-service beneficiaries aged 65 and older were hospitalized with a CR-eligible condition from 2014 to 2017. We excluded 459,953 patients from our analysis for a final sample size of 1,269,147 CR-eligible patients. Exclusions and number excluded are shown in Supplemental Figure 1.

Cohort characteristics

A total of 314,997 patients (25%) initiated CR (Table 1). Women had a lower odds of initiating CR (OR: 0.87; 95% CI: 0.86-0.88) as did Black (OR: 0.85; 95% CI: 0.82-0.87), Asian (OR: 0.89; 95% CI: 0.85-0.94), Hispanic (OR: 0.74; 95% CI: 0.70-0.78) and North American Native (OR: 0.60; 95% CI: 0.54-0.68) patients compared with White patients, after multivariable adjustment. Patients undergoing cardiac valve surgery or coronary artery bypass grafting had the highest odds of initiating CR (Table 1). A greater burden of comorbidities, Medicaid eligibility, and increasing social deprivation was associated with decreased odds of initiating CR (Table 1). Patients initiating CR attended an average of 26.1 ± 12.4 sessions, and the median wait time between discharge from the hospital and CR initiation was 39 days. CR adherence was relatively stable across sociodemographic and clinical groups, with the mean number of CR sessions attended ranging from 20.8 in patients eligible for Medicaid to 27.7 in heart or heart-lung transplant patients. At the county level, median wait time to CR initiation was negatively correlated with CR initiation rates such that decreased wait time was associated with increased CR initiation rates ($r = -0.48$, $p<0.0001$).

Geographic variation in CR initiation

Figure 1, a choropleth map of the multivariable-adjusted proportion of CR-eligible Medicare beneficiaries initiating CR by HRR (N=306) from 2014 to 2018, demonstrates wide geographic variation in CR initiation. HRRs in the northern United States had the highest adjusted CR initiation rates with some HRRs reaching >40% of eligible patients. HRRs in the southern United States had much lower CR initiation, where initiation rates <20% were the norm.

Geographic variation in CR access

We constructed a choropleth map of CR center density per 1,000 CR-eligible Medicare beneficiaries at the HRR level to visualize the relationship of CR initiation with CR access (Figure 2A). A total of 2,800 centers billed Medicare for CR services in the United States from 2014 to 2018. The West North Central Census Division had the highest CR center density per HRR, with multiple HRRs having >8 CR centers per 1,000 CR-eligible Medicare beneficiaries. In contrast, many HRRs in the southern United States had <2 CR centers per 1,000 CR-eligible Medicare beneficiaries.

We characterized CR initiation at the Census Division level (Table 2) to further evaluate regional similarities seen between CR initiation (Figure 1) and CR center density (Figure 2A). Multivariable-adjusted proportions of CR-eligible patients initiating CR by Census

Division are displayed in Table 2. The West North Central Census Division had the highest adjusted CR initiation rate (37.0%), followed by the Mountain Census Division (33.6%). The density of CR centers was highest in the West North Central Census Division (5.89 centers per 1,000 CR-eligible Medicare beneficiaries). CR wait time, or the time between discharge and CR initiation, was lowest in the West North Central Census Division (median 22 days). The Middle Atlantic Census Division, in contrast, had the second-lowest density of CR centers (1.46 centers per 1,000 CR-eligible Medicare beneficiaries) and the highest time between discharge and CR initiation (median 50 days).

The associations of CR initiation with CR center density and distance to the nearest CR center at the HRR level are shown in Figures 2B and 2C. Figure 2B displays a non-linear association between CR center density and CR initiation such that initiation increases with greater CR center density up to 6 CR centers per 1,000 CR-eligible Medicare beneficiaries and plateaus thereafter. Figure 2C displays an inverse association between average driving distance and CR initiation.

Proportion of geographic variation explained by access to CR centers

When evaluating the proportion of geographic variation explained by CR access in comparison to demographic, clinical, hospital and socioeconomic characteristics at the HRR level, density of CR centers explained 23.5% ($p<0.0001$) of the geographic variation, substantially more than the other variables (Supplemental Table 2). Average distance to the nearest CR center accounted for 7.4% ($p<0.0001$) of geographic variation, while eligibility diagnosis (acute myocardial infarction, coronary artery bypass grafting, percutaneous coronary intervention, and so on) explained 6.3% ($p=0.001$) of the variation. Other significant variables included sex (3.8% of variation; $p<0.01$), Medicaid coverage (2.1% of variation; $p<0.05$), county-level social deprivation index (4.6% of variation; $p<0.01$), Elixhauser comorbidity score (4.1% of variation; $p<0.05$), presence of a CR program at the facility where patients were hospitalized (2.2% of variation; $p<0.05$), and race/ethnicity (2.8% of variation; $p<0.05$).

