Association of Physician Certification in Interventional Cardiology With In-Hospital Outcomes of Percutaneous Coronary Intervention

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Background—The value of American Board of Internal Medicine certification has been questioned. We evaluated the Association of Interventional Cardiology certification with in-hospital outcomes of patients undergoing percutaneous coronary intervention (PCI) in 2010.

Methods and Results—We identified physicians who performed ≥10 PCIs in 2010 in the CathPCI Registry and determined interventional cardiology (ICARD) certification status using American Board of Internal Medicine data. We compared in-hospital outcomes of patients treated by certified and noncertified physicians using hierarchical multivariable models adjusted for differences in patient characteristics and PCI volume. Primary end points were all-cause in-hospital mortality and bleeding complications. Secondary end points included emergency coronary artery bypass grafting, vascular complications, and a composite of any adverse outcome. With 510708 PCI procedures performed by 5175 physicians, case mix and unadjusted outcomes were similar among certified and noncertified physicians. The adjusted risks of in-hospital mortality (odds ratio, 1.10; 95% confidence interval, 1.02–1.19) and emergency coronary artery bypass grafting (odds ratio, 1.32; 95% confidence interval, 1.12–1.56) were higher in the non–ICARD-certified group, but the risks of bleeding and vascular complications and the composite end point were not statistically significantly different between groups.

Conclusions—We did not observe a consistent association between ICARD certification and the outcomes of PCI procedures. Although there was a significantly higher risk of mortality and emergency coronary artery bypass grafting in patients treated by non–ICARD-certified physicians, the risks of vascular complications and bleeding were similar. Our findings suggest that ICARD certification status alone is not a strong predictor of patient outcomes and indicate a need to enhance the value of subspecialty certification. (Circulation. 2015;132:1816-1824. DOI: 10.1161/CIRCULATIONAHA.115.017523.)

Key Words: acute coronary syndromes ■ acute myocardial infarction ■ angioplasty ■ catheter-based coronary interventions, stents ■ chronic ischemic heart disease ■ coronary revascularization ■ health policy and outcome research ■ registries

The American Board of Internal Medicine (ABIM) was founded nearly 80 years ago in an effort to establish uniform standards for internists.1 ABIM certification indicates “that internists have demonstrated—to their peers and to the public—that they have the clinical judgment, skills and attitudes essential for the delivery of excellent patient care.”1 Over time, ABIM certification has evolved to include both recertification and, more recently, maintenance of certification requirements.2,3 Certification status plays a central role in the credentialing processes of many hospitals,4 may influence patients’ choice of a physician,5 and could be used to inform payment policies.6 Although there is strong evidence for the internal validity of the testing process and the correlation of certification with other measures of physician quality such as program director’s ratings, the findings of studies examining the association of certification with patient outcomes have been mixed.7–13

Board certification is of particular interest in the field of interventional cardiology (ICARD), where it is a relatively new development. Certification was first offered in 1999 in an

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effort to standardize a rapidly expanding field. Since then, there has been wide acceptance of the importance of ICARD certification. The current clinical competence statement for percutaneous coronary intervention (PCI) from the American College of Cardiology Foundation, the American Heart Association, and the Society for Cardiovascular Angiography and Interventions strongly recommends that physicians performing PCI hold active ICARD ABIM certification. Nevertheless, although ICARD certification has been in place for 16 years, the association between ICARD certification and the outcomes of patients undergoing PCI has not been evaluated. Critically assessing the certification process is essential because physicians have challenged the certification process in both the lay and research press, citing time and financial pressures and a perceived lack of value of the process.

To address this gap in knowledge, we linked data on physician certification in ICARD from the ABIM database with patient outcomes data from the National Cardiovascular Data Registry’s (NCDR) CathPCI Registry. Specifically, we examined the association of ABIM physician certification in ICARD with patterns of care and outcomes of patients undergoing PCI. It is important to emphasize, however, that this study addresses certification status of the performing physician at the time of the procedure, not maintenance of certification or recertification.

