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Association of Physician Certification and Outcomes Among Patients Receiving an Implantable Cardioverter-Defibrillator

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Abstract

Context—Allowing nonelectrophysiologists to perform implantable cardioverter-defibrillator (ICD) procedures is controversial. However, it is not known whether outcomes of ICD implantation vary by physician specialty.

Objective—To determine the association of implanting physician certification with outcomes following ICD implantation.

Design, Setting, and Patients—Retrospective cohort study using cases submitted to the ICD Registry performed between January 2006 and June 2007. Patients were grouped by the certification

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status of the implanting physician into mutually exclusive categories: electrophysiologists, nonelectrophysiologist cardiologists, thoracic surgeons, and other specialists. Hierarchical logistic regression models were developed to determine the independent association of physician certification with outcomes.

Main Outcome Measures—In-hospital procedural complication rates and the proportion of patients meeting criteria for a defibrillator with cardiac resynchronization therapy (CRT-D) who received that device.

Results—Of 111 293 ICD implantations included in the analysis, 78 857 (70.9%) were performed by electrophysiologists, 24 399 (21.9%) by nonelectrophysiologist cardiologists, 1862 (1.7%) by thoracic surgeons, and 6175 (5.5%) by other specialists. Compared with patients whose ICD was implanted by electrophysiologists, patients whose ICD was implanted by either nonelectrophysiologist cardiologists or thoracic surgeons were at increased risk of complications in both unadjusted (electrophysiologists, 3.5% [2743/78 857]; nonelectrophysiologist cardiologists, 4.0% [970/24 399]; thoracic surgeons, 5.8% [108/1862]; $P < .001$) and adjusted analyses (relative risk [RR] for nonelectrophysiologist cardiologists, 1.11 [95% confidence interval {CI}, 1.01–1.21]; RR for thoracic surgeons, 1.44 [95% CI, 1.15–1.79]). Among 35 841 patients who met criteria for CRT-D, those whose ICD was implanted by physicians other than electrophysiologists were significantly less likely to receive a CRT-D device compared with patients whose ICD was implanted by an electrophysiologist in both unadjusted (electrophysiologists, 83.1% [21 303/25 635]; nonelectrophysiologist cardiologists, 75.8% [5950/7849]; thoracic surgeons, 57.8% [269/465]; other specialists, 74.8% [1416/1892]; $P < .001$) and adjusted analyses (RR for nonelectrophysiologist cardiologists, 0.93 [95% CI, 0.91–0.95]; RR for thoracic surgeons, 0.81 [95% CI, 0.74–0.88]; RR for other specialists, 0.97 [95% CI, 0.94–0.99]).

Conclusions—In this registry, nonelectrophysiologists implanted 29% of ICDs. Overall, implantations by a nonelectrophysiologist were associated with a higher risk of procedural complications and lower likelihood of receiving a CRT-D device when indicated compared with patients whose ICD was implanted by an electrophysiologist.

Increases in the population of patients eligible for implantable cardioverter-defibrillator (ICD) therapy have led to a controversy over which physicians should implant ICDs.[1–7] Currently, physicians with different training implant ICDs. The training paths range from completion of an electrophysiology fellowship accredited by the American Board of Internal Medicine to industry-sponsored training programs.[8] Proponents of nonelectrophysiologist cardiologists implanting ICDs have suggested that a shortage of certified electrophysiologists could delay or prevent eligible patients from receiving this potentially life-saving therapy.[9,10] Opponents have raised concerns about the qualifications and procedural outcomes of nonelectrophysiologist cardiologists and questioned the need for more physicians who implant ICDs.[10–12] In an effort to establish standards for nonelectrophysiologist cardiologists, the Heart Rhythm Society has proposed a minimum training requirement that emphasizes didactic education and a minimum case volume. However, this approach has not been universally adopted by either hospitals or payers.[8,9]

Complicating this debate is the limited evidence comparing outcomes of ICD implantations achieved by groups with different training. An ICD implantation requires that physicians have the knowledge and skills necessary to safely implant the device that most closely matches the needs of the individual patient. Differences in training, experience, and technique may result in differences in rates of procedural complications. In addition, appropriate device selection is particularly important for patients who may benefit from an ICD capable of providing cardiac resynchronization therapy (CRT-D). A CRT-D device improves survival and quality of life in patients with systolic heart failure and abnormal ventricular conduction, but physicians who implant ICDs may be unfamiliar with indications for CRT-D or may lack the training necessary to implant a lead via the coronary sinus. It is not known whether the use of CRT-D among patients who meet criteria for this therapy varies by the training of implanting physicians.

To address these issues, we analyzed data from the ICD Registry, a national procedure-based registry of ICD implantations. The registry captures detailed clinical information about patient status, implanting physician, and in-hospital outcomes. In the present analysis, we assessed the association of physician certification with rates of ICD procedural complications and CRT-D implantation.

METHODS

Data Source

The ICD Registry was established in April 2006 at the behest of multiple governmental agencies, hospitals, industry, and professional societies to meet the requirements of the Centers for Medicare & Medicaid Services' Coverage with Evidence Development decision.[13] The registry has been funded by a combination of hospital fees and grants from both device companies and payers. Hospitals are required to submit data on all Centers for Medicare & Medicaid Services patients who receive an ICD implantation for primary prevention of sudden cardiac death. However, more than 75% of hospitals report data on all ICD implantations (irrespective of indication and payer), and these hospitals submit more than 88% of all cases in the registry.[13] The registry collects more than 130 data elements at the time of initial ICD implantation, device upgrade, and device replacement.

