

Growth in Percutaneous Coronary Intervention Capacity Relative to Population and Disease Prevalence

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Background—The access to and growth of percutaneous coronary intervention (PCI) has not been fully explored with regard to geographic equity and need. Economic factors and timely access to primary PCI provide the impetus for growth in PCI centers, and this is balanced by volume standards and the benefits of regionalized care.

Methods and Results—Geospatial and statistical analyses were used to model capacity, growth, and access of PCI hospitals relative to population density and myocardial infarction (MI) prevalence at the state level. Longitudinal data were obtained for 2003–2011 from the American Hospital Association, the U.S. Census, and the Centers for Disease Control and Prevention (CDC) with geographical modeling to map PCI locations. The number of PCI centers has grown 21.2% over the last 8 years, with 39% of all hospitals having interventional cardiology capabilities. During the same time, the US population has grown 8.3%, from 217 million to 235 million, and MI prevalence rates have decreased from 4.0% to 3.7%. The most densely concentrated states have a ratio of 8.1 to 12.1 PCI facilities per million of population with significant variability in both MI prevalence and average distance between PCI facilities.

Conclusions—Over the last decade, the growth rate for PCI centers is $1.5\times$ that of the population growth, while MI prevalence is decreasing. This has created geographic imbalances and access barriers with excess PCI centers relative to need in some regions and inadequate access in others. (*J Am Heart Assoc.* 2013;2:e000370 doi: 10.1161/JAHA.113.000370)

Key Words: acute coronary syndrome • cardiovascular disease prevalence • percutaneous coronary intervention

Percutaneous coronary intervention (PCI) is the preferred treatment strategy for ST-elevation myocardial infarction (STEMI).^{1–4} Economic factors as well as the focus on timely access for PCI in STEMI have contributed to significant growth in the number of cardiac catheterization laboratories during the last decade. Interventional cardiology remains one of the most profitable hospital service lines, and based on current economic incentives, it is likely the growth of PCI centers will continue.⁵

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This paper was handled independently by Hani Jneid, MD, as a Guest Editor.

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Received June 17, 2013; accepted September 12, 2013.

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In contrast, data supporting regionalization and volume standards provide arguments to control growth. Regional STEMI networks are designed to increase efficiency, equity, quality (through volume standards), and responsiveness of STEMI care.^{6–14} The benefits of PCI for STEMI are time-dependent and current American College of Cardiology (ACC)/American Heart Association (AHA)/Society of Cardiovascular Angiography and Interventions (SCAI) guidelines recommend a goal door-to-balloon time <90 minutes for PCI centers and ≤ 120 minutes for patients transferred from non-PCI centers.^{2,3} In a study using 2000–2001 census and hospital data, Nallamothu et al¹⁵ modeled distance to PCI facilities and found that 79% of the US population live within a 60-minute drive to the nearest PCI facility. In the last decade significant changes have occurred in both disease prevalence and PCI availability.

The ACC/AHA/SCAI have adopted standards for minimally acceptable patient procedure volumes to be performed by cardiologists and hospitals.^{3,16} Based on increased availability of appropriate team skills and resources, volume standards theoretically improve economies of scale, value, and outcomes for patients and society.^{2,3,16–19} An increase in PCI centers may lower the average volume per facility,²⁰ and may result in PCI centers which fall below volume standards

recommended by the professional societies. A comprehensive assessment of the growth and existing capacity of PCI centers in relation to disease prevalence and population density is currently not available. Therefore, our goal was to determine the rate of growth and capacity of PCI centers, and then apply geographical modeling to assess PCI capacity and growth in all 50 states in the United States. Specifically, we sought to address which areas of the country had the highest and lowest concentrations of PCI centers, adjusted for geographical distances, myocardial infarction (MI) disease prevalence, and population density. On the basis of our findings, we then discuss policy and practice implications for STEMI care.