**Methods**

**Data Sources**
The CathPCI Registry was established as a mechanism to promote quality-improvement efforts at hospitals performing diagnostic and interventional cardiac procedures. Hospitals voluntarily submit data to the registry using standardized definitions for patient demographics, medical history, risk factors, hospital presentation, initial cardiac status, procedural details, unique operator identification, medications, laboratory values, and in-hospital outcomes of the PCI procedure. Data are entered by hospital personnel, and the data are included in the analytic file only if the hospital achieves >95% completeness of specified data elements. Currently, >1,400 sites submit data to the CathPCI Registry, which account for >85% of catheterization laboratories performing PCI nationwide. Previous data-quality reviews have supported the accuracy of the data submitted to the CathPCI Registry.

The ABIM database contains data on all physicians certified in internal medicine (IM) and each of its subspecialties. The information includes demographic data, training dates, and certification status for IM, cardiovascular disease (CVD), and ICARD.

**Patient Population**
A flowchart of patient and physician selection is shown in Figure 1. All patients who underwent a PCI procedure reported to the CathPCI Registry performed between January 1, 2010, and December 31, 2010, were eligible to be included in the analysis, which included 641,178 PCIs. We excluded PCIs that could not be linked to a physician and patients who were <18 years of age at the time of the procedure. We considered only the first PCI performed during a hospitalization. After these exclusions were applied, a total of 510,708 PCIs were linked to 51,755 associated physicians.

**Physician Population**
All physicians who performed at least 10 PCI procedures in 2010 as captured in the CathPCI Registry were eligible to be included in the analysis. We identified physicians in the CathPCI Registry using their National Provider Identifier (NPI) number. NPI numbers are voluntarily submitted by participating hospitals. There were 6314 physicians with an NPI number recorded who performed a PCI in 2010. However, physicians were listed in the ABIM database with both their NPI number and their unique physician identification number. Accordingly, we used an NPI number/unique physician identification numbers crosswalk supplemented by manual searches to identify all physicians within the ABIM database. We excluded physicians who could not be linked to the ABIM data, had missing certification information in the ABIM database, or performed <10 PCIs in 2010. The final analysis included 5175 physicians.

**Physician Certification**
For the primary analysis, physicians were divided into 2 groups, certified and not certified, on the basis of their ABIM ICARD certification status on January 1, 2010. In secondary analyses, we further stratified physicians by the year that they completed their CVD fellowship training. We used CVD fellowship as a marker across physician groups because it is a prerequisite for ICARD training. Those physicians who performed PCIs before the formalization of ICARD training will not have interventional fellowship training dates recorded but will have CVD fellowship training dates available. Physicians who performed PCIs before the formation of accredited fellowship training programs were eligible for ICARD certification with the use of the ABIM’s “practice pathway,” which required certification in CVD and either a total of 500 lifetime PCIs or 150 PCIs in the previous 2 years. The first group included physicians who held ICARD certification in 2010 and had finished CVD fellowship before 1999 (the first year of the ABIM ICARD certification; n=2200); the second group included physicians who held ICARD certification in 2010 and finished CVD fellowship in 1999 or later (n=1466); the third group included physicians who had never held ICARD certification and who finished CVD fellowship before 1999 (n=1044); the fourth group included physicians who never held ICARD certification and who finished CVD fellowship before 1999 or later (n=149); and the fifth group included physicians who had previously held ICARD certification but whose certification had lapsed (n=316).

**Outcomes**
The CathPCI Registry captures information about complications occurring during or after the PCI procedure until hospital discharge. Our 2 prespecified primary end points were all-cause in-hospital mortality and bleeding complications. Bleeding complications consisted of suspected or confirmed bleeding events within 72 hours of the PCI associated with any of the following: a hemoglobin drop of ≥3 g/dL, transfusion of red blood cells, or an intervention at the bleeding site to reverse or stop the bleeding. Prespecified secondary end points included need for emergency coronary artery bypass grafting (CABG), vascular complications requiring therapy (any access-site occlusion, peripheral embolization, dissection, pseudoaneurysm, or arteriovenous fistula requiring intervention), and a composite end point of any outcome (death, bleeding, vascular complications, and emergency revascularization). These outcomes represent clinically significant, well-defined outcomes that have frequently been used in analyses of the CathPCI Registry.