Patient Population

All patients whose implant data were submitted to the registry between January 2006 and June 2007 and passed its data quality standards (91.5% of submitted cases) were eligible for analysis (n = 146 381). Patients aged 18 years or younger (n = 212), those who had an epicardial lead placed (n = 2689), and those with prior ICD implantation (27 841) were excluded. In addition, given a known volume-outcome relationship among ICD implantations,[14] patients whose physician submitted fewer than 10 ICD procedures during the study period (n = 4346) were excluded, leaving 111 293 patients undergoing initial ICD implantations by 2128 physicians in 1062 hospitals available for analysis.

Determination of Physician Certification

A combination of name and either National Provider Identifier or Unique Physician Identification Number was used to create a merged data set representative of each physician's procedures. Certification was confirmed manually using the databases of the American Board of Internal Medicine, Society for Thoracic Surgery, and the American College of Surgery. Physicians were grouped into mutually exclusive categories reflecting their current professional certification. The specific categories were electrophysiologists, nonelectrophysiologist cardiologists, thoracic surgeons, and other specialists. The other specialists group consisted of physicians who were not currently certified by any of the professional societies listed above. These included internists and surgeons who either had never been board certified or who had let their board certification lapse.

Outcomes

The first outcome was the occurrence of any procedural complication following ICD implantation. Complications occurring during or after the implant procedure until the time of hospital discharge are reported by implanting centers using standard definitions.[15] Complications were further categorized as major or minor using a previously developed classification scheme. Major adverse events included in-hospital death, cardiac arrest, cardiac perforation, cardiac valve injury, coronary venous dissection, hemothorax, pneumothorax, deep phlebitis, transient ischemic attack, stroke, myocardial infarction, pericardial tamponade, and arterial-venous fistula. Minor adverse events included drug reaction, conduction block, hematoma, lead dislodgement, peripheral embolus, superficial phlebitis, peripheral nerve injury, and infection related to the device.

The second outcome was whether patients who met criteria for CRT-D received that device. Patients were deemed eligible for resynchronization therapy if they met the following criteria: QRS duration of 120 milliseconds or higher; left ventricular ejection fraction (LVEF) of 35% or less; and New York Heart Association (NYHA) classes III or IV. These criteria are based on the 2005 American College of Cardiology and American Heart Association guidelines on the management of heart failure and the 2008 guidelines from the American College of Cardiology, American Heart Association, and Heart Rhythm Society for device-based therapy of cardiac rhythm abnormalities.[16,17]

Finally, whether patients who received an ICD for primary prevention of sudden cardiac death met the major inclusion criteria of key primary prevention studies was assessed. Patients were considered as meeting criteria if they matched at least 1 of the following groups (1) history of heart failure, NYHA class II, III, or IV symptoms at the time of implantation and LVEF of 35% or less, (2) history of myocardial infarction more than 40 days prior to implant and LVEF of 30% or less, and (3) ischemic heart disease, LVEF of 40% or less, history of nonsustained ventricular tachycardia, and an abnormal electrophysiology study.[1,4-7]

Analysis

The unadjusted differences in demographics, comorbid conditions, cardiac status, and rates of complications across physician categories were examined using χ^2 tests for categorical variables and the F test in analysis of variance for continuous variables using a 1-tailed test with 95% level for significance. The analysis of variance was performed using generalized linear models because of the unbalanced data among different physician categories. Individual centers determined and reported the race and ethnicity of patients undergoing ICD implantation. Analyses were further stratified by specific device types (single chamber, dual chamber, and biventricular) and by complication severity (major or minor).

Hierarchical generalized logistic regression models were developed to determine the independent association of physician certification and risk of in-hospital complications that accounted for clustering of patients within hospitals.[18] Model variables included demographics (age, sex, race, reason for admission), cardiac status (heart failure, NYHA class, atrial fibrillation, ventricular fibrillation, history of cardiac arrest, ischemic heart disease, LVEF, QRS duration), comorbidities (peripheral vascular disease, prior stroke, chronic lung disease, diabetes, hypertension, renal function, dialysis), physician volume, hospital volume and characteristics (bed size, census region, profit status, teaching status), and device type. Physician volume was included as a second-level variable. For all variables except LVEF, the rate of missing values was less than 1%. Accordingly, for categorical variables, missing data were assumed to represent a "no" response. For missing values for continuous variables, the median value was imputed for the entire cohort. In addition, for LVEF, a dummy variable was added to the model to indicate when it was missing. To assess the robustness of the findings, analyses were repeated in the following patient subgroups: Medicare and Medicaid patients, patients who did not undergo either percutaneous coronary intervention or coronary artery bypass graft surgery during the index hospitalization, and patients whose implants were performed at a hospital in which an electrophysiologist implanted ICDs.