Methods

Descriptive and geospatial analyses were used to compute PCI center capacity relative to population density within each state. PCI center density was defined as the relative number of PCI centers per capita. City-level population and census data were used to describe access to PCI, while hospital-level data were obtained from multiple sources to model capacity across the United States. We conducted descriptive statistical analyses such as proportions and ratios within a geographical information system, to provide accurate measures for distance traveled, proportions of populations served, and other indicators. We generated national maps to visually present the information collected.

Similar to the Cardiac Accessibility and Remoteness Index for Australia (ARIA) study, we measured access in terms of physical distances calculated from the central point of each population area to the nearest PCI-capable facility.²¹ This distance provides roughly the number of straight-distance miles between patient populations and PCI facilities and is useful since it standardizes distances in miles for access comparisons, versus converting into units of measures such as driving time which has the potential for significant variability.

To estimate the growth and capacity of PCI centers in the United States, we relied on the American Hospital Association annual survey²² and the American Hospital Directory database of US hospitals to identify all hospitals with PCI capabilities. The American Hospital Association database has been used extensively to provide reliable estimates for multiple cardiovascular studies on volumes and outcomes.^{23,24} We extracted all demographic (eg, address, services performed) and volume indicators (eg, number of PCI procedures) for all hospitals that indicated they had interventional PCI capabilities. Both data sources provide demographic profiles for facilities, and produced similar counts. We then geographically analyzed trends and patterns for all hospitals with PCI capabilities from 2003–2011. Specifically, to assess the significance of the temporal trend in PCI center growth, we used a general least square regression model with $\alpha=0.05$.

To assess geographical access, we modeled locations of these PCI centers using a geographical information system in order to create PCI population density maps to explore regional variations in capacity. We relied on aggregated state-wide measures for population and area estimates, based on U.S. Census estimates, and we used the Centers for Disease Control and Prevention's National Cardiovascular Disease Surveillance database²⁵ to determine prevalence rates of acute MI. We used acute MI (defined as both STEMI and non-STEMI) since STEMI data alone are generally not available. We also used geographical information systems to model distance in miles between population centers and the nearest PCI center. We used Microsoft MapPoint for distance arcs and geographical presentation.

Results

There are currently 4050 nonfederal short-term acute care hospitals in the United States (defined as hospitals focused on short-term injury and illness, which excludes from analysis all federal, psychiatric, long-term care, and other specialty hospitals). Of these acute facilities, 1975 (48.7%) hospitals operate cardiac catheterization labs and 1571 hospitals are capable of performing PCI (39% of all hospitals). Annually, there has been an increase from 1750 cardiac cath labs (CCL) in 2003 to just over 1975 in 2011, a growth rate of nearly 1.6% annually, or 12.9% over the 8-year period. This equates to 226 new CCLs during this period, or roughly 2.3 new facilities per month. Approximately 80% of these same hospitals have PCI capability, which has grown from 1296 PCI centers to 1571 centers (a 21.2% growth rate) during this same time period (Figure 1). This trend is statistically significant ($R^2=0.973$, $P<0.001$), and this rate of growth indicates that hospitals continue to offer more—not less—interventional care.

During this same period, the estimated total US adult (18+) population has grown only 8.3%, from 217 million in 2003 to

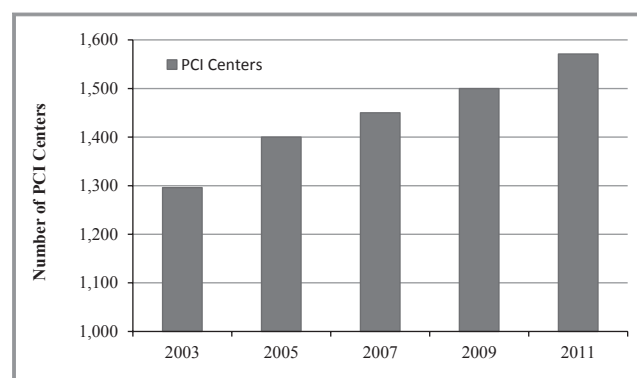


Figure 1. Growth in US PCI facilities, 2003–2011. PCI indicates percutaneous coronary intervention; US, United States.