**Discharge Medications**
To examine the association of ICARD certification with processes of care, we compared patterns of discharge medications: aspirin, statin therapy, and thienopyridines. We excluded patients with a contraindication to the medication. Furthermore, we excluded patients who did not undergo stent implantation from our assessment of thienopyridines.

**Appropriate Use Criteria**
In a secondary analysis, we examined differences in PCI procedural appropriateness as characterized by the 2012 appropriate use criteria for coronary revascularization. Procedures were characterized as appropriate, of uncertain appropriateness, inappropriate, or unmappable. Because previous analyses have shown that almost all acute PCIs were classified as appropriate, we excluded patients undergoing PCI in the setting of an acute coronary syndrome from appropriate use criteria analysis.
Analysis

We summarized physician and patient characteristics, including physician demographics, certification attributes, and baseline patient characteristics. To assess the relationship between certification status and outcomes, we used methods appropriate for clustered data.27,28 We used $\chi^2$ tests, adjusted for clustering by physician, to compare patient characteristics and outcomes across physician groups.28 Then, to account for physician and patient characteristics, we estimated for each outcome a hierarchical generalized linear model with a logistic link function and a random intercept across physicians.28 Each model was adjusted for physician PCI volume, years since the initial certification in cardiovascular medicine (as a proxy for years of experience), the PCI volume of the hospital where the physician performed most of his or her PCIs, and patient characteristics. Physician and hospital PCI volumes were calculated from procedures performed in 2010. Physician volume was included as a dichotomous variable in the model (<50 procedures, $\geq$50 procedures). To account for the fact that some physicians perform procedures at >1 hospital, we performed automated and manual abstraction of CathPCI data to identify operators who performed cases at >1 hospital submitting data to the CathPCI Registry. We included the hospital at which the provider performed the majority of his or her procedures. We also included in each model patient risk factors previously shown to be significantly associated with our outcomes of interest (including death, bleeding, emergency CABG, and vascular complications). For each model, we reported the odds ratio and 95% confidence interval for the effect of certification status (or, for the secondary outcomes, certification group) on the outcome. To improve the interpretation of multilevel model results, we used recycled predictions to express effects as absolute differences in outcome rates; this method uses the model results to predict the outcome for all patients as if they were in each exposure group and summarizes the differences.29 In a secondary analysis, we included pairwise interaction terms between physician annual volume, hospital volume category, and ICARD status in the model. All analyses were performed with Stata 13.1 (StataCorp, College Station, TX; 2013). Analyses were approved by the Yale University School of Medicine’s Human Investigation Committee.

Results

Among the 6314 eligible physicians, 717 were excluded because they were enrolled in a fellowship program in 2010, 3 were excluded who received ICARD certification after 2010, and 415 had missing certification information. The remaining 5175 interventional cardiologists performed a total of 510708 PCI procedures between January 1, 2010, and December 31, 2010. The characteristics of the patients are summarized in Table 1 on the basis of the certification status of the performing physician. Overall, patient characteristics were similar across the certification status groups. Of note, the ICARD-certified group had a slightly higher proportion of patients with heart failure (11.8% versus 11.1%), ST-segment–elevation myocardial infarction (16.3% versus 15.5%), and acute coronary syndrome (70.2% versus 68.0%). The non–ICARD-certified group had a higher proportion of patients with previous PCI (41.7% versus 40.3%) and patients undergoing elective PCI (48.9% versus 44.2%). Physician characteristics are shown in Table 2. Only 161 (3.2%) were female, and the mean age was 49.9 years. The mean age of noncertified physicians was 54.8 years compared with 48.0 in the certified group ($P<0.001$). A total of 3666 (70.8%) held ICARD certification on January 1, 2010. ICARD-certified physicians performed the majority of procedures (399153 procedures, 78.2%). Among patients for whom information about practice type was available, a higher percentage of ICARD-certified physicians practiced in an academic setting (7.8% versus 0.9%). On average, ICARD-certified physicians performed more PCIs in 2010 than non–ICARD-certified physicians (111.8 versus 75.8 PCIs), and a higher proportion performed at least 50 PCIs (77.6% versus 55.6%; $P<0.001$).

