Evidence of Systematic Duplication by New Percutaneous Coronary Intervention Programs

Thomas W. Concannon, PhD; Jason Nelson, MPH; David M. Kent, MD; John L. Griffith, PhD

Background—Evidence suggests that recent and projected future investments in percutaneous coronary intervention (PCI) programs at US hospitals fail to increase access to timely reperfusion for patients with ST-segment elevation myocardial infarction.

Methods and Results—We set out to estimate the annual number and costs of new PCI programs in US hospitals from 2004 to 2008 and identify the characteristics of hospitals, neighborhoods, and states where new PCI programs have been introduced. We estimated a discrete-time hazard model to measure the influence of these characteristics on the decision of a hospital to introduce a new PCI program. In 2008, 1739 US hospitals were capable of performing PCI, a relative increase of 16.5% (251 hospitals) over 2004. The percentage of the US population with projected access to timely PCI grew by 1.8%. New PCI programs were more likely to be introduced in areas that already had a PCI program with more competition for market share, near populations with higher rates of private insurance, in states that had weak or no regulation of new cardiac catheterization laboratories, and in wealthier and larger hospitals.

Conclusions—Our data show that new PCI programs were systematically duplicative of existing programs and did not help patients gain access to timely PCI. The total cost of recent US investments in new PCI programs is large and of questionable value for patients. (Circ Cardiovasc Qual Outcomes. 2013;06:400-408.)

Key Words: angioplasty ■ catheterization ■ mapping ■ percutaneous coronary intervention ■ ST-segment elevation myocardial infarction

For patients with ST-segment elevation myocardial infarction (STEMI), primary percutaneous coronary intervention (PCI) improves survival and reduces serious complications if it can be delivered with minimal reperfusion-related delay. Although ≈80% of the US population lives within driving distance of timely PCI, less than half of the patients with STEMI get access to PCI in an emergency. There is widespread debate about the potential of voluntary STEMI regional plans to improve use of PCI among patients with STEMI and a variety of such voluntary agreements have been implemented and evaluated. As a backdrop to regionalization, individual hospitals have acted unilaterally by introducing new PCI at a robust pace in every state since 2001. In recent work, we have shown that historical and projected future independent investments in new PCI programs do not help patients gain timely access to the procedure. Others have shown that emergent and elective use of PCI has remained flat since 2001, suggesting that new programs are not helping to increase access to the procedure. This is the first analysis using longitudinal data to assess whether new PCI programs duplicate existing ones and identify the factors associated with the decision of a hospital to introduce a new PCI program.

Methods

In previous work, we validated use of American Hospital Association (AHA) Annual Survey data for use in creating annual inventories of the number of US hospitals that can perform PCI emergently. For this analysis, we combined annual AHA survey data from 2004 through 2008 with 2000 Census data and with American Health Planning Association (AHPA) annual directories of State Certificate of Need Programs from 2004 to 2008 to (1) estimate change over time in the number of PCI programs offered by US hospitals, (2) estimate change over time in population access to timely PCI, and (3) assess the hospital-, neighborhood-, and state-level factors that are associated with the introduction of a PCI program where one did not exist before.

Study Data

To meet our inclusion criteria, a hospital had to provide acute care to the US adult (≥18 years of age) population. Government facilities, hospital units within an institution, psychiatric and drug dependency hospitals, long-term care facilities, and children’s hospitals were excluded from the analysis. We began our analysis in 2004 to coincide with the first year the AHA survey asked hospitals to specify if a laboratory was used for adult interventional care. Before 2004, hospitals were asked about ownership of cardiac catheterization laboratories of any type, not distinguishing interventional from diagnostic laboratories. We judged hospitals as having PCI capability before 2004 only if they reported both owning a catheterization laboratory and offering angioplasty as a service. Hospital-level characteristics were collected from the AHA survey. Independent variables included measures of hospital size, inpatient...
WHAT IS KNOWN

- Hospital percutaneous coronary intervention programs have grown rapidly since 2001, without clear evidence of improved patient access to the procedure.

