Expansion of Invasive Cardiac Services in the United States

Jill R. Horwitz, PhD, JD, MPP; Austin Nichols, PhD, MPP; Brahmajee K. Nallamothu, MD, MPH; Comilla Sasson, MD, MS; Theodore J. Iwashyna, MD, PhD

Background—The number of hospitals offering invasive cardiac services (diagnostic angiography, percutaneous coronary intervention, and coronary artery bypass grafting) has expanded, yet national patterns of service diffusion and their effect on geographic access to care are unknown.

Methods and Results—This is a retrospective cohort study of all hospitals in fee-for-service Medicare, 1996 to 2008. Logistic regression identified the relationship between cardiac service adoption and the proportion of neighboring hospitals within 40 miles already offering the service. From 1996 to 2008, 397 hospitals began offering diagnostic angiography, 387 percutaneous coronary intervention, and 298 coronary artery bypass grafting (increasing the proportion with services by 3%, 11%, and 4%, respectively). This capacity increase led to little new geographic access to care; the population increase in geographic access to diagnostic angiography was 1 percentage point; percutaneous coronary intervention 5 percentage points, and coronary artery bypass grafting 4 percentage points. Controlling for hospital and market characteristics, a 10 percentage point increase in the proportion of nearby hospitals already offering the service increased the odds by 10% that a hospital would add diagnostic angiography (odds ratio, 1.102; 95% confidence interval, 1.018–1.193), increased the odds by 79% that it would add percutaneous coronary intervention (odds ratio, 1.794; 95% confidence interval, 1.288–2.498), and had no significant effect on adding coronary artery bypass grafting (odds ratio, 0.929; 95% confidence interval, 0.608–1.420).

Conclusions—Hospitals are most likely to introduce new invasive cardiac services when neighboring hospitals already offer such services. Increases in the number of hospitals offering invasive cardiac services have not led to corresponding increases in geographic access. (Circulation. 2013;128:803-810.)

Key Words: access to care ■ diffusion of innovation ■ geographic variation ■ percutaneous coronary intervention

Invasive cardiac services, including diagnostic angiography, percutaneous coronary interventions (PCIs), and coronary artery bypass grafting (CABG) are among the most common procedures performed in the United States.† Yet, because individual facilities may profitably perform diagnostic angiography, PCI, and CABG once adopted, many hospitals make substantial investments in invasive cardiac treatments despite the possibility that the new capacity will be used in marginal populations and may contribute to growth in medical spending.2 Consequently, numerous payers, including the Centers for Medicare and Medicaid Services, have attempted to control invasive cardiac treatment costs while maintaining access to care.

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Although previous research has shown a rapid growth of cardiac surgical services,3 it is unclear how and where the diffusion of invasive cardiac services is occurring in the United States. On the one hand, adding new services to underserved areas may well benefit cardiac patients, particularly if the new facilities make patients more likely to get superior treatment.4 Alternatively, hospitals may adopt new cardiac services for competitive reasons. For example, because the services are well reimbursed, attract patients, or attract doctors they are typically profitable for hospitals to adopt even in areas where the services are already widely available. This would contribute to decreased local expertise from lower volume within a market, increased variation in treatment and outcomes,5,6 or possible overuse without clear medical indication. Previous studies on cardiac technology diffusion have been limited either geographically or to a single service.7 Thus, we currently do not know to what extent the number of hospitals offering diagnostic and therapeutic invasive cardiac services has grown (and the interrelationship of those twin services), and whether that growth has reduced the number of patients without geographic access to care.

Accordingly, we examined the adoption patterns for 3 cardiovascular interventions—diagnostic angiography, PCI, and CABG—over 13 years. We determined (1) the number of

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hospitals offering new services, (2) whether a hospital’s new service offering depends on the service mix at neighboring hospitals, and (3) the effect of new adoption on geographic access to care.