The proportions of patients discharged on aspirin, thienopyridines, and statins after the PCI procedure are also shown in Table 1. There were relatively small but statistically significant differences such that patients treated by certified physicians were more likely to be discharged on each medication. The proportions of appropriate procedures by certification status
A higher proportion of PCIs performed by non–ICARD-certified physicians were not mappable compared with PCIs performed by ICARD-certified physicians (42.9% versus 39.9%; \(P=0.002\)). Among procedures that were mappable, higher proportions of PCI performed by ICARD-certified physicians were classified as inappropriate (13.1% versus 11.8%; \(P=0.002\)) and appropriate (24.7% versus 23.1%; \(P=0.038\)). The proportions of procedures classified as uncertain were similar (22.2% versus 22.3%; \(P=0.934\)).

In the secondary analysis that stratified physicians on the basis of when they finished CVD training, Table 2 shows that 20.2% of physicians had never been ICARD certified and finished CVD fellowship before 1999. These physicians performed 14.2% (72,566 procedures) of all PCIs included in the analysis. A smaller proportion of PCIs (11,849 procedures, 2.3%) were performed by the 148 physicians (2.9%) who had never been ICARD certified and had finished CVD fellowship in 1999 or later. Only 309 physicians (6.1%) had a lapsed...
certification during 2010, and these physicians performed 27,140 procedures (5.3% of the total number of procedures included in the analysis). There were modest differences in patient characteristics and discharge medications across these 5 physician categories.

### Outcomes

Overall, the crude outcomes of patients treated by ICARD-certified physicians were almost identical to those of patients treated by non–ICARD-certified physicians (Table 4). As estimated by recycled predictions, this corresponded to absolute increases in mortality and emergency CABG of 0.08% and 0.03%, respectively. In contrast, there were no significant differences in the adjusted risks of bleeding and vascular complications and the composite end point of any adverse outcome. In a secondary analysis including interaction terms between physician annual volume category, hospital volume category, and ICARD status, only emergency CABG remained statistically significant.

Findings were similar when we classified physicians into the 5 categories (Table 3). In multivariable analyses, the risk