In the cohort of patients eligible for CRT-D, baseline characteristics and unadjusted rates of CRT-D were compared across physician categories. A second hierarchical generalized logistic regression model was developed to assess the independent association of physician certification and CRT-D implantation. Variables included in the model were similar to the model developed for in-hospital complications, but excluded device type. Because the rate of CRT-D implantation was high, odds ratios were converted to relative risks (RRs) using the method of Zhang and Yu.[19] The analyses were repeated in the subgroups listed above. Because the effectiveness of CRT-D in a patient with atrial fibrillation is less certain, an additional subgroup analysis was performed excluding patients with a history of atrial fibrillation.

In the cohort of patients who received an ICD for the primary prevention of sudden cardiac death, baseline characteristics and unadjusted proportions of patients who met inclusion criteria were compared across physician categories. A third hierarchical generalized logistic regression model was developed to assess the independent association of physician certification and the proportion of patients meeting trial criteria. Variables included in the model were similar to the model developed for in-hospital complications, but excluded variables used to define trial eligibility, which were heart failure, ischemic heart disease, prior myocardial infarction, NYHA class, and ventricular tachycardia.

To further assess the association of physician certification with complications and use of CRT-D, propensity analyses were performed to match patients of electrophysiologists with patients of nonelectrophysiologists. This approach was repeated separately to match patients of electrophysiologists with patients of nonelectrophysiologist cardiologists, thoracic surgeons, and other specialists. In the matched cohorts, complication rates, use of CRT-D, and the proportion of patients meeting criteria for key primary prevention trials were compared between physician groups.

To assess the degree to which lack of access to electrophysiologists was associated with implants performed by nonelectrophysiologists, the proportion of implants that were performed by nonelectrophysiologists at hospitals that did and did not have electrophysiologists implanting ICDs was determined. The median distance between hospitals with and without an electrophysiologist also was determined and implantations performed by nonelectrophysiologists were categorized by the distance to a hospital in which electrophysiologists implanted ICDs. All analyses were performed using SAS statistical software version 9.1 (SAS Institute Inc, Cary, North Carolina). The Yale University human investigation committee approved the analysis and determined that informed consent was not applicable to the data collected by the registry.

RESULTS

A total of 2128 physicians (1303 electrophysiologists, 614 nonelectrophysiologist cardiologists, 66 thoracic surgeons, and 145 other specialists) were identified who performed 10 or more ICD implantations submitted to the ICD Registry between January 2006 and June 2007. The majority of implants were performed by electrophysiologists (70.9%), with fewer implants performed by nonelectrophysiologists (nonelectrophysiologist cardiologists, 21.9%; thoracic surgeons, 1.7%; and other specialists, 5.5%).

The characteristics of patients undergoing ICD implantation differed by physician specialty in several respects, notably by age, race, and payer status (TABLE 1). There were statistically significant but clinically modest differences in measures of cardiac status such as history of congestive heart failure, NYHA class, prior cardiac arrest, history of atrial fibrillation, history of ventricular fibrillation, diabetes, hypertension, chronic lung disease, cerebrovascular disease, and use of revascularization procedures. Similarly, there were modest differences in LVEF, QRS duration, and blood urea nitrogen measurements across physician certification categories. The proportions of patients receiving an ICD for primary prevention of sudden cardiac death were similar across physician categories, but the type of device implanted varied substantially. Mean procedural volume was highest among electrophysiologists and lowest among thoracic surgeons. The characteristics of hospitals including census location, profit type, community, bed size, and teaching status also varied across physician categories.

The crude rates of complications varied significantly across physician certification categories (TABLE 2). The rates of overall and major complications were lowest among electrophysiologists at 3.5% and 1.3%, respectively, and highest among thoracic surgeons at 5.8% and 2.5%, respectively. Overall complication rates differed significantly by device type, ranging from 2.2% for single chamber devices to 5.1% for CRT-D devices. The differences in complication rates by physician certification varied by device type. Among patients who received a single-chamber ICD, total complication rates were not significantly different across physician certification categories. In contrast, there were significant differences across complication rates of dual-chamber ICDs and CRT-D devices across physician categories ($P < .001$ for interaction). For most of the individual complications, the rates did not vary significantly across physician certification categories (TABLE 3). However, rates of certain complications, notably cardiac arrest, hematoma, lead dislodgement, and pneumothorax were lowest among electrophysiologists and higher in other physician certification groups. In multivariable analysis, the risk of a complication was significantly associated with physician certification. Compared with electrophysiologists, the adjusted risk of complication among nonelectrophysiologist cardiologists and thoracic surgeons was significantly higher (TABLE 4). The complication rate of other specialists was comparable to that of electrophysiologists and nonelectrophysiologist cardiologists, with wide 95% confidence intervals (CIs) that overlapped in both groups. The interaction between physician certification and device type was not significant. Results were comparable in subgroup analyses. However, in 2 subgroups (Centers for Medicare & Medicaid Services patients; implants performed at hospitals with electrophysiologists), the 95% CIs crossed the line of unity.

Among patients included in the analysis, 35 841 (32.2%) met criteria for CRT-D. The proportion of patients potentially eligible for CRT-D varied across physician categories (electrophysiologists, 25 635 [32.5%]; nonelectrophysiologist cardiologists, 7849 [32.2%]; thoracic surgeons, 465 [25.0%]; other specialists, 1892 [30.6%]; $P < .001$). Overall, 28 924 (80.7%) of eligible patients received a CRT-D device. The unadjusted proportion of eligible patients who received a CRT-D device varied significantly across physician categories (electrophysiologists, 21 303 [83.1%]; nonelectrophysiologist cardiologists, 5950 [75.8%]; thoracic surgeons, 269 [57.8%]; other specialists, 1416 [74.8%]; $P < .001$). In multivariable analysis, patients eligible for CRT-D whose ICD was implanted by nonelectrophysiologists were significantly less likely to receive a CRT-D device compared with patients whose ICD was implanted by electrophysiologists (Table 4). Results were comparable in all subgroup analyses.