Methods

Study Design
Consistent with previous research, we identified hospitals in the Medicare Provider Analysis and Review files (1996–2008) that billed Centers for Medicare and Medicaid Services for at least 5 procedures (diagnostic angiography, PCI, or CABG) annually to patients with documented acute myocardial infarction. Our sample included all general medical and surgical hospitals in the continental United States listed in the American Hospital Association (AHA) files, excluding hospitals that serve restricted populations such as Veterans and single-service hospitals that were unlikely to compete with nearby hospitals for patients. We matched the AHA and Medicare Provider Analysis and Review files by (1) provider numbers listed in AHA, (2) independent data crosswalks, and (3) geographic coordinates determined by geocoding in the data sets. Our final sample accounted for 96% of relevant admissions in the AHA and 98% of relevant beds in the Medicare Provider Analysis and Review data, leaving only 421 unmatched, individual hospitals in the AHA. For sensitivity testing we used ArcMap 10.0 to determine the driving distance from every hospital to the centroid of every Census tract that could be reached within 60 minutes.

Statistical Analysis

Diffusion of Services
We first identified hospitals offering (1) no invasive cardiac services, (2) diagnostic angiography only, (3) diagnostic angiography and PCI, or (4) diagnostic angiography, PCI, and CABG.

Geographic Clustering Analysis
We used logistic-regression models to determine whether the probability that a hospital first adopted a new service depended on the proportion of neighboring hospitals already offering that service. Our analysis was based on discrete-time hazard models such that hospitals that had made the transition, eg, from not offering PCI to offering PCI, were removed from the risk pool in subsequent years. In such a discrete-time hazard model, a logistic regression with a binary outcome such as ours, (1) all hospitals at risk of making a transition in a year, including those who have not yet made the transition and those who already did were included, and (2) all hospitals that have made the transition in a previous year were removed from the regression because they were not at risk.

We accounted for different levels of patient demand by including independent variables based on the US Census (1990, 2000) and the American Community Survey measuring the proportion of the population who were in the labor force, unemployed, college graduates, white (non-Hispanic), or poor. We defined the market as the census tracts with centroids within 40 miles of each hospital, based on boundaries from the 2000 US Census. Although medical guidelines regarding recommended time to treatment vary, an average of 40 miles is a reasonable approximation of the market for emergent invasive cardiac treatment based on the recommended maximum 1-hour travel time. We also accounted for hospital characteristics that may have influenced a hospital to offer a new service, including measures of hospital size, membership in a hospital system, teaching status, and ownership (nonprofit, for-profit, or government). In sensitivity testing, we controlled for Certificate of Need laws governing cardiac services to measure state regulatory regimes.

The key independent variable measured the proportion of nearby hospitals previously offering each service. Because we hoped to investigate the probability of new entrants into a service line, we tried to identify the region from which potential patients might reasonably come to the hospital, not those who actually use the hospital. For this purpose, we looked at all hospitals within 40 miles of the observation hospital. In sensitivity testing, we applied alternative definitions of nearby, such as considering all hospitals as possible competitors, while weighting closer hospitals more than distant hospitals. We focused on the proportion of nearby hospitals offering a service rather than the absolute number of nearby hospitals doing so, because the proportion of competitors offering a service takes into account the size and concentration of the market and, therefore, better represents the effect of any single hospital’s decision on another hospital in the market than does the absolute number.

We report both odds ratios and, for ease of interpretation, percentage increases in the probability that new services locate near existing services. This conversion is straightforward because, when the probability of an event happening is small, as in the case of a hospital adopting a new service, the odds ratio approximates the relative risk, interpretable as the percentage chance of an event happening. All regression analyses were performed with Stata statistical software, v.11.2. Tests were 2-sided, and probability values <0.05 indicated statistical significance.