### Table 2. Physician Characteristics (n=5175)

<table>
<thead>
<tr>
<th></th>
<th>Not ICARD Certified, n (%)</th>
<th>ICARD Certified, n (%)</th>
<th>Total, n (%)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total physicians</td>
<td>1509 (29.2)</td>
<td>3666 (70.8)</td>
<td>5175 (100.0)</td>
<td>0.373</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1466 (97.2)</td>
<td>3544 (96.7)</td>
<td>5010 (96.8)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>43 (2.8)</td>
<td>122 (3.3)</td>
<td>165 (3.2)</td>
<td></td>
</tr>
<tr>
<td>Type of practice</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Teaching</td>
<td>14 (0.9)</td>
<td>287 (7.8)</td>
<td>301 (5.8)</td>
<td></td>
</tr>
<tr>
<td>Solo or group</td>
<td>455 (30.2)</td>
<td>1946 (53.1)</td>
<td>2401 (46.4)</td>
<td></td>
</tr>
<tr>
<td>HMO/other</td>
<td>29 (1.9)</td>
<td>177 (4.8)</td>
<td>206 (4.0)</td>
<td></td>
</tr>
<tr>
<td>Hospital practice</td>
<td>99 (6.6)</td>
<td>604 (16.5)</td>
<td>703 (13.6)</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>912 (60.4)</td>
<td>652 (17.8)</td>
<td>1564 (30.2)</td>
<td></td>
</tr>
<tr>
<td>Volume category, n</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>&lt;50</td>
<td>670 (44.4)</td>
<td>822 (22.4)</td>
<td>1492 (28.8)</td>
<td></td>
</tr>
<tr>
<td>≥50</td>
<td>839 (55.6)</td>
<td>2844 (77.6)</td>
<td>3683 (71.2)</td>
<td></td>
</tr>
<tr>
<td>PCI volume</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>75.8 (75.8)</td>
<td>111.8 (85.3)</td>
<td>101.3 (84.3)</td>
<td></td>
</tr>
<tr>
<td>Certification status</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td></td>
<td>disc</td>
<td></td>
</tr>
<tr>
<td>Yes, CVD before 1999</td>
<td></td>
<td></td>
<td>disc</td>
<td></td>
</tr>
<tr>
<td>Yes, CVD in 1999 or later</td>
<td>1466 (28.3)</td>
<td>disc</td>
<td>disc</td>
<td></td>
</tr>
<tr>
<td>No, CVD before 1999</td>
<td></td>
<td></td>
<td>disc</td>
<td></td>
</tr>
<tr>
<td>No, CVD in 1999 or later</td>
<td>1044 (20.2)</td>
<td>disc</td>
<td>disc</td>
<td></td>
</tr>
<tr>
<td>Lapsed</td>
<td></td>
<td></td>
<td>disc</td>
<td></td>
</tr>
<tr>
<td>Years since CVD fellowship*</td>
<td>316 (6.1)</td>
<td>disc</td>
<td>disc</td>
<td></td>
</tr>
<tr>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td>disc</td>
<td></td>
</tr>
<tr>
<td>0–5</td>
<td>52 (3.4)</td>
<td>555 (15.1)</td>
<td>607 (11.7)</td>
<td></td>
</tr>
<tr>
<td>6–10</td>
<td>81 (5.4)</td>
<td>762 (20.8)</td>
<td>843 (16.3)</td>
<td></td>
</tr>
<tr>
<td>11–15</td>
<td>185 (12.2)</td>
<td>730 (19.9)</td>
<td>915 (17.7)</td>
<td></td>
</tr>
<tr>
<td>16–20</td>
<td>284 (18.8)</td>
<td>578 (15.8)</td>
<td>862 (16.7)</td>
<td></td>
</tr>
<tr>
<td>21–30</td>
<td>659 (43.7)</td>
<td>897 (24.5)</td>
<td>1556 (30.1)</td>
<td></td>
</tr>
<tr>
<td>&gt;30</td>
<td>247 (16.4)</td>
<td>144 (3.9)</td>
<td>391 (7.6)</td>
<td></td>
</tr>
<tr>
<td>Hospital PCI volume, n</td>
<td>129 (8.5)</td>
<td>283 (7.7)</td>
<td>412 (8.0)</td>
<td>0.016</td>
</tr>
<tr>
<td>Mean (SD), y</td>
<td>54.8 (7.3)</td>
<td>48.0 (8.0)</td>
<td>49.9 (8.4)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

CVD indicates cardiovascular disease; HMO, health maintenance organization; ICARD, interventional cardiology; and PCI, percutaneous coronary intervention.

*Years since the end date of the general CVD fellowship.
of death was significantly higher in patients treated by non–ICARD-certified physicians who finished CVD fellowship before 1999, and the risk of emergency CABG was significantly higher for patients treated by both non–ICARD-certified groups (Table 4). Again, there were no significant differences in the adjusted risks of bleeding and vascular complications and the composite end point of any adverse outcome.

**Discussion**

In the United States in 2010, interventional cardiologists who did not hold ICARD certification performed a substantial proportion of PCI procedures. This included both physicians who had never been ICARD certified and those who had allowed their certification to lapse. We found that the care and outcomes of patients undergoing PCI procedures were generally similar regardless of the ICARD certification status of the performing physician. After adjustment for patient characteristics and PCI volume, the risks of mortality and emergency CABG were statistically higher among non–ICARD-certified physicians compared with ICARD-certified physicians. However, the overall event rates were low, and the clinical significance of these differences may be modest.

The requirements for obtaining certification in ICARD are rigorous. Given this rigor, it is notable that the majority of practicing interventional cardiologists have obtained ABIM ICARD certification. This is particularly striking among physicians who completed their CVD training after ICARD certification was introduced in 1999. In this group, certification has become the norm, and only 2.9% were not certified in 2010. The reasons why physicians choose to become certified are probably multifactorial, but surveys of physicians suggest that both professional pride and hospital credentialing policies play major roles. As noted, ABIM certification has been symbolic of professionalism in medicine and has been seen as indicative of a commitment to excellence and continued learning on the part of the physician.