In the study cohort, 92 801 patients (83.4%) received an ICD for the primary prevention of sudden cardiac death. This proportion varied by physician category (Table 1). Overall, the number of patients who received an ICD for the primary prevention of sudden cardiac death and met criteria for the primary prevention studies was 77 086 (83.1%). This proportion varied modestly across physician certification categories in both unadjusted (electrophysiologists, 54 977 [83.5%]; nonelectrophysiologist cardiologists, 16 771 [82.4%]; thoracic surgeons, 1185 [76.8%]; other specialists, 4153 [81.9%]; overall $P < .001$) and adjusted analyses (RR for nonelectrophysiologist cardiologists, 0.99 [95% CI, 0.98–1.01]; RR for thoracic surgeons, 0.92 [95% CI, 0.88–0.96]; RR for other specialists, 0.98 [95% CI, 0.96–1.00]).

In the propensity analyses, 13 705 patients of electrophysiologists were matched with 13 705 patients of nonelectrophysiologist cardiologists, 868 patients of electrophysiologists were matched with 868 patients of thoracic surgeons, and 4390 patients of electrophysiologists were matched with 4390 patients of other specialists. In each matched cohort, the absolute differences in outcomes between electrophysiologists and nonelectrophysiologists were comparable with those of the overall analysis.

Among the 1062 hospitals included in the analysis, 827 (78%) had an electrophysiologist implanting ICDs, and these hospitals submitted 99 818 (90%) of ICD implants included in the analysis. Among 32 436 ICDs implanted by nonelectrophysiologists, 20 761 (64%) were implanted at hospitals with an electrophysiologist on staff (TABLE 5). The median distance between hospitals with and without electrophysiologists was 36.8 km (interquartile range, 8–72 km). Only 2851 ICDs (8.8%) implanted by nonelectrophysiologists were at hospitals that were located more than 80 km from a hospital with an electrophysiologist on staff.

COMMENT

We demonstrate that among patients undergoing ICD implantation, complication rates vary by the board certification status of the implanting physician. Nonelectrophysiologists, particularly those certified in thoracic surgery, have higher complication rates compared with electrophysiologists. Further, nonelectrophysiologists are significantly less likely to implant CRT-D devices in patients meeting established guideline criteria for this therapy. Finally, the majority of ICD implantations performed by nonelectrophysiologists took place at or relatively near hospitals in which an electrophysiologist also implanted ICDs.

Electrophysiologists perform the majority of implants captured by the ICD Registry, and the overall in-hospital complication rate is low. However, we identified significant differences in complication rates across physician categories such that the complication rates of physicians certified in nonelectrophysiology cardiology and thoracic surgery were higher than those of electrophysiology. These findings build upon those of Al-Khatib et al,[20] who reported that the complication rate of thoracic surgeons was significantly higher than that of other physician categories. However, their analysis used administrative claims data, which limited their ability to adjust for potentially important differences in case mix. Our finding of increased risk associated with nonelectrophysiologist cardiologists differs from their analysis and may reflect differences in both sample size and the period of assessment. In our analysis, there was 1 excess complication for every 64 implantations performed by thoracic surgeons and 1 for every 262 implantations performed by cardiologists. Applied to the study population, ICD implants by thoracic surgeons and cardiologists were associated with approximately 122 excess complications. Although the absolute number of excess complications is modest, particularly in the comparison of nonelectrophysiologist cardiologists with electrophysiologists, they are clinically significant given their impact on quality of life, length of stay, and increased cost.[21]

The mechanisms underlying the observed differences in complication rates are not clear, but they may reflect differences in training, experience, and operative technique. We cannot exclude the possibility of unmeasured differences in the characteristics of patients cared for by physician categories that may confound the observed relationship between physician certification and outcome. However, our findings persisted after multivariable adjustment that accounted for measured differences in a wide range of patient characteristics as well as the procedural volume of the physicians. Furthermore, our findings are consistent with literature supporting the association of specialty training with improved outcomes in a broad range of patient populations.[22–25]

Our data also suggest that nonelectrophysiologists are less likely to implant CRT-D devices in patients who have been shown to benefit from this therapy. Given the substantial benefits associated with CRT-D both in terms of improved survival and quality of life, the decision not to implant a CRT-D device carries significant implications for patient care.[16,17] Compared with the rates of CRT-D implantation by electrophysiologists, thoracic surgeons missed 1 CRT-D opportunity for every 6 patients who might have benefited from it. Cardiologists missed 1 CRT-D opportunity for every 17 eligible patients, and other specialists missed 1 CRT-D opportunity for every 40 eligible patients. In total, up to 570 fewer patients received a CRT-D device than if the implantations had been performed by electrophysiologists.