235 million today.²⁶ Similarly, prevalence rates for both CAD and acute MI have declined—CAD from 4.3% national median in 2003 to 3.7% in 2009, and acute MI from 4.0% to 3.7% since 2003.²⁵ Therefore, PCI centers have grown at a faster pace than the population at a time when disease prevalence has decreased. To understand the geographic balance of this growth, we geospatially analyzed the current PCI-capable hospitals. There is a higher concentration of facilities in the eastern half of the United States than in the west. The west central region from North Dakota through Idaho and south through Nevada to New Mexico is particularly less concentrated with PCI-capable hospitals.

Less populated states require fewer PCI centers. To assess the density of PCI centers by state, we mapped the total number of PCI facilities divided by the state’s total population (1 million capita as the denominator) (Figure 2). We evenly divided the states into 3 tertiles, based on this density ratio (8.1 to 12.1, 5.9 to 8.0, 3.2 to 5.8 PCI facilities for every million in population). The median of all states was 6.95 and the mean was 6.98 PCI facilities for every million. The state with the fewest facilities per capita is Vermont, followed by Minnesota, Wyoming, New York, and California. Vermont and Minnesota in particular have advanced STEMI systems of care

in place, which may contribute to the low density, although we did not attempt to statistically analyze those relationships here. Many of the states in the highest tertile have few PCI centers, but also small populations relatively, so the density of PCI per capita is actually high in places like North Dakota, South Dakota, Montana, Nebraska, West Virginia, and Maine. These data are summarized by state for MI prevalence and PCI center density (Table).

As Figure 2 demonstrates, the United States can be divided into several clusters. The south-central region (Louisiana, Mississippi, and Alabama) and the north-central region (Montana and North Dakota) have the highest concentration of facilities, significantly higher than the median. The only two states outside of this region that have similarly high ratios are Maine and New Hampshire. The rest of the northeast and eastern coasts hover below the median ratio, while states on the west coast (California, Oregon, and Washington) are below the median.

The prevalence of acute MI is also an important factor in determining the need for PCI facilities. Some states (such as Nevada), have higher prevalence rates than the median with few PCI facilities and very long distances between patients and facilities. Figure 3 presents the distance arcs overlaid on