WHAT THE STUDY ADDS

- From 2004 to 2008, 251 new PCI programs added $2 to $4 billion in new costs to the US healthcare system without improving access to PCI.
- During this period, hospitals were more likely to adopt PCI if they were larger, they operated in more competitive markets, and PCI was already offered in the same market.
- Hospitals facing stronger Certificate of Need regulation were 40% less likely each year to adopt PCI.
- The methods of this study could be used to evaluate the drivers and outcomes of change in other medical technologies in US hospitals.

The competitive environment was estimated with 2 measures: a market share variable to indicate the presence of another PCI laboratory for time to develop a program and report its appearance to the AHA.

The CON variable was selected variables from the Census within uniquely estimated neighbors. Several skewed variable distributions were transformed on the computed tomography, single-photon emission computed tomography, and multislice computed tomography, (3) positron emission tomography, and (2) multislice computed tomography.

Several skewed variable distributions were transformed on the natural log scale.

Area and state characteristics were estimated by aggregating selected variables from the Census within uniquely estimated neighborhood boundaries for every hospital in the United States, as described below (Model 2). Census variables included area estimates of sex, age, race, income, and foreign birth. To facilitate comparison, these variables were standardized to a z-distribution; we report effects that are associated with 1 SD change in each of these demographic characteristics.

State-by-state Certificate of Need (CON) policy data were collected from American Health Planning Association annual directories. We specified states with no program as the reference category against states with programs that did not require review of catheterization laboratories (class 2) and states with programs that did require review of catheterization laboratories (class 3). The CON variable was allowed to vary over time and was lagged 2 years to account for time to develop a program and report its appearance to the AHA.

The competitive environment was estimated with 2 measures: a design variable to indicate the presence of another PCI laboratory in the neighborhood surrounding the hospital (duplication of PCI); and a modified Herfindahl–Hirschman Index, a measure combining the market shares of all the sellers in a marketplace (concentration of PCI). We modeled Herfindahl–Hirschman Index as the sum of squares of the share of each hospital of the total adjusted average daily hospital census within a neighborhood.

Model 1: The Number and Total Costs of New PCI Programs

We used AHA data to identify hospitals in all 50 states and the District of Columbia that were capable of performing emergent PCI each year from 2004 to 2008 (Table 1). All hospitals were uniquely identified through their AHA identification number and located within a geographic information system using latitude and longitude coordinates. Using longitudinal data, we identified new programs at individual hospitals. We imputed missing observations of PCI capability during the study period by carrying the last observation forward if PCI capability was in place at any time during 1994 to 2007 and by carrying the most recent observation backward if a hospital reported no PCI capability during 2004 to 2008. To track change over time in the number of PCI programs, we estimated both relative and absolute change in the number of new PCI programs for each year after 2004, taking into account hospitals that were lost to follow-up because of closures, mergers, and survey nonresponse.

We updated a previously developed framework for estimating the construction, medical equipment and operations, and costs of introducing a new PCI program to 2008 US dollars, using the National Income and Product Accounts Gross Domestic Product deflator. The introduction of a new PCI program may be made in hospitals with and without existing cardiac surgery programs, but access to onsite or nearby (via transfer) cardiac surgery backup is recommended or required in most places. Hospitals without onsite or nearby backup surgery may, therefore, have to invest in that service along with the opening of a new PCI program. To estimate lower and upper bounds for the cost of new PCI programs to the US healthcare system over our study period, we multiplied the unit cost for a new program developed with and without existing surgical backup.

Model 2: Access to PCI

To assess change in access to PCI, we estimated annual proportions of the population >18 years of age living within a 60-minute drive of every PCI hospital (Table 1). To do this, we followed methods described in previous work on drive times to US hospitals. We defined a neighborhood specific to every hospital in the United States, defined as the area covered by a 60-minute drive time to the hospital from neighboring census tracts. Drive times were estimated using road network and speed limit data from Environmental Systems Research Institute, Inc’s (ESRI) ArcGIS StreetMap data set with the Network Analyst extension. Extra time was added to account for dispatch of the emergency medical services vehicle (1.4 minutes for urban and suburban tracts and 2.9 minutes for rural tracts), time from emergency medical services depot to scene (total time was multiplied by a constant of 1.6, 1.5, or 1.4 for urban, suburban, or rural tracts, respectively) and time spent on scene (13.5 minutes for urban and suburban tracts and 15.1 minutes for rural tracts). These constants were derived in a meta-analysis of empirically determined prehospital care times for trauma.