Although speculative, observed differences in rates of CRT-D implantation may be due to differences in knowledge base (ie, indications for CRT-D) or technical skills (ie, expertise in coronary sinus lead placement). However, the analysis also may be confounded by differences in case mix. Not all patients who meet criteria for CRT-D would necessarily benefit from it. For example, the ICD Registry does not capture measures of mechanical cardiac dyssynchrony, which has been proposed as a method of identifying patients who are more likely to benefit from CRT-D. However, studies of dyssynchrony-guided CRT-D have yielded inconsistent results.[26] Similarly, we were unable to determine whether patients were in sinus rhythm at the time of ICD implantation, which is relevant because the benefits of CRT-D in patients with atrial fibrillation or flutter are less certain.27 Nevertheless, findings were unchanged when we restricted the analysis to patients without a history of atrial fibrillation or flutter.

The main justification for training nonelectrophysiologists to implant ICDs has been that it could improve access to a potentially life-saving technology. Proponents have argued that there are too few electrophysiologists to keep up with the increased demand for ICDs created by expanding indications. Our analysis, however, suggests that the majority of ICDs implanted by nonelectrophysiologists are not significantly affecting geographic access. The median distance between hospitals with and without electrophysiologists was modest, and two-thirds of implantations by nonelectrophysiologists were performed at hospitals in which an electrophysiologist was also implanting ICDs. The availability of nonelectrophysiologists to implant ICDs could still improve access if wait times for electrophysiologists were excessive, but published survey data suggests that this is not the case.[28] Thus, for the majority of patients, factors other than geography, including preexisting referral patterns, financial remuneration, or patient preference may influence the decision to proceed with implantation by a nonelectrophysiologist. Accordingly, it may be appropriate for hospitals and payers to reassess whether implantations by nonelectrophysiologists are warranted in a given location, balancing potential barriers to access to electrophysiologists against the potential benefits observed in our analysis associated with implants by electrophysiologists.

Aspects of this analysis merit further consideration. First, our analysis of procedural complications was limited to events occurring during the index hospitalization. Accordingly, it is not known whether the current findings can be extended to longer periods of assessment. Nevertheless, previous studies have demonstrated that most ICD-associated complications with the exception of infection are recognized during the index hospitalization.[20] Second, this analysis reflects the average results within each physician category. There may be substantial variation within each group such that there are nonelectrophysiologists who achieve excellent patient outcomes as well as electrophysiologists with below-average outcomes. Third, hospitals participating in the ICD Registry are only required to submit cases mandated by the Centers for Medicare & Medicaid Services Coverage with Evidence Development, so the decision and the analysis may not reflect all cases performed by all physicians who implant ICDs. However 75% of hospitals, accounting for 88% of the reported implants, enter information on all ICD procedures to the registry.[13] In addition, results were similar when we restricted the analysis to Medicare and Medicaid patients. Fourth, we categorized physicians by their current certification status, which will differ from their training if certification is either pending or expired. We would expect, however, that misclassification of physician certification would obscure differences across physician categories. Fifth, data entered into the registry is self-reported, and planned chart reviews to assess accuracy of data have not been implemented. Finally, we restricted our analysis to physician certification, and did not consider the effect of completion of non–American Board of Internal Medicine training pathways and certification on outcomes of nonelectrophysiologists.

CONCLUSIONS

Nonelectrophysiologists implant 29% of ICDs in the ICD Registry. Patients whose ICDs are implanted by nonelectrophysiologists are at increased risk of procedural complications and are less likely to receive CRT-D when eligible compared with those whose devices are implanted by electrophysiologists. If confirmed, these findings may warrant a reappraisal of the need for and methods of training nonelectrophysiologists to implant ICDs.

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Table 1

Baseline Characteristics Stratified by Physician Certification

	Total, No. (%)[a] (N = 111 293)	Physician Certification, No. (%)[a] Electrophysiologist (n = 78 857)	Nonelectrophysiologist Cardiologist (n = 24 399)	Thoracic Surgeon (n = 1862)	Other Specialist (n = 6175)	Overall P Value
Physician volume, mean (SD)		93.7 (57.0)	76.2 (60.7)	45.5 (30.1)	71.3 (40.0)	< .001
Patient Admission Characteristics						
Age, mean (SD), y	67.8 (12.6)	67.6 (12.6)	68.1 (12.4)	70.1 (11.8)	67.3 (12.8)	< .001
Female sex	29 784 (26.8)	21 165 (26.8)	6503 (26.7)	472 (25.3)	1644 (26.6)	.50
Race						
White	91 626 (82.3)	64 652 (82.0)	20 485 (84.0)	1635 (87.8)	4854 (78.6)	
Black	13 921 (12.5)	10 146 (12.9)	2700 (11.1)	165 (8.9)	910 (14.7)	<.001
Other	5746 (5.2)	3893 (4.9)	1214 (5.0)	62 (3.3)	411 (6.7)	
Hispanic ethnicity	5683 (5.1)	3893 (4.9)	1150 (4.7)	211 (11.3)	429 (6.9)	<.001
Payer status						
Medicare	75 368 (67.7)	52 741 (66.9)	17 098 (70.1)	1398 (75.1)	4131 (66.9)	
Medicaid	4995 (4.5)	3429 (4.3)	1137 (4.7)	63 (3.4)	366 (5.9)	
Commercial or HMO	26 790 (24.1)	19 782 (25.1)	5252 (21.5)	333 (17.9)	1423 (23.0)	<.001
Other or self-pay	4140 (3.7)	2905 (3.7)	912 (3.7)	595 (3.2)	155 (2.5)	
Patient History and Risk Factors						
History of heart failure	86 834 (78.0)	61 706 (78.3)	18 866 (77.3)	1418 (76.2)	4844 (78.4)	.003
NYHA class (current status)						
I	14 062 (12.6)	10 395 (13.2)	2712 (11.1)	243 (13.1)	712 (11.5)	
II	39 471 (35.5)	28 338 (35.9)	8348 (34.2)	623 (33.5)	2162 (35.0)	
III	52 604 (47.3)	36 911 (46.8)	11 891 (48.7)	817 (43.9)	2985 (48.3)	<.001
IV	5156 (4.6)	3213 (4.1)	1448 (5.9)	179 (9.6)	316 (5.1)	
Prior cardiac arrest						