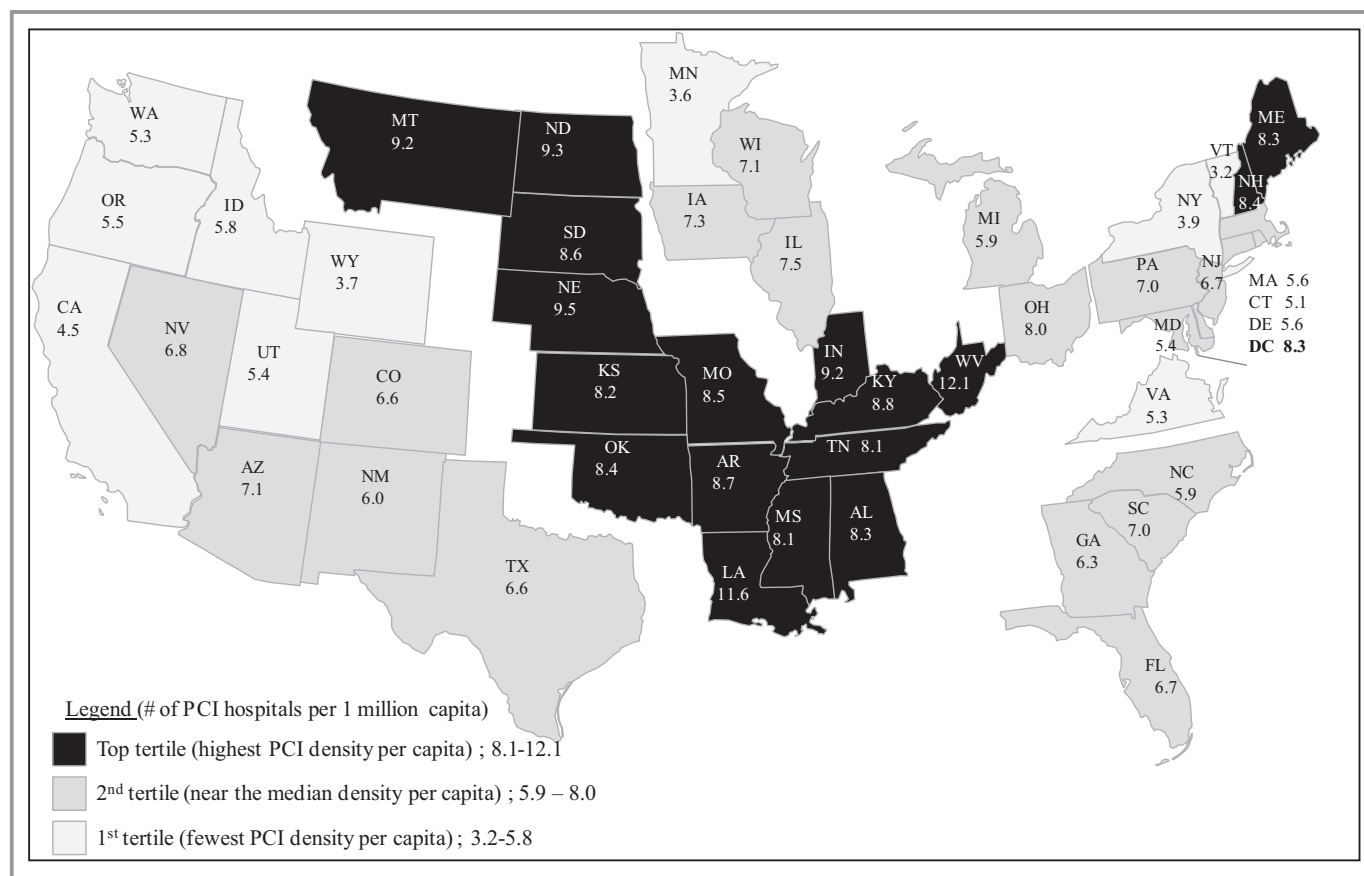


Figure 2. Percutaneous coronary intervention (PCI) facilities, density map, PCI centers per 1 MM capita.

Table. State PCI Ratios

State	MI Prevalence Rate (Per 1000 Persons)	PCI Centers Per 1000 Square Mile	PCI Centers Per 1 MM Capita
AK	42	0.6	5.7
AL	49	74.4	8.3
AR	47	47.0	8.7
AZ	42	41.2	7.1
CA	34	100.8	4.5
CO	32	31.7	6.6
CT	28	324.7	5.1
DC	21	7316.4	8.3
DE	39	200.9	5.6
FL	42	188.6	6.7
GA	40	104.3	6.3
HI	26	82.3	6.9
IA	37	39.1	7.3
ID	36	10.8	5.8
IL	36	167.5	7.5
IN	47	162.0	9.2
KS	35	28.0	8.2
KY	56	94.0	8.8
LA	42	100.3	11.6
MA	37	350.6	5.6
MD	34	249.9	5.4
ME	39	31.1	8.3
MI	41	61.0	5.9
MN	28	21.9	3.6
MO	40	73.2	8.5
MS	46	49.6	8.1
MT	37	6.1	9.2
NC	42	102.2	5.9
ND	35	8.5	9.3
NE	31	22.0	9.5
NH	33	117.6	8.3
NJ	34	665.0	6.7
NM	34	9.9	6.0
NV	51	16.3	6.8
NY	32	139.3	3.9
OH	40	205.2	8.0
OK	49	44.4	8.4
OR	38	21.3	5.5
PA	39	191.1	7.0
RI	36	388.3	5.7