Cardiac rehabilitation deserts

Given the significant proportion of geographic variation in CR initiation that is related to CR access, we conducted geospatial analyses to identify areas where CR access is particularly limited. A total of 39 counties of 3006 nationally were identified as CR deserts (areas with disproportionately low CR access) by Getis-Ord Gi* hotspot analysis (Figure 3). No cold spots, or areas of oversaturation of CR facilities, were identified because no county clusters had disproportionately low patient loads per CR center. CR deserts contained 13% of the U.S. population age ≥65 years (approximately 6.5 million persons of a total U.S. population of 49 million age ≥65 years[29]) and were disproportionately urban as defined by the 2013 National Center for Health Statistics Urban-Rural Classification[30] (Supplemental Table 3). CR deserts also had a much higher proportion of Hispanic (30% vs. 9% for all counties) and Black (12% vs. 9% for all counties) residents age ≥65 years.

Sensitivity analysis including Medicare beneficiaries with systolic heart failure

We added 606,571 Medicare beneficiaries with systolic heart failure to the main cohort in a sensitivity analysis (Supplemental Table 4). A very low proportion of Medicare beneficiaries with systolic heart failure (4%) initiated CR and similar geographic patterns in CR initiation were observed when these beneficiaries were combined with the main cohort (Supplemental Figure 2). The hotspot analysis also demonstrated a similar geographic distribution of CR deserts, comprising a total of 41 counties (Supplemental Figure 3, Supplemental Table 5).

Discussion

In this study we demonstrate that CR initiation remains low nationally, that there is wide geographic variation in CR initiation, and that a substantial portion of this geographic variation is caused by differential access to CR centers (Central Illustration). Further, we characterize a group of largely urban counties as CR deserts, or hotspots with very high estimated patient loads per CR center. A sensitivity analysis including patients with systolic heart failure yielded a similar geographic distribution of CR initiation and CR deserts. These findings are important for efforts to improve CR initiation nationally and ameliorate disparities in CR initiation.

In 1997, only 19% of Medicare beneficiaries with ischemic heart disease initiated CR.[6] Our data, coupled with that of other groups,[8,10] indicates that CR initiation among Medicare beneficiaries has remained largely static since then despite numerous quality improvement efforts. These include the adoption of CR referral as a quality measure in 2007[31] and a subsequent increase in CR referral rates of over 80% of eligible patients in a registry of patients hospitalized with acute myocardial infarction.[32] The geographic variation in CR initiation seen in our study and others[8,10] has also maintained a similar pattern over the last 20 years.[6] The intractable problem of low CR initiation combined with static patterns in geographic variation suggests there are major structural barriers to CR initiation such as access to CR programs.

In evaluating CR access, we focused on unique characteristics of the West North Central and Mountain Census Divisions, which have persistently had the highest CR initiation rates in the United States.[6,8] These Census Divisions have the highest density of CR programs and the lowest CR wait times (time between discharge and CR initiation). CR wait time is a surrogate for CR capacity and has been inversely associated with CR initiation in prior work.[33,34] Interestingly, our study found that distance to the nearest CR center did not affect CR initiation as much as CR center density, suggesting that CR capacity is more important than previously thought. For example, the Middle Atlantic Census Division (which has a low adjusted proportion of patients initiating CR) has comparatively shorter average distances to CR centers but the second-lowest density of CR programs and highest wait times.

In addition to HRR-level analyses, we employed geospatial techniques to identify more granular areas in the United States where CR access is particularly limited. Getis-Ord Gi* hotspot analysis has been used to characterize food deserts[35], pharmacy deserts[36], and the spatial accessibility of primary care providers[37] and is a novel method with which to study CR access. The counties identified as CR deserts are almost all urban and densely populated, representing 13% of the US population age 65 or older. Improving access in CR desert counties has the potential of substantially increasing CR initiation for a large segment of the population. Improved CR access may be particularly important for ameliorating disparities in Hispanic patients, because the proportion of Hispanic residents age ≥65 years is 3 times higher than the national average in CR deserts and only 5% of eligible Hispanic patients attended CR in our cohort.

These findings may inform several policy efforts. Legislation has been introduced (H.R. 1956)[38] that would allow physician assistants and nurse practitioners to supervise CR programs. Scope of practice expansion efforts such as these could expand CR capacity and potentially allow for higher CR initiation in CR deserts. CMS introduced the Hospital without Walls initiative[39] in response to the COVID-19 pandemic, which allows CR to be delivered virtually for the duration of the public health emergency. Home-based CR programs have demonstrated efficacy in a variety of formats,[40–44] and an extension of CMS coverage for these programs may substantially improve access in CR deserts.

Study Limitations

First, our analyses were limited to patients enrolled in fee-for-service Medicare and may not be generalizable to patients enrolled in Medicare private health plans. However, fee-for-service Medicare still accounted for 71% of Medicare beneficiaries in 2013.[45] Second, we used population numbers age ≥65 years as a surrogate for CR-eligible Medicare beneficiaries in the analyses evaluating distance to the nearest CR center as the Medicare Limited Data Set provides only county-level residence data. However, more than 85% of Medicare beneficiaries are age ≥65 years.[45] Finally, we cannot rule out the possibility of reverse causality in the association between CR center density and CR utilization, because CR centers may be more likely to open in areas of higher utilization and to close in areas of lower utilization.