	Total, No. (%)[a] (N = 111 293)	Physician Certification, No. (%)[a] Electrophysiologist (n = 78 857)	Nonelectrophysiologist Cardiologist (n = 24 399)	Thoracic Surgeon (n = 1862)	Other Specialist (n = 6175)	Overall *P* Value
Bradycardia	1041 (0.9)	694 (0.9)	258 (1.1)	30 (1.6)	59 (1.0)	<.001
Tachycardia	8648 (7.8)	6336 (8.0)	1700 (7.0)	110 (5.9)	502 (8.1)	
History of atrial fibrillation	34 656 (31.1)	24 582 (31.2)	7507 (30.8)	665 (35.7)	1902 (30.8)	<.001
History of ventricular tachycardia						
Nonsustained	26 184 (23.5)	18 677 (23.7)	5351 (21.9)	517 (27.8)	1639 (26.5)	<.001
Monomorphic sustained	9252 (8.3)	6785 (8.6)	1798 (7.4)	104 (5.6)	565 (9.1)	
Polymorphic sustained	2574 (2.3)	1937 (2.5)	433 (1.8)	33 (1.8)	171 (2.8)	
Nonischemic dilated cardiomyopathy	35 096 (31.5)	25 136 (31.9)	7454 (30.6)	536 (28.8)	1970 (31.9)	<.001
Ischemic heart disease	73 463 (66.0)	51 503 (65.3)	16 623 (68.1)	1295 (69.5)	4042 (65.5)	<.001
Previous myocardial infarction	60 984 (54.8)	42 739 (54.2)	13 800 (56.6)	1079 (57.9)	3366 (54.5)	<.001
Previous revascularization	60 333 (54.2)	42 275 (53.6)	13 766 (56.4)	1044 (56.1)	3248 (52.6)	<.001
Cerebrovascular disease	16 220 (14.6)	11 130 (14.1)	3856 (15.8)	367 (19.7)	867 (14.0)	<.001
Chronic lung disease	24 733 (22.2)	16 757 (21.2)	5924 (24.3)	550 (29.5)	1502 (24.3)	<.001
Diabetes	40 977 (36.8)	28 702 (36.4)	9145 (37.5)	742 (39.8)	2388 (38.7)	<.001
Hypertension	82 123 (73.8)	57 409 (72.8)	18 526 (75.9)	1509 (81.0)	4679 (75.8)	<.001
End-stage renal disease	4581 (4.1)	3208 (4.1)	973 (4.0)	113 (6.1)	287 (4.6)	<.001
Revascularization during admission						
Coronary artery bypass graft surgery	1684 (1.5)	1252 (1.6)	304 (1.2)	45 (2.4)	83 (1.3)	<.001
Percutaneous coronary intervention	3849 (3.5)	2729 (3.5)	812 (3.3)	115 (6.2)	193 (3.1)	<.001
Left ventricular ejection fraction, mean (SD), %	27.1 (10.5)	27.3 (10.7)	26.6 (9.1)	25.9 (9.8)	27.1 (10.5)	<.001
QRS duration, mean (SD)	125.7 (34.3)	126.1 (34.3)	125.0 (34.4)	123.2 (34.4)	124.0 (34.4)	<.001
Blood urea nitrogen level, mean (SD), mg/dL	24.3 (14.1)	24.4 (14.1)	24.2 (13.9)	25.1 (16.0)	24.2 (14.0)	.008
Primary prevention	92 801 (83.4)	65 845 (83.5)	20 342 (83.4)	1543 (82.9)	5071 (82.1)	.04
Implantable cardioverter-defibrillator type						