The population of a census tract was considered to have access to PCI if its centroid, the geographic location that represents the mean center of a polygon, lay within the neighborhood boundary of the hospital. Populations in tracts covered by multiple hospitals were counted once to avoid duplication. We estimated annual and total change in the potential reach of PCI programs across the United States, the 4 Census Regions, 50 states, and the District of Columbia.

Model 3: Hospital-, Neighborhood-, and State-Level Factors Associated With New PCI Programs

To assess the hospital-, neighborhood-, and state-level factors that are associated with the decision to adopt PCI, we estimated a series...
<table>
<thead>
<tr>
<th>Region</th>
<th>Statistic</th>
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<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
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<td>4614</td>
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<td>4629</td>
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<td>1603</td>
<td>1673</td>
<td>1697</td>
<td>1739</td>
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<td>35.8</td>
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<td>Hospitals with new PCI (N)</td>
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<td>84</td>
<td>69</td>
<td>52</td>
<td>46</td>
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<td>Annual growth (%)</td>
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<td>5.5</td>
<td>4.3</td>
<td>3.1</td>
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<td></td>
<td>Total growth (%)</td>
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<td>---</td>
<td>16.5</td>
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<td>Pop. within 1 hour drive to any hospital (%)</td>
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<td>94.6</td>
<td>94.4</td>
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<td>Pop. within 1 hour drive to PCI hospital (%)</td>
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<td>80.3</td>
<td>80.5</td>
<td>80.9</td>
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<td>Pop. with PCI as closest hospital within 1 hour drive (%)</td>
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<td>54.2</td>
<td>55.5</td>
<td>56.5</td>
<td>57.4</td>
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<td>25.9 (21.4, 34.2)</td>
<td>25.7 (21.3, 34.1)</td>
<td>25.7 (21.3, 34)</td>
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<td>420</td>
<td>433</td>
<td>437</td>
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<td>28.9</td>
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<td>Annual growth (%)</td>
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<td>4.0</td>
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<td>Pop. within 1 hour drive to any hospital (%)</td>
<td>95.4</td>
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<td>95.5</td>
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<td>Pop. with PCI as closest hospital within 1 hour drive (%)</td>
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<td>59.4</td>
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<td>Median (IQR) estimated elapsed time from 911 call to closest PCI hospital within 1 hour (mins.)</td>
<td>25.6 (21.1, 34.8)</td>
<td>25.4 (21.3, 34.1)</td>
<td>25.3 (20.9, 34)</td>
<td>25.3 (20.9, 33.9)</td>
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<td>602</td>
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<td>40.1</td>
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<td>8</td>
<td>9</td>
<td>7</td>
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<tr>
<td></td>
<td>Annual growth (%)</td>
<td>---</td>
<td>4.8</td>
<td>3.3</td>
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<td></td>
<td>Total growth (%)</td>
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<td>---</td>
<td>15.2</td>
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<td></td>
<td>Pop. within 1 hour drive to any hospital (%)</td>
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<td>97.9</td>
<td>97.9</td>
<td>97.9</td>
<td>97.8</td>
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<td>87.4</td>
<td>87.5</td>
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<td>Pop. with PCI as closest hospital within 1 hour drive (%)</td>
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<td>48.0</td>
<td>50.1</td>
<td>52.5</td>
<td>55.2</td>
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<td>Median (IQR) estimated elapsed time from 911 call to closest PCI hospital within 1 hour (mins.)</td>
<td>25.6 (20.8, 34.4)</td>
<td>25.2 (20.6, 34.1)</td>
<td>24.8 (20.3, 34)</td>
<td>24.7 (20.3, 34)</td>
<td>24.7 (20.2, 33.9)</td>
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<td>South</td>
<td>Eligible hospitals (N)</td>
<td>1774</td>
<td>1794</td>
<td>1820</td>
<td>1807</td>
<td>1816</td>
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<td>Hospitals with PCI (N)</td>
<td>595</td>
<td>613</td>
<td>655</td>
<td>664</td>
<td>675</td>
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<td>Hospitals with PCI (%)</td>
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<td>36.0</td>
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<td>Annual growth (%)</td>
<td>---</td>
<td>4.9</td>
<td>6.4</td>
<td>3.1</td>
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(Continued)
of discrete-time hazard models on hospitals that did and did not adopt PCI after 2004 (Table 2). Hospital-level covariates were included in the models and time-varying effects were accounted for. In the event that a new hospital entered the data set, current year values were used in place of nonexistent lagged data. Univariate models were used to identify candidate covariates from AHA-, Census-, and American Health Planning Association-derived variables. Independent variables that were moderately strongly associated ($P < 0.10$) with new PCI adoption in univariate models were selected for inclusion in the initial multivariate models.