Alternative Technology Diffusion Models
In simulations, we alternately allocated diagnostic angiography, PCI, and CABG to the same number of hospitals that actually adopted them over the study period, but we allocated them by using various counterfactual approaches. In all cases, we counted a person as having geographic access if they resided in a census tract whose centroid was within 40 miles of a service, and varied this measure in sensitivity testing (alternately using 20- and 40-mile distances, and 60 minutes driving time determined from mapping software for all, urban, or rural hospitals, as well). First, we allocated new services by using a public health planning approach, one that allocated the same number of new services that were adopted during the study period to hospitals to maximize the population gaining new access to care within 40 miles.

Second, in an alternative allocation approach, we allocated those services to existing hospitals fully at random. In constructing the simulation, we designated all hospitals that did not previously offer the service as eligible to offer it. This modeling choice rests on a somewhat unrealistic assumption, because some hospitals to which we allocated new services are ill-equipped to offer invasive cardiac services and would be unlikely to do so. However, the assumption that all hospitals that did not previously offer the service were eligible to offer it is the most conservative modeling assumption; it assigns new services to hospitals that are located in relatively unpopulated areas and, therefore, adds few potential patients to our estimates of the number of people who would be newly served. We performed this random simulation 500 times and averaged the results.

In determining both the population newly served by the actual addition of services by hospitals and the population that would be served if the 2 simulation methods were adopted (optimal diffusion and random diffusion), we used a fixed distance (40 miles, or, in sensitivity testing, other mileage or a 60-minute drive) to count the number of people newly served. Because the areas around some hospitals overlap with the areas around other hospitals, the newly served populations are counted more than once, making numeric estimates of the number of new people served inaccurate. This is necessary, because an effort to apportion each person in the United States to 1 and only 1 hospital’s potential market would be both arbitrary and a poor representation of how patients actually choose hospitals. However, because the manner of overcounting is identical for both the actual and hypothetical exercises, the comparisons among exercises are valid. Moreover, if there is any bias present it would be toward undercounting the number of people newly served by random placement of services, because we included all hospitals without services as eligible to offer them, including rural hospitals that serve areas with few potential patients and are far from other hospitals.

Results

Trends in Invasive Cardiac Service Provision
The rate of new, cardiac service offerings by hospitals varied by the particular service. From 1996 through 2008, 8% of hospitals provided new diagnostic angiography, 7% PCI, and 6% CABG (Table 1).
Many hospitals progressed from offering diagnostic services to treatments, and fewer hospitals offered only diagnostic services in 2008 (9.7%) than they did in 1996 (17.6%). However, adopting diagnostic angiography was not merely a first stage toward treatment (ie, PCI or CABG). On average over the study period, almost 15% of the hospitals in the sample provided only diagnostic services. Among urban hospitals, 1 in 5 acute-care hospitals offered only diagnostic care, although that number was falling (25% to 18% over the study period).

**Neighbor Effects**

Larger hospitals were more likely than smaller hospitals to add new capabilities. However, hospitals were more likely to adopt new services if a hospital within 40 miles already offered that service, even after controlling for hospital size, population size, other market characteristics, and the proportion of people who already lived within 40 miles of a service (Table 2). Hospitals with similar numbers of potential patients available, whether those patients already had geographic access or not, were more likely to offer a new cardiac service if a neighboring hospital was already offering it.

The results were largest for PCI, with hospitals considerably more likely to adopt new PCI technology when a higher proportion of neighboring hospitals offered PCI. A 10 percentage point increase in the rate of nearby hospitals offering PCI increases the odds of offering PCI by a factor of 1.794, or a 79.4% increase (95% confidence interval, 1.29–2.50). That is, a hospital is nearly twice as likely to offer PCI, conditional on characteristics of the neighboring population, in a market of 10 equal-sized hospitals when 1 other hospital adds PCI. Hospitals are less likely to adopt new PCI technology if nearby hospitals already had CABG capability, after controlling for the fact that nearby hospitals that offer CABG also offer PCI (odds ratio, 0.726; 95% confidence interval, 0.575–0.916).