Conclusions

CR remains profoundly underutilized among Medicare beneficiaries. There is wide geographic variation in CR use, and a substantial portion of this variation may be because of differential access to CR centers. Approximately 13% of the population age ≥65 years resides in a CR desert where CR services will be very difficult to obtain. These findings invite further study on interventions to increase CR access.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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sources is for identification only and does not imply endorsement by the U.S. Department of Health and Human Services.

Abbreviations

ACS	American Community Survey
CMS	Centers for Medicare & Medicaid Services
CR	Cardiac rehabilitation
HRR	Hospital referral region

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Perspectives

Competency in Systems-Based Medicine:

Access to CR centers varies widely across the United States, with little access to these services in many areas.

Transitional Outlook:

Further efforts are needed to understand the causes of this disparity and expand access to CR programs in underserved areas.

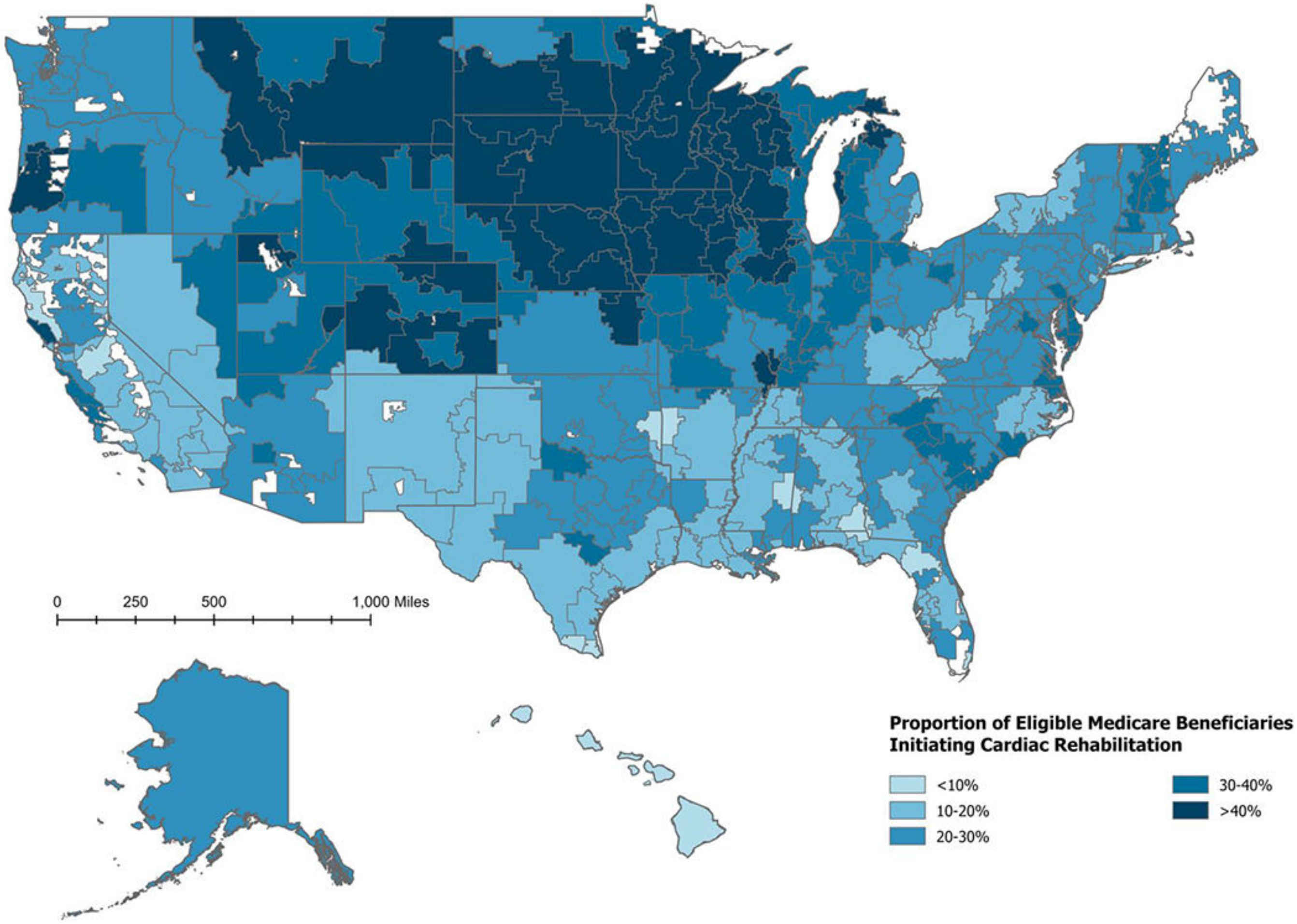


Figure 1. Proportion of Medicare Beneficiaries Participating in Cardiac Rehabilitation

Proportion of Medicare beneficiaries eligible for cardiac rehabilitation (CR) participating in CR programs by hospital referral region (n=306) from 2014 to 2018. Eligibility diagnoses include acute myocardial infarction, percutaneous coronary intervention, coronary artery bypass surgery**,** cardiac valve surgery and heart or heart-lung transplant. CR initiation in each hospital referral region was adjusted for age, gender, race/ethnicity, eligibility diagnosis, socioeconomic status, and comorbidities.

