Impact of Community Wealth on Use of Cardiac-Resynchronization Therapy With Defibrillators for Heart Failure Patients

Steven A. Farmer, MD, PhD; Elizabeth J. Tuohy, MD; Dylan S. Small, PhD; Yongfei Wang, MS; Peter W. Groeneveld, MD, MS

Background—Disparities in cardiovascular disease treatment are a major health policy concern. A complex interplay of patient, provider, and social contextual factors affect inequities in care.

Methods and Results—We used data regarding 22,205 patient stays in the National Cardiovascular Data Registry to explore the effect of hospital resources on receipt of a heart failure therapy, cardiac-resynchronization therapy with defibrillation (CRT-D). When added to patient-level variables, hospital ownership, cardiac patient volume, cardiac procedure availability, CRT-D, implantable cardioverter-defibrillator implantation volumes, and hospital financial characteristics were individually predictive of CRT-D receipt. In the full hierarchical model, average median household income ($P<0.0001$) and implantable cardioverter-defibrillator implantation volume ($P<0.001$) remained significant predictors of CRT-D receipt. Patients treated at hospitals in affluent communities were more likely to receive CRT-D than patients treated in poor communities, despite accounting for other patient and hospital characteristics, including insurance status.

Conclusions—These findings suggest that the likelihood of receiving CRT-D is mediated by community wealth and hospital resources, and that health policy targeting insurance coverage alone may be ineffective in resolving inequities in care. (Circ Cardiovasc Qual Outcomes. 2012;5:798-807.)

Key Words: defibrillation ■ heart failure ■ pacing ■ registries

Disparities in health care and health outcomes based on racial, ethnic, sex, and geographic differences have been widely described. A myriad of reasons have been invoked to explain inequities in care, including issues related to patients, providers, and healthcare systems.1–8 Disparities in the treatment of cardiovascular diseases are a major health policy concern; however, a complex interplay of patient, provider, and contextual factors complicate health disparities research. For example, patient preferences may lead to legitimate variations in care, and variations in health insurance status might result in differential access to care. Provider-level factors such as level of training, experience, and extent of hospital resources impact quality of care. Finally, health care occurs in a broader social context, and factors such as community wealth, cultural norms, and infrastructure may affect the availability of advanced healthcare resources. In this article, we make a distinction between hospital fiscal health, as reflected in hospital operating margin, and community wealth, as defined by the median household income of the zip code where the hospital is located.

Using data from a large national registry, we previously demonstrated variations by race and ethnicity in use of medical devices for the treatment of advanced heart failure.9 Patients in the study received either an implantable cardioverter-defibrillator (ICD) or cardiac-resynchronization therapy with defibrillation (CRT-D). An ICD is indicated in patients who have severe systolic heart failure or in patients who are survivors of sudden cardiac death.10 CRT-D is a more advanced technology that, in addition to defibrillation, synchronizes left and right ventricular contraction, thereby improving overall cardiac function. A CRT-D is indicated in patients with systolic dysfunction (left ventricular ejection fraction <35%), evidence of electrical dyssynchrony (QRS >120 ms), and New York Heart Association Class III or IV heart failure despite optimal medical therapy.11,12 For eligible patients, CRT-D has been shown to reduce mortality, reduce hospitalizations, and improve quality of life compared with ICD alone.13–16 The cost of implantation is $28,000 to $39,000 for either of the devices.17 Notably, implantation of CRT-D is more technically challenging and

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WHAT IS KNOWN

• Research on healthcare disparities is complicated by a complex interplay of patient, provider, and contextual factors.
• Variations by race and ethnicity exist in the use of medical devices for the treatment of advanced heart failure, especially in the use of sophisticated technologies such as cardiac-resynchronization therapy with defibrillators.

WHAT THE STUDY ADDS

• This article adds to the understanding of how contextual factors impact cardiovascular health disparities.
• The analysis illustrates how community wealth has a greater impact on the care that patients receive than any single socioeconomic or demographic factor.
• The findings have important implications for efforts to address healthcare disparities.

requires special training. In the present analysis, we examine the effect of social context on the likelihood of CRT-D receipt. Specifically, among patients with severe heart failure who were eligible for CRT-D in the NCDR ICD Registry, we assess the relative impact of patient-, hospital-, and community-level factors on the likelihood of CRT-D receipt.

Methods

Data

The National Cardiovascular Data Registry-Implantable Cardioverter-Defibrillator (NCDR-ICD) Registry was developed in collaboration with the American College of Cardiology and the Heart Rhythm Society. This registry includes a rich data set of clinical and socioeconomic information for patients who have received an ICD/CRT-D.15-20 Since 2005, registry use has been mandated by the Centers for Medicare and Medicaid Services, although there has been widespread registration of non-Medicare recipients of all devices.19-20 Hospital-level data sets were linked by each hospital’s single, unique institutional Medicare provider number.

Using Medicare Provider Analysis and Review data, we formed a hospital-level data set by identifying hospitals from fee-for-service hospital claims in 2006 and merging these claims with hospital-level data from the 2006 Hospital Cost Report Information System, the 2000 US Census, the 2002 Area Resource File, and data from the American Association of Medical Colleges. The NCDR Registry data and hospital-level data sets were linked by each hospital’s single, unique institutional Medicare provider number.