The patterns are similar for diagnostic angiography. Hospitals were more likely to adopt new diagnostic angiography technology if more neighboring hospitals already had it, and they were less likely to do so if more neighboring hospitals offered PCI, a more sophisticated technology. A 10 percentage point increase in the rate of nearby hospitals offering diagnostic angiography corresponded to a 10.2% increase in the odds of offering diagnostic angiography (odds ratio, 1.102; 95% confidence interval, 1.02–1.19). The pattern was imprecisely estimated for CABG, with nonsignificant point estimates suggesting an increased likelihood of offering CABG if more nearby hospitals offered PCI (odds ratio, 1.44) or recently added PCI (odds ratio, 2.30), but somewhat less if nearby hospitals offered diagnostic angiography (0.81) or CABG (0.93).

**Geographic Access to Care**

Our results also demonstrated that existing diffusion methods lead to clusters of services, adding little geographic access to care. In 1997, 94% of the US population lived within 40 miles of a hospital that provided diagnostic angiography; 88% lived within 40 miles for both PCI and CABG. Despite widespread adoption of new services, by 2008, there was a 1 percentage point increase in the population with geographic access to diagnostic angiography (5 percentage points for PCI, and 4 percentage points for CABG).

On average over the study period, ~90% of those people served by new cardiac services—ie, residents within 40 miles of a newly offered service—already lived within 40 miles of other hospitals with those services. Over the study period, the duplication of services increased; more services were added where at least 1 hospital previously offered the service. In 1996, ~80% of people who lived within 40 miles of a cardiac service newly added in the past year already had access to those services; by 2008, that number was 95%.

Alternative methods of service allocation would have generated greater geographic access to care. In comparison with a method of service distribution optimized to increase geographic access, the efficiency of actual allocation (measured

<table>
<thead>
<tr>
<th>Year</th>
<th>None</th>
<th>DxCath</th>
<th>PCI</th>
<th>CABG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>5037</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1997</td>
<td>4863</td>
<td>68</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>1998</td>
<td>4857</td>
<td>39</td>
<td>14</td>
<td>26</td>
</tr>
<tr>
<td>1999</td>
<td>4797</td>
<td>34</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td>2000</td>
<td>4773</td>
<td>30</td>
<td>27</td>
<td>18</td>
</tr>
<tr>
<td>2001</td>
<td>4739</td>
<td>26</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>2002</td>
<td>4725</td>
<td>38</td>
<td>21</td>
<td>33</td>
</tr>
<tr>
<td>2003</td>
<td>4675</td>
<td>35</td>
<td>47</td>
<td>32</td>
</tr>
<tr>
<td>2004</td>
<td>4662</td>
<td>32</td>
<td>44</td>
<td>21</td>
</tr>
<tr>
<td>2005</td>
<td>4896</td>
<td>25</td>
<td>50</td>
<td>21</td>
</tr>
<tr>
<td>2006</td>
<td>4869</td>
<td>34</td>
<td>52</td>
<td>29</td>
</tr>
<tr>
<td>2007</td>
<td>4884</td>
<td>20</td>
<td>37</td>
<td>22</td>
</tr>
<tr>
<td>2008</td>
<td>4900</td>
<td>16</td>
<td>38</td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>397</td>
<td>387</td>
<td>298</td>
<td></td>
</tr>
</tbody>
</table>

CABG indicates coronary artery bypass grafting; DxCath, diagnostic cardiac catheterization; and PCI, percutaneous coronary intervention.
as the ratio of actual to simulated optimally allocated new coverage) was <1% in all years for all 3 services. For example, on average over the study period, new diagnostic angiography allowed access for 0.16% of the population that could have had new access to care (again defined as living in a census tract with a centroid within 40 miles of the new service) had diagnostic angiography been assigned to other existing hospitals so as to maximize geographic access (Table 3). Similarly, new PCI (or CABG) services reached 0.23% (0.35% for CABG) of the potential population that could have had new access to care had PCI been assigned to maximize new access to care.