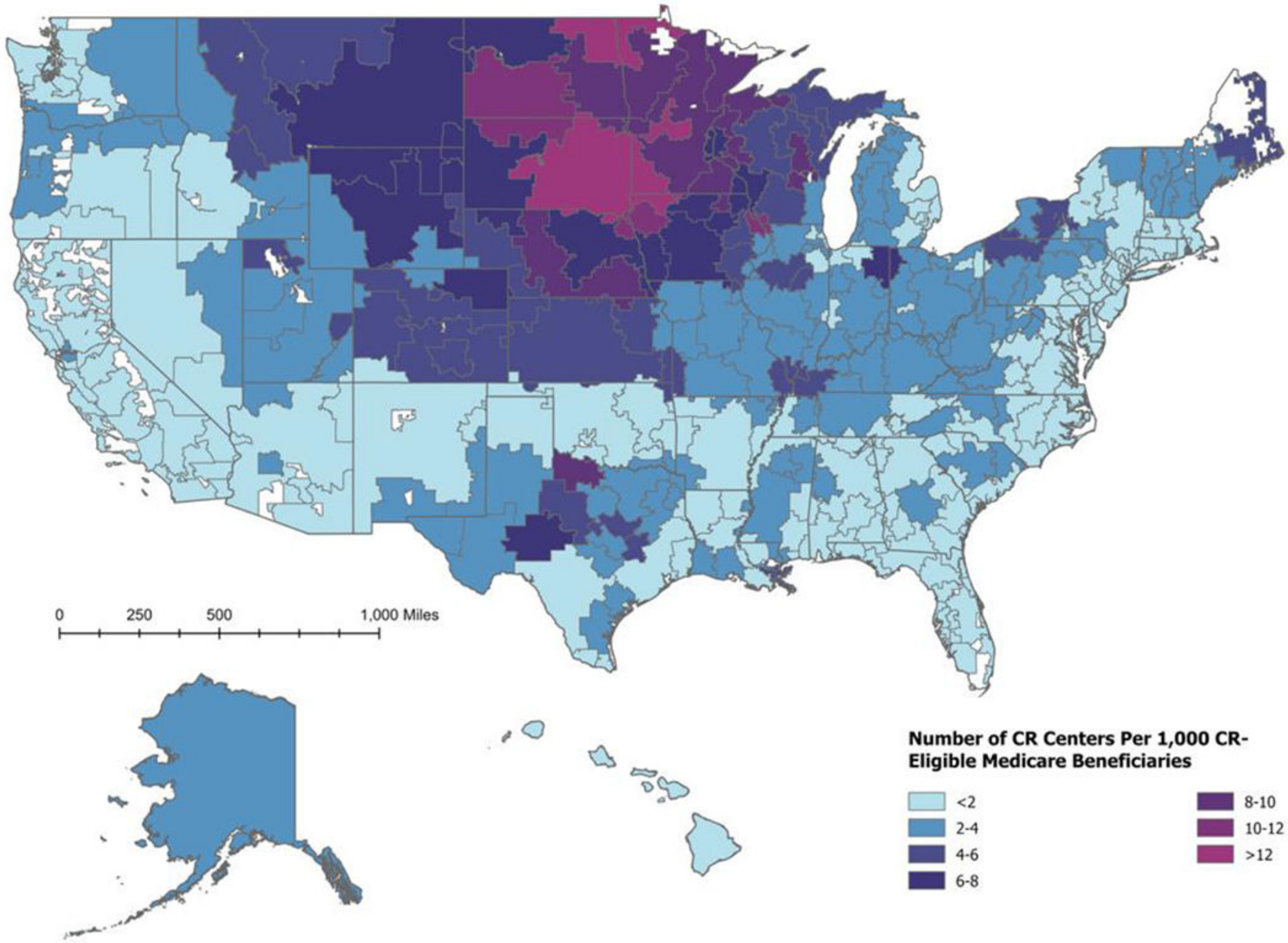


Figure 2. Density of Cardiac Rehabilitation Programs by Hospital Referral Region

Density of cardiac rehabilitation programs per 1000 cardiac rehabilitation-eligible Medicare beneficiaries by hospital referral region (n=306) from 2014-2018 **(2A)**. The proportion of cardiac rehabilitation (CR)-eligible Medicare beneficiaries in each hospital referral region was plotted by CR center density **(B)** and average distance to the nearest CR center **(C)**. Figures were adjusted for age, gender, race/ethnicity, eligibility diagnosis, socioeconomic status and comorbidities. **B** was also adjusted for average distance to the nearest CR center, and **C** was also adjusted for CR center density per 1000 CR-eligible Medicare beneficiaries.