We estimated 2 models with alternative measures of neighborhood competition. In model 3.1, we measured duplication of PCI with a time-varying and 2-year lagged indicator for the presence of another PCI program within the neighborhood of the hospital (Duplication Model). In model 3.2, we measured concentration of market share with a time-varying and 2-year lagged modified Herfindahl–Hirschman Index (Concentration Model). We assumed proportional hazards and estimated 3 sequential equations for each model, with hospital covariates alone, hospital + neighborhood covariates, and hospital + neighborhood + state covariates. We assessed deviations from the assumption of proportional hazards by graphing the hazard function over time and by testing the significance of independent variable interactions with time. All statistical analyses were completed with SAS version 9.2 (SAS Institute, Cary, NC).

## Results

Table 1 reveals substantial growth in the number of hospitals that introduced a new PCI program between 2004 and 2008. In 2004, 1524 (33.5%) of 4544 acute care hospitals in the 50 states and the District of Columbia were capable of performing adult interventional PCI. Four years later, 1739 (37.1%) of 4686 acute care hospitals were capable of performing the procedure. After accounting for hospital closures and mergers, this increase represented 251 new interventional PCI programs and a 16.5% total growth in the number of PCI-capable hospitals. Both the relative and absolute annual rates of growth in PCI capability declined over time from a high of 5.5% relative growth in 2005 (absolute increase of 84 hospitals or 1.8%) to a low of 2.7% in 2008 (absolute increase of 46 or 1.0%) and averaged 3.9% relative annual growth over the 4 years.

Our estimate of the 2008 per-program cost of introducing a new PCI program was $7.8 million if backup for surgical revascularization already existed onsite and $16.4 million if it did not. The total cost for 251 new PCI programs under these 2 scenarios would, therefore, be $1.9 billion if all 251 hospitals already had cardiac surgery programs in place and $4.1 billion if none of them did. This calculation suggests the total cost of new PCI programs during our study period was $2 to $4 billion.

Table 2 shows that access to PCI grew by a small margin over the period, from 79.1% of the population in 2004 to 80.9% in 2008. Access to PCI was highest in the Northeast (87.4% in 2004 and 88.5% in 2008) and lowest in the South (74.4% in 2004 and 76.8% in 2008). Access to PCI also varied by state. More than 90% of the population had 60-minutes access to PCI in 2008, including California (91.1%), Connecticut (90.1%), Florida (88.8%), and New York (87.6%). We estimated that approximately 14% of the population had 60-minutes access to PCI in 2008.
Table 2. Factors Associated with New PCI Programs (Model 3)