The geographic clustering of services can be seen most easily in the figures. The black dots indicate existing hospitals that did not offer diagnostic angiography (Figure 1) or PCI, Figure 2 or CABG, Figure 3) in 1997, and the dark blue dots indicate hospitals that offered that service. The light blue dots identify hospitals that adopted that service by the end of the study period, 2008. All hospitals are located by their latitude and longitude. The substantial duplication of new service offerings is evident in both the US map and the detailed Houston area map, chosen to give a clearer idea of duplicative adoption patterns. The red circle represents a radius of 40 miles, indicating the hospitals within the recommended distance of central Houston. Note that new service tends to be added near existing service, rather than outside the 40-mile radius.

Had the same number of new services been randomly distributed to existing hospitals without cardiac services, new geographic access to those services would not be statistically different from that which we observed (Table 3). Although, on average over the study period, new diagnostic angiography reached 32% more, PCI 3% fewer, and CABG 31% more people than a purely random allocation, the annual percentages were highly variable, and all lie within the confidence intervals generated by the random distribution of new services to existing hospitals.

### Discussion
This analysis of national Centers for Medicare and Medicaid Services, Census, and AHA data demonstrates at least 2 novel results. First, confirming other research demonstrating the increase in PCI services, we find that the number of hospitals offering diagnostic cardiac catheterization, PCI, and CABG increased substantially over the study period. Second, hospitals

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**Table 2. Odds Ratios for Hospitals Offering Invasive Cardiac Services According to Hospital and Population Characteristics, 1996 to 2008**

<table>
<thead>
<tr>
<th>Service</th>
<th>Diagnostic Angiography</th>
<th>PCI</th>
<th>CABG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nearby proportion of hospitals with diagnostic angiography, per 10%</td>
<td>1.102*</td>
<td>0.775</td>
<td>0.808</td>
</tr>
<tr>
<td>95% confidence interval</td>
<td>1.018–1.193</td>
<td>0.581–1.034</td>
<td>0.597–1.094</td>
</tr>
<tr>
<td>Nearby proportion of hospitals with PCI, per 10%</td>
<td>1.059</td>
<td>1.794†</td>
<td>1.442</td>
</tr>
<tr>
<td>95% confidence interval</td>
<td>0.910–1.233</td>
<td>1.288–2.498</td>
<td>0.926–2.245</td>
</tr>
<tr>
<td>Nearby proportion with CABG, per 10%</td>
<td>0.920</td>
<td>0.726†</td>
<td>0.929§</td>
</tr>
<tr>
<td>95% confidence interval</td>
<td>0.787–1.075</td>
<td>0.575–0.916</td>
<td>0.608–1.420</td>
</tr>
</tbody>
</table>

### Table 3. Access to New Cardiac Treatments, Duplication Versus Newly Served Population

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Diagnostic angiography, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual increase/public health planning increase</td>
<td>0.42</td>
<td>0.13</td>
<td>0.02</td>
<td>0.16</td>
</tr>
<tr>
<td>Actual/random</td>
<td>135</td>
<td>105</td>
<td>44</td>
<td>132</td>
</tr>
<tr>
<td>PCI, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual increase/public health planning increase</td>
<td>0.17</td>
<td>0.29</td>
<td>0.09</td>
<td>0.23</td>
</tr>
<tr>
<td>Actual/random</td>
<td>125</td>
<td>170</td>
<td>47</td>
<td>97</td>
</tr>
<tr>
<td>CABG, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual increase / public health planning increase</td>
<td>0.53</td>
<td>0.42</td>
<td>0.05</td>
<td>0.35</td>
</tr>
<tr>
<td>Actual/random</td>
<td>154</td>
<td>124</td>
<td>41</td>
<td>131</td>
</tr>
</tbody>
</table>