In the present study, we did not observe a consistent association between ICARD certification and patient outcomes. Although patients treated by non–ICARD-certified physicians were at statistically significantly higher risk of both mortality and emergency CABG, we did not see a similar association for the clinical endpoints of bleeding and vascular complications and a composite of any adverse outcome. Furthermore, the clinical significance of the mortality and CABG findings is subject to interpretation. The adjusted absolute increase in mortality was 0.08%, which corresponds to 1 additional death for every 1250 patients. Similarly, there was 1 additional emergency bypass surgery for every 3333 patients treated by noncertified physicians compared with certified physicians. Finally, a smaller proportion of nonacute PCI procedures performed by non–ICARD-certified physicians were classified as inappropriate compared with procedures performed by ICARD-certified physicians. Collectively, our findings suggest that ICARD certification status alone is not a strong predictor of quality of care and in-hospital outcomes.

**Table 3. Crude Outcomes of Primary and Secondary Analyses**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Not ICARD Certified, n (%)</th>
<th>ICARD Certified, n (%)</th>
<th>ICARD Certified, CVD Fellowship Before 1999, n (%)</th>
<th>ICARD Certified, CVD Fellowship in 1999 or Later, n (%)</th>
<th>ICARD Certified, CVD Fellowship Before 1999, n (%)</th>
<th>ICARD Certified, CVD Fellowship in 1999 or Later, n (%)</th>
<th>Lapsed, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total PCIs</td>
<td>111555 (21.8)</td>
<td>399153 (78.2)</td>
<td>242452 (47.5)</td>
<td>156701 (30.7)</td>
<td>72566 (14.2)</td>
<td>11849 (2.3)</td>
<td>27140 (5.3)</td>
</tr>
<tr>
<td>In-hospital death</td>
<td>1509 (1.4)</td>
<td>5436 (1.4)</td>
<td>3245 (1.3)</td>
<td>2191 (1.4)</td>
<td>1016 (1.4)</td>
<td>173 (1.5)</td>
<td>320 (1.2)</td>
</tr>
<tr>
<td>Bleeding</td>
<td>1878 (1.7)</td>
<td>7116 (1.8)</td>
<td>4321 (1.8)</td>
<td>2795 (1.8)</td>
<td>1232 (1.7)</td>
<td>190 (1.6)</td>
<td>456 (1.7)</td>
</tr>
<tr>
<td>Vascular complication</td>
<td>475 (0.4)</td>
<td>1851 (0.5)</td>
<td>1084 (0.4)</td>
<td>767 (0.5)</td>
<td>296 (0.4)</td>
<td>57 (0.5)</td>
<td>122 (0.4)</td>
</tr>
<tr>
<td>Emergency CABG</td>
<td>255 (0.2)</td>
<td>707 (0.2)</td>
<td>405 (0.2)</td>
<td>302 (0.2)</td>
<td>174 (0.2)</td>
<td>32 (0.3)</td>
<td>49 (0.2)</td>
</tr>
<tr>
<td>Composite*</td>
<td>3740 (3.4)</td>
<td>13659 (3.4)</td>
<td>8156 (3.4)</td>
<td>5503 (3.5)</td>
<td>2473 (3.4)</td>
<td>408 (3.4)</td>
<td>859 (3.2)</td>
</tr>
</tbody>
</table>

CABG indicates coronary artery bypass graft; CVD, cardiovascular disease; and ICARD, interventional cardiology.

*Composite end point of any adverse event (including in-hospital death, bleeding, vascular complication, and emergency CABG).
There are several potential explanations for this finding. First, PCI is a much safer and more reliable procedure today than in its early development. As previous studies have demonstrated, the introduction of coronary stents greatly improved procedural success and reduced the need for emergency CABG. Similarly, increasing use of radial access and novel anticoagulant and antithrombotic strategies has likely reduced the risks of periprocedural bleeding and myocardial infarction.

In addition, there is increasing recognition that the outcomes of patients undergoing PCI are less attributable to an individual provider and more reflective of the totality of care delivered by the team treating the patient both during and after the PCI procedure. Collectively, these factors may have had the effect of leveling the playing field, making it possible for interventional cardiologists with different training, knowledge, and technical expertise to achieve comparable results.