<table>
<thead>
<tr>
<th></th>
<th>Model 3.1 Duplication (Obs = 11,293)</th>
<th>Model 3.2 Concentration (Obs = 10,919)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR (95% CI)</td>
<td>HR (95% CI)</td>
</tr>
<tr>
<td>Year</td>
<td>0.83 (0.74–0.94)**</td>
<td>0.85 (0.75–0.95)**</td>
</tr>
<tr>
<td>Hospital-level</td>
<td></td>
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</tbody>
</table>
| Ratio of outpatient-to-
  inpatient revenue†           | 0.78 (0.67–0.93)**                   | 0.70 (0.59–0.85)**                    |
| Total hospital expenses§ †‡  | 2.13 (1.70–2.64)**                   | 2.17 (1.73–2.68)**                    |
| FTE physicians and
dentists, n†† | 0.91 (0.83–0.99)*                    | 0.91 (0.84–0.99)*                     |
| Hospital beds, n†           | 2.48 (2.13–2.89)**                   | 2.37 (2.03–2.77)**                    |
| Total surgical operations, n†‡ | 1.07 (0.96–1.22)                     | 1.07 (0.95–1.22)                      |
| ER visits, n††              | 1.06 (0.98–1.17)                     | 1.09 (0.98–1.23)                      |
| Other outpatient visits, n†‡ | 0.89 (0.84–0.95)**                   | 0.90 (0.85–0.97)**                    |
| Accreditation (Ref: low)     | 1.50 (1.05–2.19)*                    | 1.39 (0.97–2.04)                      |
| Part of a hospital system (yes vs no) | 1.19 (0.87–1.66)                  | 1.16 (0.85–1.61)                      |
| Teaching hospital (Ref: no)  | 0.73 (0.51–1.03)                     | 0.75 (0.52–1.06)                      |
| Ownership of advanced
technology (Ref: low)  | 1.40 (1.03–1.92)*                    | 1.41 (1.03–1.94)*                     |
| Neighborhood-level           |                                      |                                       |
| PCI hospital in neighborhood (Ref: no) | 1.48 (1.05–2.10)*                | ...                                   |
| HH§                          | ...                                  | 0.80 (0.65–0.98)*                     |
| Foreign born, percentage of neighborhood§ | 0.71 (0.59–0.84)**              | 0.70 (0.58–0.83)**                    |
| >65 y of age, percentage of neighborhood§ | 0.71 (0.57–0.88)**              | 0.71 (0.57–0.88)**                    |
| <2×FPL, percentage of neighborhood§ | 1.10 (0.92–1.29)                  | 1.09 (0.91–1.23)                      |
| Male, percentage of neighborhood§ | 0.94 (0.76–1.12)                  | 0.95 (0.76–1.14)                      |
| Non-Hispanic White, percentage of neighborhood§ | 0.96 (0.76–1.23)              | 0.95 (0.75–1.22)                      |
| State-level                  |                                      |                                       |
| CON (Ref: States with no-CON program) | 1.19 (0.81–1.74)                | 1.21 (0.83–1.77)                      |
| CON State without cath
laboratory review              | 1.60 (0.42–0.85)**                   | 0.57 (0.40–0.82)**                    |
| CON State with cath
laboratory review              | 1.19 (0.81–1.74)                    | 1.21 (0.83–1.77)                      |

All variables are time varying and lagged 2 years except census data and new hospital indicator. Demographic variables come from the 2000 US Census. CI indicates confidence interval; CON, Certificate of Need; ER, emergency room; FPL, Federal poverty level; FTE, full-time equivalent; HH, Herfindahl–Hirschman Index; HR, hazard ratio; and PCI, percutaneous coronary intervention.

*P value <0.05, **P value <0.01, ***P value <0.001.
† Log transformed; hazard is expressed as the association of doubling in the predictor in the original scale.
‡ Standardized to 100 beds.
§ Normalized to Z score.

(93.6%), Delaware (91.7%), Florida (91.6%), Maryland (92.5%), Massachusetts (94.6%), New Jersey (96.0%), Rhode Island (96.3%), and Washington, DC (100.0%). Less than 50% of the population in 7 states had 60-minute access to the procedure in 2008, including North Dakota (48.9%), South Dakota (44.6%), Vermont (38.3%), West Virginia (46.4%), Alaska (44.3%), Montana (45.3%), and Wyoming (30.5%). Mississippi had the biggest percentage change in access to PCI during the 5-year period, growing from 42.0% of the population in 2004 to 59.2% in 2008, representing a relative rate increase of 40.9%. This growth was achieved through the expansion of PCI to 14 hospitals that did not offer the procedure in 2004, a relative increase of 140%.