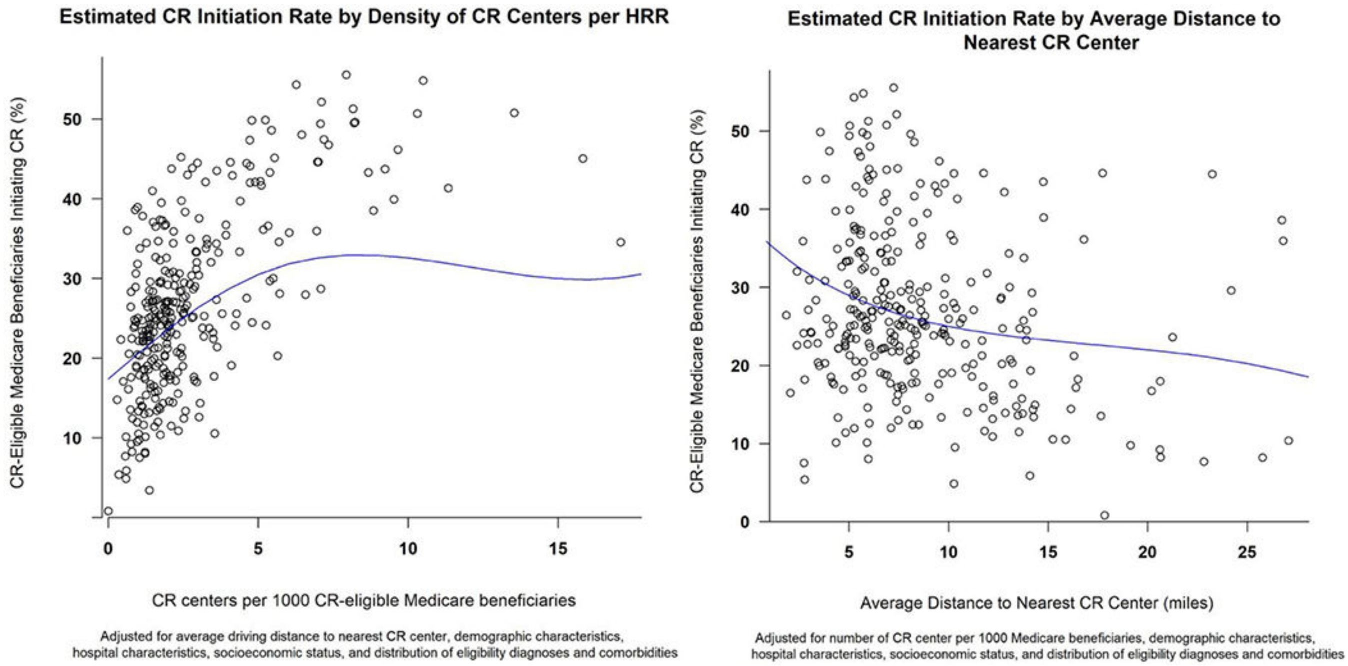
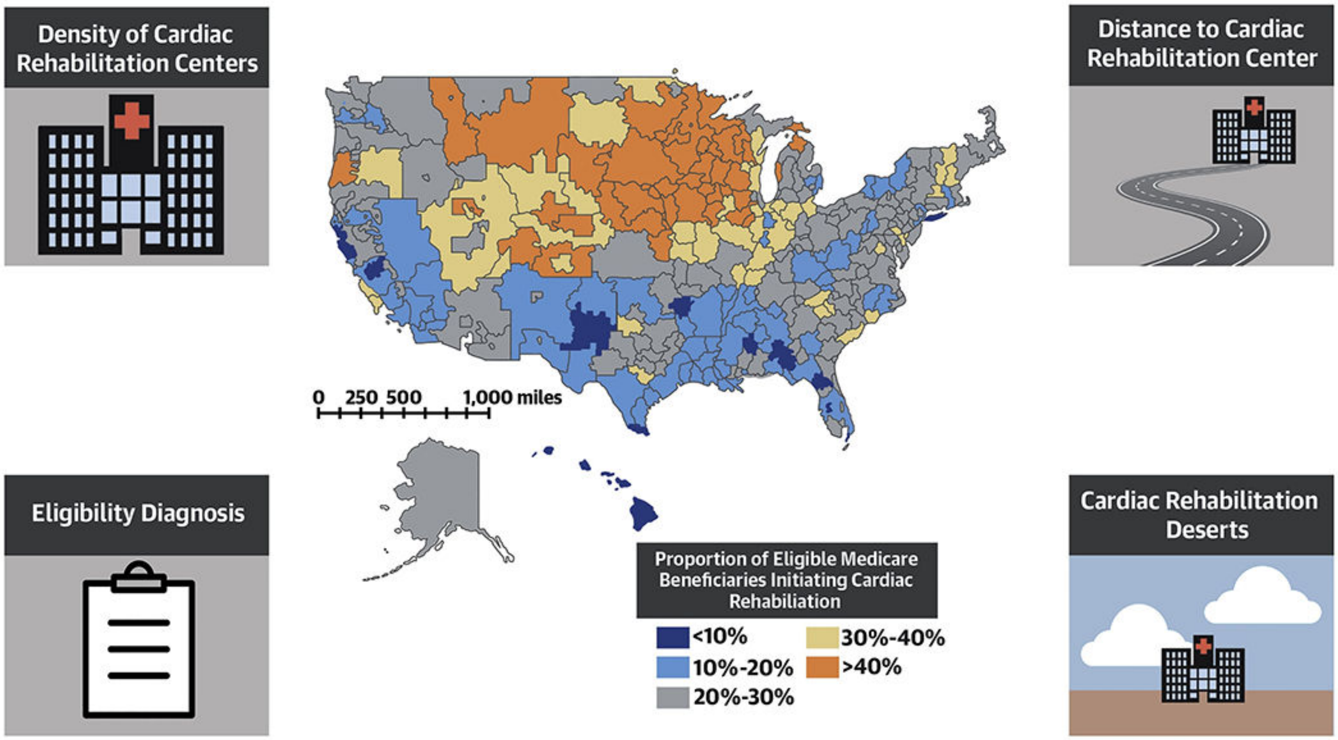