	Total, No. (%)[a] (N = 111 293)	Physician Certification, No. (%)[a] Electrophysiologist (n = 78 857)	Nonelectrophysiologist Cardiologist (n = 24 399)	Thoracic Surgeon (n = 1862)	Other Specialist (n = 6175)	Overall P Value
Single chamber	27 819 (25.0)	19 808 (25.1)	6254 (25.6)	378 (20.3)	1379 (22.3)	<.001
Dual chamber	44 506 (40.0)	30 546 (38.7)	10 052 (41.2)	1055 (56.7)	2853 (46.2)	
Cardiac resynchronization therapy	38 798 (34.9)	28 382 (36.0)	8057 (33.0)	428 (23.0)	1931 (31.3)	
Hospital Characteristics						
Census location						
New England	4570 (4.1)	4221 (5.4)	278 (1.1)	0	71 (1.1)	<.001
Mid-Atlantic	14 809 (13.3)	11 446 (14.5)	2380 (9.8)	361 (19.4)	622 (10.1)	
South Atlantic	25 399 (22.8)	17 645 (22.4)	5776 (23.7)	573 (30.8)	1405 (22.8)	
East North Central	21 578 (19.4)	15 491 (19.6)	3861 (15.8)	89 (4.8)	2137 (34.6)	
East South Central	9145 (8.2)	5636 (7.1)	3149 (13.0)	166 (8.9)	194 (3.1)	
West North Central	9719 (8.7)	6822 (8.7)	2393 (9.8)	128 (6.9)	376 (6.1)	
West South Central	12 129 (10.9)	7913 (10.0)	3174 (13.0)	348 (18.7)	694 (11.2)	
Mountain	4842 (4.4)	3802 (4.8)	846 (3.5)	0	194 (3.1)	
Pacific	9002 (8.1)	5803 (7.4)	2530 (10.4)	197 (10.6)	472 (7.6)	
Profit type						
Government	1226 (1.1)	694 (0.9)	255 (1.0)	163 (8.8)	114 (1.8)	<.001
Private/community	95 393 (86.0)	65 774 (83.4)	22 853 (93.7)	1593 (85.6)	5173 (83.8)	
University	14 152 (12.7)	12 031 (15.3)	1147 (4.7)	106 (5.7)	868 (14.1)	
Community						
Rural	11 082 (10.0)	6343 (8.0)	3763 (15.4)	268 (14.4)	708 (11.5)	<.001
Suburban	28 849 (26.0)	20 140 (25.7)	6490 (26.6)	580 (31.1)	1639 (26.5)	
Urban	70 840 (64.0)	52 016 (66.0)	14 002 (57.4)	1014 (54.5)	3808 (61.7)	
Patient beds, mean (SD)	488.2 (263.6)	509.2 (265.3)	430.3 (256.8)	452.4 (259.7)	458.2 (228.2)	<.001
Teaching hospital	61 413 (55.2)	46 451 (58.9)	10 544 (43.2)	933 (50.1)	3485 (56.4)	<.001

Abbreviations: HMO, health maintenance organization; NYHA, New York Heart Association.

SI conversion factor: To convert blood urea nitrogen to mmol/L, multiply by 0.357.

[a]Unless otherwise indicated. The numbers in the column headings are the total numbers of implantations performed by each physician certification category.

Table 2

Complications Stratified by Physician Certification and Device Type[a]

All Devices	Total, No. (%) (N = 111 293)	Physician Certification, No. (%) Electrophysiologist (n=78 857)	Nonelectrophysiologist Cardiologis (n=24 399)	Thoracic Surgeon (n = 1862)	Other Specialist (n = 6175)	Overall *P* Value
Any complication	4068 (3.7)	2743 (3.5)	970 (4.0)	108 (5.8)	247 (4.0)	< .001
Major complication	1623 (1.5)	1058 (1.3)	416 (1.7)	47 (2.5)	102 (1.7)	< .001
Single-Chamber ICD						
	(n = 27 819)	(n = 19 808)	(n = 6254)	(n = 378)	(n = 1379)	
Any complication	613 (2.2)	407 (2.1)	158 (2.5)	10 (2.6)	38 (2.8)	.06
Major complication	246 (0.9)	148 (0.7)	75(1.2)	5 (1.3)	18 (1.3)	.002
Dual-Chamber ICD						
	(n = 44 506)	(n = 30 546)	(n = 10 052)	(n = 1055)	(n = 2853)	
Any complication	1489 (3.3)	958 (3.1)	374 (3.7)	60 (5.7)	97 (3.4)	< .001
Major complication	647 (1.5)	409 (1.3)	171 (1.7)	28 (2.7)	39 (1.4)	< .001
Cardiac Resynchronization Therapy ICD						
	(n = 38 798)	(n = 28 382)	(n = 8057)	(n = 428)	(n = 1931)	
Any complication	1962 (5.1)	1376 (4.8)	436 (5.4)	38 (8.9)	112 (5.8)	< .001
Major complication	729 (1.9)	501 (1.8)	169 (2.1)	14 (3.3)	45 (2.3)	.01

Abbreviation: ICD, implantable cardioverter-defibrillator.

[a]The numbers in the column headings are the total numbers of implantations performed by each physician certification category.