Of populations living within a maximum of 60 minutes from a PCI-capable hospital, the estimated elapsed time from 9-1-1 call to arrival at the closest of those hospitals decreased from a national median of 26.1 minutes in 2004 (interquartile range, 21.5–34.6) to 25.7 minutes in 2008 (interquartile range, 21.2–33.8), a drop of 24 seconds for the typical patient. The median drive time also varied by location in 2004, from a low of 21 to 23 minutes in Illinois, Washington, DC, and Wyoming to a high of 33 to 35 minutes in Missouri and Vermont. This measure did not change by >2 minutes during the 4-year follow-up in any state except Missouri, where it dropped from 33 to 29 minutes.

Model 3 (Table 2) demonstrated that several factors are associated with the decision to introduce a new PCI program. Hospitals were more likely to adopt PCI if they were newly opened, larger (ie, had higher expenditures and more hospital beds), and owned other expensive medical technology, and if PCI was already offered in the neighborhood. By far, the strongest influence on PCI adoption was its inclusion as part of an entirely new hospital, which increased the hazard 13-fold in a year. Hospitals with twice the annual average expenditure of other non-PCI hospitals had a >2-fold increased risk of adoption each year. Similarly, having twice the average number of beds than other non-PCI hospitals increased the annual risk of adoption 2-fold. Ownership of other expensive medical technology was associated with a 40% increased yearly risk of adopting PCI, and the previous existence of another PCI laboratory in the neighborhood increased the chances of adoption annually by 50%. The Figure depicts duplicated and newly served census tracts within 60 minutes of new PCI programs after 2004.

Hospitals were less likely to adopt PCI if they had a higher volume of outpatient services (higher outpatient/inpatient revenue and more nonemergency outpatient visits) and if they operated in a more concentrated market, in a neighborhood with a higher percentage of foreign-born and elderly residents, and in a state that maintained laws requiring automatic review of new catheterization laboratories. Having twice the average ratio of outpatient-to-inpatient revenue of other non-PCI hospitals had a >2-fold increased risk of adoption each year. Similarly, having twice the average number of visits reduced the risk by 10%. One SD above the mean percentage of foreign-born or elderly residents in the neighborhood of a hospital was associated with a decreased risk of adoption each year by 30%. One SD above mean Herfindahl–Hirschman Index reduced the annual risk of adoption by 20%. Teaching hospitals trended toward a lower risk of adopting PCI. Emergency room and surgical volumes were not associated.
with adoption of PCI, nor were area sex, income, or percentage of the population that was of non-Hispanic white race.

Operating in a state that maintained CON with automatic review of catheterization laboratories reduced the risk of PCI adoption by $\approx 40\%$. We ran subanalyses to explore this effect in more detail. We interacted CON and our duplication measure to see whether this effect was modified in areas without duplication, but the interaction was nonsignificant. We also assessed whether CON had any effect on times to treatment and access to care. The median estimated elapsed time from 911 to closest hospital declined by 0.3 minutes in no-CON states, by 0.3 minutes in CON states without automatic review, and by 0.8 minutes in CON states with automatic review. These elapsed time reductions amount to 18, 18, and 48 seconds, respectively, not long enough to change outcomes in patients with STEMI. However, we did find a potentially substantial effect of CON with automatic review on access to PCI. In no-CON states, access to PCI was extended to 1.5\% of the population, and the population living closest to PCI grew by 1.8\%. In states maintaining CON without automatic review, these figures were 2.2\% and 3.7\%, respectively.

In states maintaining CON with automatic review, they were 2.0\% and 8.3\%, respectively. Automatic review of catheterization laboratories seemed to result in a substantial increase to the population whose closest hospital could perform PCI.