Figure 3. Cardiac Rehabilitation Deserts

Cardiac rehabilitation (CR) deserts (N=39), or counties with disproportionately high average patient loads per CR center. Patient load was estimated using Centers for Disease Control and Prevention coronary heart disease hospitalization rates and total population ≥65 for each county. CR deserts were defined as statistically significant county hot spots with a CI of 95% or above by Getis-Ord Gi* analysis.



Central Illustration. Major Causes of Geographic Variation in Cardiac Rehabilitation Initiation

Regional variation in cardiac rehabilitation (CR) in the United States is caused by several factors, including density of CR centers, distance to the nearest CR center, eligibility diagnosis, and the presence of CR deserts, where CR access is disproportionately low.

Table 1:

Cohort characteristics and proportion of eligible Medicare beneficiaries initiating cardiac rehabilitation from 2014-2017.

Characteristic	Number of patients (%)	Number initiating CR (%)	Odds ratio[a] for CR initiation [95% CI]	Median wait times in days (Q1, Q3)	Mean number of sessions amongst attendees (±SD)	β Estimate[a,b] for Δ Number of Sessions [95% CI]
All	**1,269,147**	**314,997 (25)**	--	39 (24, 63)	26.1 ± 12.4	--
Demographic Traits						
Age						
65-74 (Ref)	574,998 (45)	185,637 (32)	Referent	38 (23, 60)	26.1 ± 12.4	Referent
75-84	452,728 (36)	108,720 (24)	0.73 [0.73, 0.74]	41 (25, 66)	26.4 ± 12.3	0.34 [0.25, 0.44]
≥85	241,421 (19)	20,640 (9)	0.31 [0.31, 0.32]	42 (24, 71)	24.4 ± 13.0	−1.36 [−1.53, −1.18]
Sex						
Men (Ref)	700,489 (55)	207,572 (30)	Referent	38 (23, 60)	26.7 ± 12.2	Referent
Women	568,658 (45)	107,425 (19)	0.87 [0.86, 0.88]	42 (25, 69)	24.9 ± 12.8	−1.35 [−1.44, −1.26]
Race/Ethnicity						
White (Ref)	1,126,076 (89)	292,009 (26)	Referent	39 (23, 62)	26.1 ± 12.4	Referent
Black	78,428 (6)	10,463 (13)	0.85 [0.82, 0.87]	48 (29, 77)	25.8 ± 12.8	0.14 [−0.11, 0.38]
Asian	16,211 (1)	2,193 (14)	0.89 [0.85, 0.94]	47 (30, 75)	25.2 ± 12.7	−0.07 [−0.59, 0.44]
Hispanic	15,085 (1)	1,231 (8)	0.74 [0.70, 0.78]	46 (27, 77)	23.3 ± 13.4	−0.77 [−1.45, −0.08]
North American Native	6,767 (0.5)	1,000 (15)	0.60 [0.54, 0.68]	36 (22, 59)	22.4 ± 14.3	−2.44 [−3.20, −1.68]
Other/Unknown	26,580 (2)	8,101 (30)	1.11 [1.07, 1.15]	40 (24, 62)	27.0 ± 12.1	0.50 [0.23, 0.77]
Census Division						
New England (Ref)	76,111 (6)	20,130 (26)	Referent	48 (31, 76)	25.9 ± 12.0	Referent
Middle Atlantic	172,972 (14)	34,203 (20)	0.63 [0.55, 0.71]	50 (33, 77)	26.6 ± 11.9	−0.10 [−0.58, 0.38]
East North Central	212,804 (17)	66,457 (31)	1.06 [0.95, 1.18]	37 (23, 59)	26.0 ± 12.2	−0.40 [−0.88, 0.08]
West North Central	94,207 (7)	36,640 (39)	1.19 [1.04, 1.35]	23 (13, 41)	24.9 ± 12.3	−0.86 [−1.39, −0.33]
South Atlantic	272,564 (21)	63,613 (23)	0.74 [0.66, 0.81]	45 (29, 69)	26.8 ± 12.3	−0.14 [−0.60, 0.31]
East South Central	96,012 (8)	18,880 (20)	0.69 [0.60, 0.79]	39 (25, 61)	26.3 ± 12.6	−0.29 [−0.87, 0.28]
West South Central	140,717 (11)	28,184 (20)	0.56 [0.49, 0.64]	33 (21, 55)	27.4 ± 13.5	−0.11 [−0.66, 0.44]
Mountain	71,487 (6)	20,625 (29)	0.71 [0.63, 0.81]	31 (17, 52)	24.5 ± 12.8	−1.57 [−2.13, −1.01]