Continued

Table. Continued

State	MI Prevalence Rate (Per 1000 Persons)	PCI Centers Per 1000 Square Mile	PCI Centers Per 1 MM Capita
SC	42	99.9	7.0
SD	36	9.1	8.6
TN	43	121.0	8.1
TX	34	60.7	6.6
UT	32	17.7	5.4
VA	37	98.2	5.3
VT	33	20.8	3.2
WA	30	49.1	5.3
WI	32	61.1	7.1
WV	56	90.8	12.1
WY	32	2.0	3.7

MI indicates myocardial infarction; PCI, percutaneous coronary intervention.

the MI prevalence rates delineated in the CDC National Cardiovascular Disease Surveillance database. The 4 distance arcs on the map represent the greatest potential access difficulties in terms of transport times and would appear to most benefit from a regionalized transfer system involving air ambulances. The distances with the highest priority are those mapped over darker states, which signifies greater acute MI prevalence rates (such as Nevada).

Discussion

The growth of PCI centers has been substantial over the last decade, and has created significant over-capacity in certain regions and geographical imbalances in others. We specifically mapped PCI access and capacity in relation to MI prevalence and the density of PCI centers per population. Since time and distance are important factors in improving the diagnoses and treatment of STEMI, we felt geospatial analyses would help to depict the current situation visually and improve our understanding of the national picture. Overall, the number of PCI centers has grown 21% over the last 8 years. This is not surprising given the economic incentives and effectiveness of PCI in patients with acute coronary syndromes.¹⁻⁵ Cardiac procedures are generally profitable for hospitals, so investments in the capital assets and technology required to operate interventional cardiac labs are rewarded. However, our data indicate PCI centers are not evenly distributed throughout the United States. Overall the eastern half of the United States has more PCI capacity, although lower density per population than the central region. The north- and south-central regions have high numbers of PCI centers in proportion to the population, which correlates