Second, the group of non–ICARD-certified physicians is heterogeneous, consisting of physicians who did and did not complete an accredited fellowship in ICARD. In our analyses, we did not identify a significant interaction between physician training year and certification status, but we observed that the risks of mortality and emergency CABG were highest among physicians without ICARD certification who completed their CVD training after 1999. Further research is warranted to determine whether the differences between ICARD-certified and non–ICARD-certified physicians will become more apparent over time.

Third, despite the rigor of the ABIM certification requirements, it is possible that the qualities and abilities currently captured by the certification process may not be the same as those needed to discriminate between physicians who perform PCI. For example, the certification examination can be used to assess an individual’s knowledge, but it cannot test many of the qualities that are associated with highly skilled proceduralists, including the ability to make good decisions under extreme stress, superior manual dexterity, and quickly recognizing and effectively treating procedural complications. One promising approach to better assess this skill set could be the use of simulators, which could be folded into fellowship training and perhaps incorporated into the certification process. Alternatively, there may be a role for direct observation of procedural skills by interventionalists specifically trained in the observation and assessment of procedural skills.

Our findings must be interpreted in the context of several limitations. Our analysis examined only in-hospital outcomes, and it is possible that differences in the procedural quality may become evident only over longer periods of time or when other PCI-relevant outcomes, including quality of life, are considered. We considered only patients who had a PCI, and we could not assess whether certification status was associated with differences in the overall management of patients with acute and stable coronary artery disease. Nevertheless, the characteristics and measures of procedural appropriateness were similar across the 2 groups. The clinical end points that we examined are relatively infrequent in occurrence and therefore may have made it difficult to find variation across operators. In addition, our study reflects the outcomes of patients undergoing PCI in 2010, and it is possible that the underlying associations between ICARD certification status and outcomes may be different in more recent data. However, studies using more recent CathPCI data show similar rates of complications.

The ABIM identified 6172 physicians who held ICARD certification in 2010, but we were unable to identify certification status for 16.2% of these physicians (997) in the linked data set. This likely includes physicians who were practicing at non-NCDR hospitals and physicians whose NPI numbers were not available (because this was not a mandatory field on the NCDR data reporting sheet). Nevertheless, the case mixes of physicians who could and could not be matched were comparable, suggesting that our findings are generalizable. Our study was also limited to hospitals that participate in the NCDR CathPCI Registry. The primary goal of the NCDR is to drive quality improvement through measurement and feedback, and substantial research has demonstrated the power and importance of feedback for professional development.

It is possible that physician participation in NCDR-related activities may mitigate the association of certification with PCI outcomes. As noted, we assessed only ICARD certification at the time of the procedure; we did not evaluate whether participation or completion of the maintenance of certification program affects PCI outcomes. Finally, the development of

<table>
<thead>
<tr>
<th>Outcome</th>
<th>ICARD Certified</th>
<th>Not ICARD Certified</th>
<th>P Value</th>
<th>OR, ICARD Certified, CVD Before 1999</th>
<th>OR, Lapsed</th>
<th>OR, Not ICARD Certified, CVD Fellowship in 1999 or Later</th>
<th>OR, Not ICARD Certified, CVD Before 1999</th>
<th>OR, Lapsed</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-hospital death</td>
<td>Referent</td>
<td>1.10 (1.02–1.19)</td>
<td>0.018</td>
<td>Referent</td>
<td>1.17 (0.90–1.52)</td>
<td>0.91 (0.79–1.06)</td>
<td>0.94 (0.78–1.14)</td>
<td>1.12 (1.02–1.24)</td>
</tr>
<tr>
<td>Bleeding</td>
<td>Referent</td>
<td>0.96 (0.89–1.04)</td>
<td>0.322</td>
<td>Referent</td>
<td>0.94 (0.86–1.04)</td>
<td>0.77 (0.59–1.02)</td>
<td>0.90 (0.86–1.18)</td>
<td>0.87 (0.87–1.33)</td>
</tr>
<tr>
<td>Vascular complication</td>
<td>Referent</td>
<td>0.98 (0.87–1.11)</td>
<td>0.784</td>
<td>Referent</td>
<td>0.93 (0.80–1.08)</td>
<td>0.77 (0.59–1.02)</td>
<td>0.90 (0.86–1.18)</td>
<td>0.87 (0.87–1.33)</td>
</tr>
<tr>
<td>Emergency CABG</td>
<td>Referent</td>
<td>1.32 (1.12–1.56)</td>
<td>0.001</td>
<td>Referent</td>
<td>1.29 (1.06–1.57)</td>
<td>0.97 (0.70–1.34)</td>
<td>1.32 (0.91–1.91)</td>
<td>1.86 (1.10–3.09)</td>
</tr>
<tr>
<td>Composite end point</td>
<td>Referent</td>
<td>1.03 (0.98–1.09)</td>
<td>0.276</td>
<td>Referent</td>
<td>1.03 (0.96–1.10)</td>
<td>0.97 (0.80–1.17)</td>
<td>0.96 (0.84–1.09)</td>
<td>0.97 (0.87–1.07)</td>
</tr>
</tbody>
</table>