Data and methods are described in the text. Random allocations are averaged over 500 random draws. Actual increases in each type of service are compared with alternative placement of the same number of new service locations, one planned to add the largest possible number of new population covered and one random. For example, new diagnostic angiography in 2002 (middle column) led to new access to care for those living within 40 miles, who were not already within 40 miles of a hospital offering it. This increase was an eighth of a percent of the increase that would have been possible had a public health planning approach been used. In contrast, it was 5% greater than the increase in newly accessible population that would have occurred, on average, in a purely random allocation. CABG indicates coronary artery bypass grafting; and PCI, percutaneous coronary intervention.
were more likely to adopt these technologies if more nearby hospitals already offered them, even controlling for the potential patient population of hospital markets. Third, despite widespread new cardiac capacity, there has been only a modest increase in geographic access to care. The findings have implications for capacity planning, spending, and quality of care.

The rapidly aging population and developments in medical technology have led policy experts to predict workforce

Figure 1. New diagnostic angiography adoption 1997 to 2008. The black dots represent the location of hospitals that did not offer diagnostic angiography in 1997. The dark blue dots represent the location of hospitals that offered diagnostic angiography in 1997. The light blue dots indicate the hospitals that offered diagnostic angiography by the end of 2008. The close proximity of the light blue and dark blue dots indicates that services tend to cluster rather than expand geographic access to care. The small map represents the Houston area, with the red circle identifying a 40-mile radius (an approximation of the market for invasive cardiac treatment based on 1-hour travel time). The new services (represented by light blue dots) tend to occur near previously existing services, rather than outside of the red circle, where they might serve patients otherwise without geographic access. All dots are located according the latitude and longitude of the hospitals. Diag indicates diagnostic angiography.

Figure 2. New PCI adoption 1997 to 2008. The black dots represent the location of hospitals that did not offer PCI in 1997. The dark blue dots represent the location of hospitals that offered PCI in 1997. The light blue dots indicate the hospitals that offered PCI by the end of 2008. The close proximity of the light blue and dark blue dots indicates that services tend to cluster rather than expand geographic access to care. The small map represents the Houston area, with the red circle identifying a 40-mile radius (an approximation of the market for invasive cardiac treatment based on 1-hour travel time). The new services (represented by light blue dots) tend to occur near previously existing services, rather than outside of the red circle, where they might serve patients otherwise without geographic access. All dots are located according the latitude and longitude of the hospitals. PCI indicates percutaneous coronary intervention.
shortages,13 not only in primary care but also for specialty services14 such as cardiology.15 By demonstrating a growth in services, our results demonstrate that the system has overall capacity to address the needs of an aging population in aggregate, but also that the system struggles to match new capacity with population health needs.

Although our study does not directly address the health risks associated with current patterns of cardiac care diffusion, the mismatches we identified between technology supply and population suggest possible implications for both cost-effectiveness and quality.16 Previous research has demonstrated that the availability and use of cardiac services varies dramatically by region, yet cannot be explained by differences in patient indications.5 We extended these findings by showing that hospitals are more likely to adopt new services where they already exist. This suggests a possible competitive mechanism for the clustering of services and for why some areas remain without access to services while others appear to have greater capacity.

Moreover, our results may have quality and cost implications. Some of these implications suggest decreases in quality. First, some proponents argue that rapid access to treatments such as PCI leads to mortality reductions for acute myocardial infarction.17,18 Although our data cannot speak to patient-level outcomes, if PCI is being expanded to improve population health by reducing door-to-balloon times in acute myocardial infarction, then our results suggest this is not being done very efficiently because many areas remain without these services. Second, geographic duplication of services likely leads to declines in hospital volume. In fact, Medicare patients have increasingly obtained CABG at low-volume hospitals.5 Given the positive, although attenuating, association between volume and outcomes,19 the diffusion patterns we identified could decrease quality, because some researchers have found that the lower volume occurring where hospitals have newly adopted CABG has caused increased mortality.6 And, although researchers have found that CABG mortality decreased in the 1990s despite decreases in volume, they point to quality and technology improvements as the cause.2