Table 3

Individual Complications Stratified by Physician Certification

	Total, No. (%) (N = 111 293)	Physician Certification, No. (%)				
		Electrophysiologist (n = 78 857)	Nonelectrophysiologist Cardiologist (n = 24 399)	Thoracic Surgeon (n = 1862)	Other Specialist (n = 6175)	*P* Value
Hematoma	1243 (1.1)	870 (1.1)	261 (1.1)	35 (1.9)	77 (1.2)	.01
Lead dislodgement	1156 (1.0)	784 (1.0)	282 (1.2)	27 (1.5)	63 (1.0)	.05
Pneumothorax	548 (0.5)	346 (0.4)	159 (0.7)	14 (0.8)	29 (0.5)	< .001
Cardiac arrest	350 (0.3)	218 (0.3)	86 (0.4)	15 (0.8)	31 (0.5)	< .001
Coronary venous dissection	162 (0.1)	110 (0.1)	40 (0.2)	1 (<0.1)	11 (0.2)	.51
Drug reaction	121 (0.1)	84 (0.1)	33 (0.1)	0	4 (<0.1)	.19
Hemothorax	104 (0.1)	74 (0.1)	24 (0.1)	3 (0.2)	3 (<0.1)	.51
Cardiac perforation	95 (0.1)	60 (0.1)	25 (0.1)	3 (0.2)	7 (<0.1)	.33
Pericardial tamponade	86 (0.1)	52 (0.1)	24 (0.1)	3 (0.2)	7 (<0.1)	.14
Stroke	68 (0.1)	39 (0.1)	26 (0.1)	1 (<0.1)	2 (<0.1)	.01
Phlebitis (superficial)	55 (0.1)	37 (0.1)	7 (<0.1)	5 (0.3)	6 (<0.1)	< .001
Conduction block	54 (0.1)	38 (0.1)	12 (<0.1)	1 (<0.1)	3 (<0.1)	> .99
Myocardial infarction	39 (<0.1)	32 (<0.1)	0	2 (0.1)	5 (<0.1)	.001
Phlebitis (deep)	34 (<0.1)	26 (<0.1)	5 (<0.1)	2 (0.1)	1 (<0.1)	.17
Infection related to device	31 (<0.1)	22 (<0.1)	6 (<0.1)	1 (<0.1)	2 (<0.1)	.90
Transient ischemic attack	27 (<0.1)	23 (<0.1)	1 (<0.1)	0	3 (<0.1)	.08
Arteriovenous fistula	10 (<0.1)	7 (<0.1)	2 (<0.1)	0	1 (<0.1)	.91
Peripheral nerve injury	5 (<0.1)	5 (<0.1)	0	0	0	.56
Cardiac valve injury	2 (<0.1)	2 (<0.1)	0	0	0	.84
Peripheral embolus	0	0	0	0	0	.37

Table 4

Independent Association of Physician Certification

	Physician Certification, RR (95% CI)			
	Electrophysiologist	Nonelectrophysiologist Cardiologist	Thoracic Surgeon	Other Specialist
		With Complications[a]		
Overall	1 [Reference]	1.11 (1.01–1.21)	1.44 (1.15–1.79)	1.09 (0.94–1.26)
Subgroup analyses				
Medicare and Medicaid patients only	1 [Reference]	1.07 (0.97–1.17)	1.48 (1.16–1.88)	1.06 (0.90–1.24)
Patients without PCI or CABG surgery during admission	1 [Reference]	1.10 (1.00–1.20)	1.41 (1.11–1.78)	1.10 (0.95–1.28)
Implants performed at hospitals with an electrophysiologist	1 [Reference]	1.09 (0.99–1.21)	1.61 (1.24–2.09)	1.05 (0.89–1.23)
		With Use of Cardiac Resynchronization Therapy[b]		
Overall	1[Reference]	0.93 (0.91–0.95)	0.81 (0.74–0.88)	0.97 (0.94–0.99)
Subgroup analyses				
Medicare and Medicaid patients only	1 [Reference]	0.93 (0.91–0.95)	0.81 (0.73–0.88)	0.97 (0.94–1.00)
Patients without PCI or CABG surgery during admission	1 [Reference]	0.94 (0.92–0.96)	0.84 (0.76–0.90)	0.97 (0.93–1.00)
Implants performed at hospitals with an electrophysiologist	1 [Reference]	0.94 (0.92–0.96)	0.86 (0.78–0.93)	0.97 (0.94–1.00)
Patients with no history of atrial fibrillation	1 [Reference]	0.93 (0.90–0.96)	0.79 (0.66–0.86)	0.97 (0.93–1.00)

Abbreviations: CABG, coronary artery bypass graft; CI, confidence interval; PCI, percutaneous coronary intervention; RR, relative risk.

[a]Adjusted for patient characteristics (age, sex, race, payer status, reason for admission, prior heart failure, current New York Heart Association symptom status, cardiac arrest, atrial fibrillation, ventricular tachycardia, etiology of cardiomyopathy, prior myocardial infarction, prior revascularization, prior valve surgery, cerebrovascular disease, chronic lung disease, diabetes, hypertension, renal failure, left ventricular ejection fraction, QRS duration, blood urea nitrogen, implantable cardioverter-defibrillator device type), physician volume, hospital volume, and hospital characteristics (census region, profit type, location, bed size, and teaching status).

[b] Adjusted for everything in footnote [a] except for device type.

Table 5

Geographic Distribution of Nonelectrophysiologist Implants

	Total, No. (%) (n = 32 436)	Physician Certification, No. (%)			Overall *P* Value
		Nonelectrophysiologist Cardiologist (n = 24 399)	Thoracic Surgeon (n = 1862)	Other Specialist (n = 6175)	
Electrophysiologist in hospital	20 761 (64.0)	14 779 (60.6)	1239 (66.5)	4816 (78.0)	<.001
Distance to hospital with electrophysiologist, km					
≤40	5864 (18.1)	4671 (19.1)	298 (16.0)	860 (13.9)	
41–80	2960 (9.1)	2547 (10.4)	69 (3.7)	330 (5.3)	
81–160	2667 (8.2)	2292 (9.4)	235 (12.6)	118 (1.9)	
>160	184 (0.6)	110 (0.5)	21 (1.1)	51 (0.8)	