**Discussion**

New PCI programs from 2004 to 2008 were systematically targeted to neighborhoods that were already served by existing programs, where competition for patients was high, and where they did not improve timely access for patients with STEMI. This finding elaborates on results from previous work on PCI program adoption\(^4\) and is consistent with the findings of a similar study on new cardiac surgery (coronary artery bypass graft) programs in the United States.\(^29\)

Hospital investments in PCI from 2004 to 2008 continued at a fast but slowing pace and have been expensive. During the study period, 251 new programs were introduced in the United States. In the last 2 years of our analysis, 52 and 46 new programs opened up, respectively. Every 50 new PCI programs costs an estimated $400 to $800 million, representing a sizable fixed cost that presumably redounds to increased

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**Figure.** Timely Access to Primary PCI from 251 New PCI Programs (2005-2008). This map illustrates 60-minute drive times surrounding 251 PCI programs at US hospitals that were newly introduced in 2005-2008. Black-shaded areas depict Census tracts that already had timely access to PCI in 2004 and for which the new program represented duplication. Grey-shaded areas depict Census tracts that did not have timely access to PCI in 2004 and for which the new PCI program represented new access. PCI indicates percutaneous coronary intervention.
insurance premiums, Medicare and Medicaid program costs, and patients’ out-of-pocket costs.

Our analysis shows that, on average, recent large investments in new PCI programs have been of low value for patient health because they did not lead to increased access or decreased treatment times. This is true not only for emergent PCI, the focus of our study, but also for elective PCI. If adoption through 2008 was meant to increase access to elective procedures, it has not succeeded: elective procedure rates have also been flat since at least 2001, when approximately fewer programs were in place. In this era of flat use, furthermore, systematic duplication can only reduce average hospital PCI volumes, a trend that could result in lower procedure quality and worse outcomes for patients with coronary artery disease. Hospital leaders and other stakeholders may hope that every new program will improve patient health, but quite the opposite may now be happening after introduction of PCI. Future introductions of this service should be assessed in this light.

There are important caveats to our findings. First, in regions with low baseline rates of access to the procedure in 2004, new programs in 2005 and beyond did improve access for patients with STEMI. This was the case in Mississippi, where access to the procedure was low in the baseline year and grew substantially after new PCI programs were introduced in the follow-up years. This may also have been the case in Missouri, where median projected transport times dropped by 4 minutes during the 4-year follow-up. This finding suggests that there may be a role for new PCI programs in underserved areas. Second, the pace of investment in new PCI programs is slowing over time. This suggests that there is an upper limit to the introduction of new PCI programs, and many regions of the United States may be approaching that limit.

At least 3 types of health system strategies are available around the United States to increase or maintain access to PCI for patients with STEMI and to minimize further duplication of existing PCI programs.

**Voluntary Interventions**

One class of strategies is the development of voluntary STEMI systems of care in local communities or in states. Known as STEMI Systems or STEMI Regional Plans, these may be defined as the systematic, iterative assessment and implementation of voluntary agreements between hospitals and emergency medical service systems that are designed to improve access to timely PCI. The largest such program in the United States, the North Carolina Reperfusion of Acute Myocardial Infarction in Carolina Emergency Departments (RACE) protocol, has successfully established interhospital agreements and has shown benefit for patients with coronary artery disease. Other plans have been implemented elsewhere and have shown promising results.

**Market-Based Interventions**

Market interventions such as payment reform may also help to address duplicative investments in PCI. Our results show that PCI investments are declining over time and may soon approach zero; therefore, the prime opportunity for targeted payment reform in this procedure may have passed as many as 10 years ago. There is evidence, however, of continued robust investment in PCI. If investments continue while use of the procedure remains flat, payment for these procedures may be reduced potentially to discourage future investments without reducing access to the procedure. Other candidates for this kind of analysis and reform may include interventions in robotics, lasers, nuclear medicine, and radiology.

**Regulatory Interventions**

Health systems interventions do not have to be voluntary or market based. Twenty-seven states in the United States are equipped with regulatory programs that can be used to compel a formal review of hospitals that wish to open new interventional catheterization laboratories. Our analysis showed that hospitals in states with robust CON programs were 40% less likely to introduce a new PCI program in any given year, suggesting that this policy mechanism can restrain diffusion of interventional catheterization laboratories. Of note, automatic review was the only nonvoluntary regulation that seemed to have an inhibitory effect on the introduction of new PCI programs. Other CON mechanisms, such as review of major medical equipment and capital expenditures above specified thresholds, seemed to have no effect. Further work is needed to establish whether this review mechanism works to restrain low-value diffusion in other medical technologies.