On the other hand, there is the potential for new competition to reduce the prices that hospitals charge for cardiac care, although this potential is limited to the extent that hospitals rely on government reimbursement for cardiac services. In addition, there is a body of research suggesting that competition can increase quality. In a study of the effects of hospital competition on patients who had acute myocardial infarction from 1985 to 1994, for example, Kessler and McClellan20 show that although the effects of competition on expenditures and outcomes were ambiguous in the 1980s, competition led to lower expenditures on treatment and better outcomes in the 1990s. Moreover, Cutler et al21 have found that quality of care for CABG patients improved slightly after the repeal of Certificate of Need in Pennsylvania, an improvement they attribute to the redistribution of operations to higher-quality surgeons.

The clustering patterns we observed raise potential policy interventions. Despite active Certificate of Need programs in several states, we find no regulatory effect on clustering, suggesting that Certificate of Need regulations could be more rigorously enforced or better designed to address geographic access. For example, programs could require a demonstration that new services will address geographic need, not only population need as is often the focus of such regulations. Moreover, because technology adoption regulation is
primarily state based, the system is subject to local regulatory capture and cannot account for cross-border effects. To address such problems, federal agencies such as Centers for Medicare and Medicaid Services could play a more active role in licensing and, perhaps, tie reimbursement to geographic, and other forms of access, as well.

Our study has several limitations. First, the data introduced some challenges. Because we identified hospitals offering cardiac services from the Medicare Provider Analysis and Review, our sample excludes hospitals serving only non-Medicare patients. Our population measures came from the US Census, which is based on residence, not work location. We also relied on self-reported measures of hospital characteristics. Second, unlike our regression estimates, the simulation results define access only in geographic terms, unadjusted for population density; in metropolitan areas, sufficient access may require many hospitals to offer cardiac services. Third, because our focus is on hospitals that compete over many services, we excluded specialized cardiac hospitals. Because single-service hospitals tend to locate in a few regions, however, including them would likely have strengthened our findings.

Finally, and most importantly, we cannot determine whether the propensity of hospitals to adopt new services near existing services is a response to unmet demand in the market. Patients in geographic areas that appear to be underserved may obtain cardiac services through networks of hospitals that successfully provide services to geographically remote areas. And it may be that rural hospitals that wish to adopt cardiac services are unable to find doctors to provide those services. We can only conclude that such clustering of services did not expand geographic access in the sense that services tended to be opened in locations where the population was already located within 40 miles of existing services and not elsewhere.

To our knowledge, this is the first national assessment of the new adoption of the 3 main invasive cardiac services and the resulting effects on geographic access. Significant new capacity for invasive cardiac services has been added to the United States in the 13 years under study. However, current methods of cardiac technology diffusion, some combination of market competition and technology regulation, do not increase geographic access to care but rather lead to the duplication of services. Innovative healthcare policies to develop a coordinated system of care that is based in part on increasing geographic access, within and across state borders, may be a next step in improving the diffusion of these lifesaving cardiovascular technologies and ultimately improving the health of the population.

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Disclosures
None.

References


**CLINICAL PERSPECTIVE**

Invasive cardiac services, including diagnostic angiography, percutaneous coronary interventions, and coronary artery bypass grafting are rapidly growing, but we do not know how and where this expansion of capacity is occurring. We examined nationwide Medicare data for 1996 to 2008 and found that hospitals were most likely to add diagnostic angiography and percutaneous coronary intervention services if other hospitals nearby already provided such services, and were particularly likely to add percutaneous coronary intervention services if nearby hospitals had recently added new services. The increase in capacity resulted in little increase in geographic access to such services. Our findings suggest that existing decentralized approaches to the addition of new invasive cardiac capacity may not be optimal for expanding geographic access to care, and their cost-effectiveness and public health impact should be examined.
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