CABG indicates coronary artery bypass graft; CI, confidence interval; CVD, cardiovascular disease; ICARD, interventional cardiology; and OR, odds ratio.

*Reference group is the ICARD-certified group in the primary analysis.
†Reference group is the ICARD group certified before 1999 in the secondary analysis.
ICARD certification was a relatively recent event, and most if not all non–ICARD-certified physicians participated in a training program even if it was not formally recognized. Thus, our findings may not be generalizable to other specialties.

Conclusions
We found that the outcomes of patients undergoing PCI were excellent and varied modestly, depending on the certification status of the performing physician. Our findings suggest that there is an opportunity to enhance the value of subspecialty certification.

Acknowledgments
Drs Curtis and Fiorilli had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Disclosures
Dr Lipner is currently employed by ABIM. Drs Hess and Holmboe were employed by ABIM when the study began. Dr Hess is currently a consultant for ABIM and is co-inventor on a US patent (No. 08452610) titled “Method and System for Determining a Fair Benchmark for Physicians’ Quality of Patient Care.” Dr Holmboe receives royalties for a textbook from Mosby-Elsevier. Dr Curtis receives salary support from the American College of Cardiology’s NCDR to provide analytic services and from the Centers for Medicare & Medicaid Services to support development of quality measures. Dr Curtis holds equity interest in Medtronic. The other authors report no conflicts.

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**CLINICAL PERSPECTIVE**

We examined whether the care and outcomes of percutaneous coronary intervention procedures performed by physicians certified in interventional cardiology by the American Board of Internal Medicine differed from those performed by noncertified physicians. To accomplish this, we linked data from the National Cardiovascular Disease Registry’s CathPCI Registry with physician certification data from the American Board of Internal Medicine. The primary end points assessed were all-cause in-hospital mortality and bleeding complications, and secondary end points included need for emergency coronary artery bypass grafting, vascular complications, and a composite end point of any adverse outcome. Our analysis included 510708 percutaneous coronary intervention procedures performed by 5175 interventional cardiologists. We adjusted for baseline patient and physician characteristics, including years since certification in cardiovascular medicine (a proxy for experience) and annual physician volume. Overall, we did not observe a consistent association between initial certification and in-hospital outcomes of patients undergoing percutaneous coronary intervention. The adjusted risks of in-hospital mortality and emergency bypass surgery were significantly higher in the group of patients treated by noncertified physicians, but there were no significant differences in risk of other end points. The clinical significance of the bleeding and mortality differences was modest, corresponding to 1 additional death for every 1250 patients treated by noncertified physicians and 1 additional emergency bypass surgery for every 3333 patients treated. Given the significant time commitment and financial investment required for certification, our findings suggest the opportunity to enhance the value of subspecialty certification.
Association of Physician Certification in Interventional Cardiology With In-Hospital Outcomes of Percutaneous Coronary Intervention
Paul N. Fiorilli, Karl E. Minges, Jeph Herrin, John C. Messenger, Henry H. Ting, Brahmajee K. Nallamothu, Rebecca S. Lipner, Brian J. Hess, Eric S. Holmboe, Joseph J. Brennan and Jeptha P. Curtis

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