Our findings and those from studies of other technology-intensive medicine also suggest a new priority for health services research: an urgent need to track and assess the value obtained from health system investments in medical technology. Rapid change in medical technology has been a chief suspect in the escalation of US health expenditures for decades, but its value for patient and population health has been unclear. Health technology assessments and economic research have sought to address the role of technology in patient and national outcomes, respectively, but the relationship between change in medical technology over time and outcomes in hospitals, accountable care organizations, and other health systems is poorly understood. Better information and methods are needed to assist decision makers in these settings plan for capital investments, regional partnerships, service-line offerings, and other critical health services decisions. Recent advances in spatial statistics, data collection, and computing power have spurred novel methods to describe changes over time in the availability, use, outcomes, and costs of medical technology in cardiac care, imaging, cancer, surgery, trauma, burns, stroke, and other clinical domains. Health services researchers could make strides in our understanding of the effects of medical technology change in health systems, but a special focus is needed on this theme.

The AHA Annual Survey offers a comprehensive source of information on US hospitals and their capabilities, but it is subject to the usual limitations of self-reported survey data, including problems with nonresponse and misclassification. To address a small amount of missing data in our outcome variable, we used a widely accepted imputation procedure, allowing us to infer the nonexistence of PCI laboratories in hospitals that later reported not owning one and the continued existence of a PCI laboratory in hospitals that previously reported owning one. Some survey data may also suffer from misclassification. In past research, we
have validated AHA self-reports of PCI capability against hospital use data, finding a high rate of congruence between the 2 data sources.4

In summary, our data show that new PCI programs in the 4 years after 2004 were systematically duplicative of existing programs and did not help patients gain access to timely PCI. The total cost of recent US investments in new PCI programs is large and of questionable value for patients. We recommend 3 policy options that may help to improve patient access to timely PCI and restrain duplicative investments in PCI programs. We also recommend an emerging priority for health services research to track and assess medical technology change in health systems.

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Disclosures

Dr Concannon had primary responsibility for designing the research, overseeing data collection and analysis, interpreting model results, and writing the article. J. Nelson had responsibility for managing data collection and analysis, interpreting model results, and drafting the article. Drs Kent and Griffith had responsibility for data analysis, interpreting model results, and drafting the article. Dr Concannon was supported by the Agency for Healthcare Research and Quality or National Institutes of Health via Advancing Translational Sciences (UL1 TR000073), National Institutes of Health via National Center for Research Resources (UL1 RR025752) and the National Center for Biomedical Computing (UL1 RR024153). J. Nelson was supported by the Tufts Medical Center Research Institute, and通过 the Mayo Clinic ST-Elevation Myocardial Infarction (STEMI) Registry. Drs Kent and Griffith had responsibility for data analysis, interpreting model results, and drafting the article. Drs Kent and Griffith were supported by the Agency for Healthcare Research and Quality (K01 HS017726) and by the Tufts Medical Center Research Fund. J. Nelson was supported by the Tufts Medical Center Research Fund. Drs Kent and Griffith were supported by the National Center for Research Resources (UL1 RR025752) and the National Center for Advancing Translational Sciences (UL1 TR000073), National Institutes of Health. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Agency for Healthcare Research and Quality or National Institutes of Health.

References

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In the article by Concannon et al., “Evidence of Systematic Duplication by New Percutaneous Coronary Intervention Programs,” which appeared in the July 2013 issue of the journal (Circ Cardiovasc Qual Outcomes. 2013;6:400–408), on page 404, column 2, last paragraph, the opening sentence reads:

“Hospitals were less likely to adopt PCI if they had a higher volume of outpatient services (higher outpatient/inpatient revenue and more nonemergency outpatient visits) and if they operated in a more competitive market, in a neighborhood with a higher percentage of foreign-born and elderly residents, and in a state that maintained laws requiring automatic review of new catheterization laboratories.”

It should read:

“Hospitals were less likely to adopt PCI if they had a higher volume of outpatient services (higher outpatient/inpatient revenue and more nonemergency outpatient visits) and if they operated in a more concentrated market, in a neighborhood with a higher percentage of foreign-born and elderly residents, and in a state that maintained laws requiring automatic review of new catheterization laboratories.”

This has been corrected online. The authors regret the error.