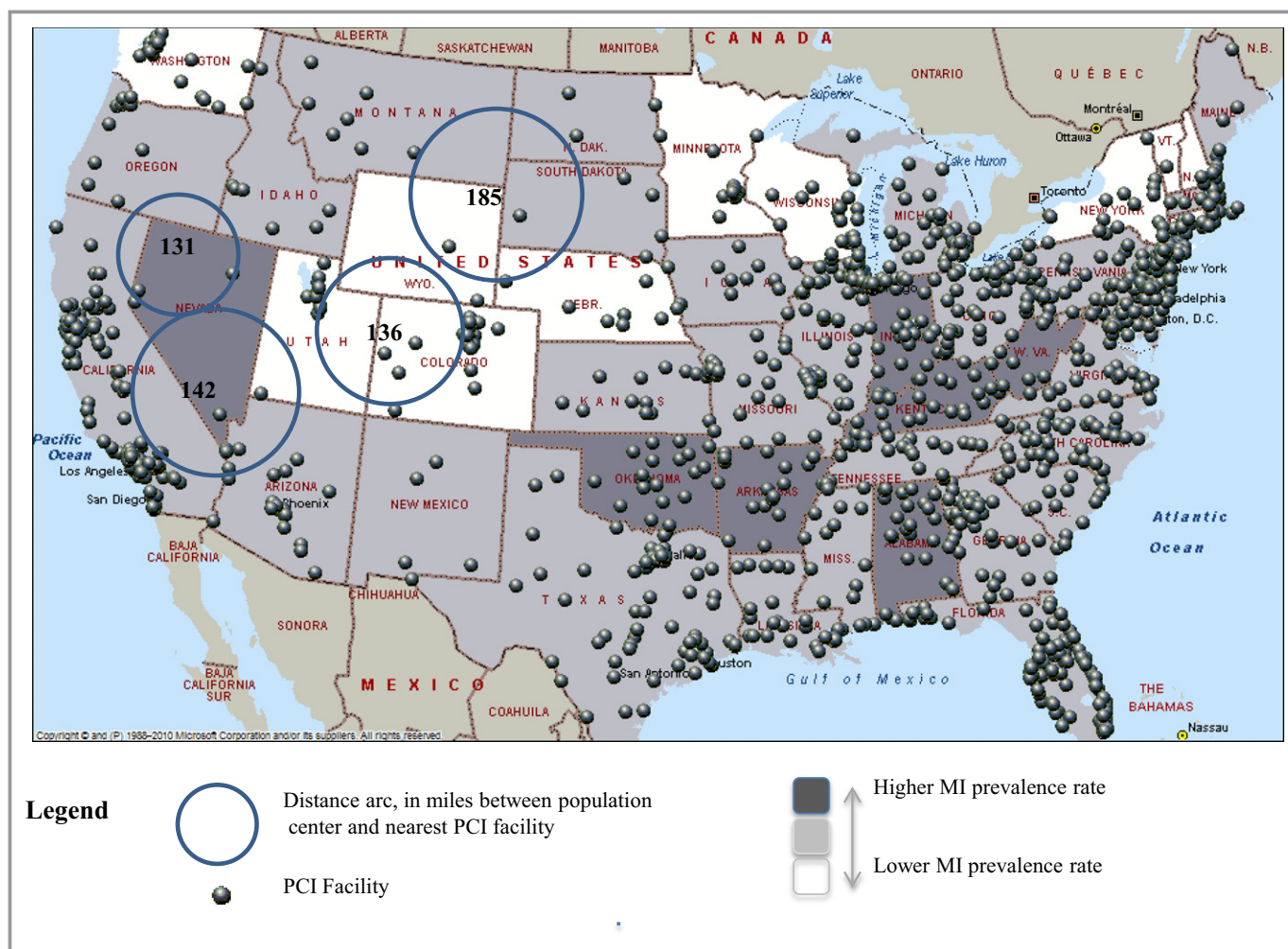


Figure 3. Geographic distance to nearest PCI-capable hospital (overlaid on state AMI prevalence rates). AMI indicates acute myocardial infarction; PCI, percutaneous coronary intervention.

with a higher disease prevalence rate in those regions. However, certain states, such as Nevada, have a high disease prevalence rate with only an average number of PCI centers in proportion to the population.

We used a secondary measure of PCI density adjusted not by population but by the number of PCI facilities per 100 000 square miles. This ratio is better for communities that have wide geographic area and small populations, such as rural frontier states. This measures access or availability specifically, since distance often equates to time, and time-to-treatment is important in STEMI and other cardiovascular emergencies.^{2–4,9,27} States with very long distances between PCI capable hospitals and the population served create logistical access issues for the EMS agencies which are also more likely to be volunteer in rural areas (Figure 3). Based on PCI hospitals per 100 000 square miles, Arkansas (0.60), Wyoming (2.04), and Montana (6.12) are the states with the lowest density, while the District of Columbia, with its relatively small area, has a ratio of PCI facilities per

100 000 square miles that is 10 times higher than that of the state with the second highest PCI per capita density. This of course may be impacted at times by communities in neighboring states. Generally, if the number of miles between a facility and the patient is >60 miles, the likelihood of meeting current time-to-treatment guidelines is difficult unless sophisticated integrated transfer systems are in place involving air transportation.^{11–13} In most parts of the heavily concentrated areas, such as the northeast, the average distance is 10 miles, except for the most northern parts of New York and Maine. The eastern part of Montana has the highest overall distance to travel, with 185 miles between certain locations and the nearest facility, which is in a neighboring state. Similarly, parts of Nevada, Oregon, Utah, and the western edge of Oklahoma have distances ranging between 120 and 140 miles and frequently require crossing state lines. Access to PCI facilities in those states likely will require a great deal of systems of care integration including the use of air ambulances.