Characteristic	Number of patients (%)	Number initiating CR (%)	Odds ratio[a] for CR initiation [95% CI]	Median wait times in days (Q1, Q3)	Mean number of sessions amongst attendees (±SD)	β Estimate[a,b] for Δ Number of Sessions [95% CI]
Pacific	132,273 (10)	26,265 (20)	0.55 [0.48, 0.62]	44 (28, 69)	25.7 ± 12.9	−0.59 [−1.14, −0.04]
Eligibility diagnosis						
AMI (Ref)	523,113 (41)	37,176 (7)	Referent	49 (27, 88)	24.9 ± 13.1	Referent
PCI	394,272 (31)	112,928 (29)	3.70 [3.59, 3.82]	31 (18, 55)	25.5 ± 13.0	0.48 [0.33, 0.64]
CABG	161,305 (13)	86,579 (54)	10.69 [10.26, 11.14]	41 (28, 60)	27.2 ± 11.8	1.97 [1.80, 2.14]
Cardiac Valve Surgery	189,901 (15)	78,182 (41)	7.55 [7.23, 7.89]	43 (28, 65)	26.4 ± 11.8	1.63 [1.46, 1.80]
Heart or Heart-Lung Transplant	556 (0.05)	132 (24)	2.96 [1.89, 4.63]	63 (32, 104)	27.7 ± 11.4	3.10 [1.03, 5.17]
Comorbidities						
Elixhauser score						
0-2 Comorbidities (Ref)	456,871 (36)	143,941 (32)	Referent	35 (21, 56)	26.5 ± 12.2	Referent
3 Comorbidities	238,656 (19)	65,786 (28)	0.82 [0.81, 0.83]	40 (24, 63)	26.3 ± 12.3	−0.32 [−0.43, −0.20]
4-5 Comorbidities	342,113 (27)	75,896 (22)	0.67 [0.66, 0.68]	43 (27, 69)	25.8 ± 12.6	−0.82 [−0.93, −0.71]
6+ Comorbidities	231,507 (18)	29,374 (13)	0.43 [0.43, 0.44]	49 (30, 81)	24.5 ± 13.1	−2.01 [−2.17, −1.86]
Socioeconomic Traits						
Medicaid Eligibility						
No Medicaid (Ref)	1,092,979 (86)	301,456 (28)	Referent	39 (23, 62)	26.3 ± 12.3	Referent
Medicaid	176,168 (14)	13,541 (8)	0.38 [0.37, 0.39]	45 (27, 75)	20.8 ± 13.8	−4.78 [−5.00, −4.57]
Median Income [c]						
Q1: 10,113 – 44,750 (Ref)	323,026 (25)	62,497 (19)	Referent	40 (25, 64)	26.0 ± 12.6	Referent
Q2: 44,751 – 51,824	320,883 (25)	84,035 (26)	1.29 [1.24, 1.34]	37 (22, 59)	26.2 ± 12.7	0.35 [0.20, 0.51]
Q3: 51,825 – 60,610	310,467 (25)	82,579 (27)	1.28 [1.23, 1.34]	37 (22, 60)	25.9 ± 12.3	0.28 [0.12, 0.44]
Q4: 60,611 – 125,635	314,771 (25)	85,886 (27)	1.36 [1.29, 1.44]	42 (26, 68)	26.3 ± 12.2	0.21 [0.02, 0.41]
Social Deprivation Index [c]						
Q1: 0-22 (Ref)	317,636 (25)	99,344 (31)	Referent	37 (21, 60)	25.9 ± 12.2	Referent
Q2: 23-45	323,894 (26)	87,104 (27)	0.96 [0.92, 0.99]	38 (23, 61)	25.9 ± 12.5	−0.17 [−0.31, −0.03]
Q3: 46-69	317,821 (25)	73,913 (23)	0.93 [0.89, 0.96]	40 (25, 63)	26.1 ± 12.5	−0.11 [−0.27, 0.05]
Q4: 70+	309,796 (24)	54,636 (18)	0.90 [0.85, 0.95]	43 (27, 69)	26.7 ± 12.7	0.24 [0.05, 0.43]