This study has several limitations. While distance is related to transport time, it is not always equivalent. Traffic, time of day, available air versus ground transport, and other factors may influence transport time and need to be taken into account in the design of regional STEMI centers. We used acute MI to determine prevalence because specific STEMI data are difficult to determine. The prevalence of NSTEMI has increased so the impact of STEMI is likely underestimated in our study.²⁸ This study does not assess the quality of the care received at these PCI centers, or determine whether the available PCI centers are meeting the needs of the populations served. Unfortunately it is difficult to obtain comprehensive data on the volume of procedures performed by each of these PCI centers beyond procedures reimbursed by Medicare. Ideally, future studies would incorporate a measure of procedures, or demand, at each center to geographically map which centers are meeting volume criteria and which are not in order to more accurately determine if there are regions of the country with too many PCI centers. Additionally, this would allow for a clearer understanding of the effects of regionalization policies on PCI center volume. Finally, although PCI is clearly the preferred therapy for acute coronary syndromes, the appropriateness of elective PCI procedures is another factor which is difficult to consider in this analysis.

One of the difficulties in interpreting the PCI facility volume is that different sources of data lead to slightly different volume counts. For example, a previous study of nationwide PCI capacity in 2006 reported that 36% (1695) of US hospitals have primary PCI capability.²⁹ One of the primary aims of that study was to compare 2 different data sources for measuring PCI capability. One source was an inpatient procedural volume database (Healthcare Cost Utilization Project); the other was the self-reported American Hospital Association summary data. The Concannon study confirmed that both sources were strongly correlated and that the American Hospital Association data only would be a reliable source of information for future estimations of PCI access. Therefore in the current study, we relied on the American Hospital Association data exclusively to estimate growth patterns over the last 8 years of available data. The PCI hospital counts in this study vary slightly from the Concannon study since our analyses rely exclusively on the American Hospital Association data, versus those that billed for 4 or more PCI procedures during any given year. An example of a mismatch of growth and need was reported in Michigan.²⁰ The addition of 12 hospitals without on-site cardiac surgery led to increased access for 4.8% of the population. Three of these centers increased access to 4.3% of the population while the remaining 9 centers increased access by only 0.5%, likely decreasing volume to nearby PCI centers with on-site cardiac surgery.²⁰

This study has several policy implications. First, it is clear from this analysis that the distribution of PCI centers does not necessarily correspond with MI prevalence or population density in the United States, suggesting that some areas may need more PCI capacity while other areas may need less PCI capacity. More research is needed to determine how many PCI centers with low procedure volumes do not meet ACC/AHA/SCAI guidelines.^{2,3} Regionalization policies may need to be reexamined for areas with high numbers of PCI centers in proportion to disease prevalence and population density. Additionally, for rural areas of the United States with large geographic distances between PCI centers, regional STEMI networks and coordination of care between EMS and hospitals may need to be developed or strengthened. In some cases this may involve coordination of care between organizations across state lines to facilitate the most efficient STEMI care.

In conclusion, this study shows that the number of PCI centers in the United States has grown substantially over the last 8 years. However, the growth of these centers has not necessarily reflected the disease prevalence or population density throughout the United States. The geographic imbalances seen in this study need to be examined further to understand if these imbalances are creating geographical access barriers (due to distance) for some patients, or if they are lowering PCI procedure volumes in other areas (due to too many PCI centers relative to local need). Distance creates access problems without an integrated regionalized transfer system capable of meeting the 120-minute window. On the other hand, densely concentrated areas create inefficiency for the overall community since required facility volume standards cannot be met for necessary procedures if this growth rate continues. Finding the right balance where time-to-treatment is minimized and volume standards are maximized is a challenge that policy makers and hospital administrators should confront. The findings in this study suggest that both of these problems may be occurring simultaneously, and both have the potential to contribute to suboptimal care of STEMI patients.

Disclosures

None.

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