Characteristic	Number of patients (%)	Number initiating CR (%)	Odds ratio[a] for CR initiation [95% CI]	Median wait times in days (Q1, Q3)	Mean number of sessions amongst attendees (±SD)	β Estimate[a,b] for Δ Number of Sessions [95% CI]
Hospital Characteristics [d]						
Presence of CR Program						
No CR Program (Ref)	194,971 (15)	30,309 (16)	Referent	43 (27, 68)	26.1 ± 12.6	Referent
CR Program	1,074,176 (85)	284,688 (27)	2.21 [1.93, 2.53]	39 (23, 62)	26.1 ± 12.4	0.63 [0.09, 1.16]
Bed Size						
<50 Beds (Ref)	32,724 (3)	3,851 (12)	Referent	35 (21, 61)	26.4 ± 14.4	Referent
50-199 Beds	264,973 (21)	52,969 (20)	1.35 [1.19, 1.54]	34 (19, 58)	25.7 ± 12.9	0.05 [−0.75, 0.84]
200-399 Beds	448,993 (35)	111,149 (25)	1.34 [1.16, 1.55]	39 (23, 62)	26.0 ± 12.4	0.11 [−0.71, 0.93]
400+ Beds	522,457 (41)	147,028 (28)	1.18 [1.02, 1.38]	41 (26, 65)	26.3 ± 12.2	−0.03 [−0.88, 0.81]
Hospital Ownership						
Not-for-Profit (Ref)	954,191 (75)	252,486 (26)	Referent	39 (24, 63)	26.0 ± 12.3	Referent
For-Profit	201,344 (16)	37,631 (19)	0.64 [0.57, 0.72]	37 (23, 61)	26.5 ± 13.2	0.04 [−0.36, 0.45]
Government	113,612 (9)	24,880 (22)	0.86 [0.76, 0.98]	40 (25, 64)	26.2 ± 12.5	−0.06 [−0.55, 0.43]
Critical Access Status						
Not Critical Access (Ref)	1,251,415 (99)	312,991 (25)	Referent	39 (24, 63)	26.1 ± 12.4	Referent
Critical Access	17,732 (1)	2,006 (11)	0.92 [0.77, 1.08]	35 (21, 61)	25.2 ± 13.0	−1.28 [−2.28, −0.28]
Cardiac Cath Lab						
No Cath Lab (Ref)	198,234 (16)	31,255 (16)	Referent	43 (27, 69)	26.1 ± 12.6	Referent
Cath Lab	1,070,913 (84)	283,742 (27)	0.69 [0.60, 0.79]	39 (23, 62)	26.1 ± 12.4	−0.79 [−1.39, −0.18]
Cardiac Surgery Program						
No Cardiac Surgery (Ref)	271,899 (21)	43,299 (16)	Referent	42 (25, 68)	25.8 ± 12.7	Referent
Cardiac Surgery	997,248 (79)	271,698 (27)	0.88 [0.78, 0.99]	39 (23, 62)	26.1 ± 12.4	0.25 [−0.22, 0.73]

CABG, coronary artery bypass grafting; AMI, acute myocardial infarction; PCI, percutaneous coronary intervention.

[a]Presented odds ratios and effect sizes are derived from multivariable logistic and linear regression models adjusted for all listed covariates.

[b]Beta estimate from multivariable linear regression model representing the average difference in number of sessions attended when compared to the referent group.

[c]Measured at the county level.

[d]Characteristics of hospital where qualifying diagnosis/procedure occurred.

Table 2:

Geographic variation in cardiac rehabilitation (CR) initiation[a] among Census Divisions.

Census Division	Adjusted proportion of CR initiation[b] [95% CI]	Median wait times in days (Q1, Q3)	Density of CR programs per 1000 CR-eligible Medicare beneficiaries	Median distance (miles) to nearest CR center for residents age >65 (Q1, Q3)
New England	28.8% [23.8, 33.7]	48 (30, 76)	1.79	5.53 (5.04, 8.08)
Middle Atlantic	26.0% [23.8, 28.2]	50 (33, 78)	1.46	5.92 (4.24, 7.56)
East North Central	31.5% [29.2, 33.7]	37 (22, 60)	2.71	5.58 (4.40, 7.23)
West North Central	37.0% [34.0, 39.9]	22 (13, 41)	5.89	6.88 (5.71, 8.64)
South Atlantic	23.9% [22.2, 25.6]	45 (29, 70)	1.51	7.55 (5.78, 9.75)
East South Central	21.1% [19.0, 23.2]	39 (25, 61)	1.86	9.81 (7.62, 13.06)
West South Central	21.0% [18.7, 23.2]	34 (20, 56)	2.19	10.83 (8.21, 13.90)
Mountain	33.6% [29.6, 37.6]	31 (17, 52)	2.73	11.68 (5.69, 16.80)
Pacific	21.3% [19.0, 23.7]	44 (28, 70)	1.44	7.46 (6.12, 13.41)

States in Census Divisions: New England: CT, MA, ME, NH, RI, VT; Middle Atlantic: NJ, NY, PA; East North Central: IN, IL, MI, OH, WI; West North Central: IA, KS, MN, MO, NE, ND, SD; South Atlantic: DE, DC, FL, GA, MD, NC, SC, VA, WV; East South Central: AL, KY, MS, TN; West South Central: AR, LA, OK, TX; Mountain: AZ, CO, ID, MT, NM, NV, UT WY; Pacific: AK, CA, HI, OR, WA

[a]Eligibility diagnoses include acute myocardial infarction, percutaneous coronary intervention, coronary artery bypass surgery, cardiac valve surgery, and heart or heart-lung transplant.

[b]Negative binomial model aggregates Medicare beneficiaries at the Hospital Referral Region level and is additionally adjusted for age, sex, race/ethnicity, eligibility diagnosis, comorbidities, Medicaid eligibility, median county income, county-level social deprivation index, and hospital characteristics listed in Table 1.