Patient Cohort

Of 108,341 patients in the NCDR-ICD Registry, 22,205 patients were eligible for the study (Figure 1). Patients who did not meet American College of Cardiology criteria for CRT-D were excluded (n=73,043). The criteria for CRT-D are QRS duration >120 ms, left ventricular ejection fraction <35%, New York Heart Association Class III or IV congestive heart failure, and concurrent optimal pharmacotherapy for congestive heart failure.11,12 Patients with any previous pacemaker or ICD implantation (n=8,284) were excluded.

Figure 1. Patients included in the analysis. The numbers are from patients included in the National Cardiovascular Data Registry for Implantable Cardioverter-Defibrillators who received a device between January 2005 and April 2007. CRT-D indicates cardiac-resynchronization therapy with defibrillator; ICD, implantable cardioverter-defibrillator; LVEF, left ventricular ejection fraction; and NYHA, New York Heart Association.

Patients who were not white, black, or Hispanic were excluded (n=1005). Only providers enrolling 100% of all ICD and CRT-D implantations were included in the analysis, which excluded an additional 3804 procedures.

Hospital- and Community-Level Variables

To quantify the hospital size, the total number of cardiovascular inpatient days was calculated for year 2006. Medicare Provider Analysis and Review data and facilities were categorized by thirds as small, medium, or large. Hospitals were characterized by major academic affiliation, ownership, urban/rural location, and region. Service availability was characterized by performance of diagnostic catheterization, interventional catheterization, and cardiovascular surgery. We did not differentiate between referral centers and community hospitals in this analysis. Our hypothesis assumed that hospitals in poorer communities would be less likely to have the resources needed to offer the more sophisticated CRT-D procedure, regardless of their designation as a referral center or a community hospital.

To account for hospital financial status, we identified those facilities that receive disproportionate share payments from the Federal government. We also used Medicare Cost Report Data to calculate patient care, other operations, and government appropriations operating margin. We chose the broadest expression of operating margin as it most closely reflects the global financial resources available to

WHAT THE STUDY ADDS

This article adds to the understanding of how contextual factors impact cardiovascular health disparities. The analysis illustrates how community wealth has a greater impact on the care that patients receive than any single socioeconomic or demographic factor. The findings have important implications for efforts to address healthcare disparities.
hospitals, inclusive of government sources, rather than the profitability of patient-care services alone. The ability to make capital investments and hire staff in the future is in large part based on past financial performance and takes time to execute. We therefore used a 3-year trailing average to model the impact of patient care, other operations, and government appropriations margin on likelihood of CRT-D receipt.

Finally, to control for the potential confounding effects of hospital area community wealth, we obtained zip code-level median per capita income from the 2000 US Census.

**Statistical Analysis**

Baseline demographic and clinical characteristics of ICD and CRT-D recipients were compared using \( \chi^2 \) tests for categorical variables and t test in general linear models for continuous variables.

We fit a series of multivariate logistic regression models to estimate the contribution of patient- and hospital-level variables to the likelihood of CRT-D receipt. We first fit a patient-level logistic regression model with a primary outcome of receipt of either an ICD or CRT-D. Independent patient-level variables included race/ethnicity, age, sex, cardiomyopathy pathogenesis, duration of heart failure, left ventricular ejection fraction, QRS duration, QRS morphology, previous revascularization, and clinical comorbidities such as hypertension, cerebrovascular disease, chronic lung disease, diabetes mellitus, and renal failure. Hospital site was incorporated as a random effect. Payer status was added in the model at the patient level. The complete patient-level analysis has been previously described.

We then fit a series of multivariate models to assess the impact of payer status and selected hospital-level characteristics on likelihood of CRT-D receipt. Multilevel models allow the simultaneous examination of individual- and hospital-level variables relative to patient-level outcomes. Using individual covariates from the first model as fixed effects, we added hospital-level variables separately such that each model included only 1 hospital-level variable at a time. We assessed each of these models using a C-statistic, and we considered a value \( >0.7 \) acceptable.

To complete the full multilevel logistic regression model, we included all patient-level variables and payer status as fixed effects. We then used backward stepwise regression to identify the most important hospital- and community-level variables. In this procedure, only variables with a 2-tailed \( P \) value \( >0.05 \) were retained. Finally, to facilitate interpretation of the multilevel model, we translated patient-, hospital-, and community-level variables from a logit to a probability scale. This analysis allows comparison of the predictive change in outcome variable for a unit change in each variable while holding other inputs constant. The results allow a direct comparison of the effect of patient-, hospital- and community-level variables to the probability of receipt of CRT-D.

Statistical analyses were performed using SAS 9.1 (Cary, NC). The authors had full access to the data and take responsibility for its integrity. All authors have read and agreed to the article as written. The Institutional Review Board of the Yale University School of Medicine approved the study.

**Results**

A total of 22,205 patients were eligible to receive CRT-D and were included in the analysis. Of these, 17,511 (79%) received the more sophisticated CRT-D, whereas 4694 (21%) received the simpler ICD. Baseline characteristics of both groups of patients are presented in Table 1.

Of 831 hospitals in the data set, 634 (76.3%) implanted at least 5 CRT-D devices during the study period, and the procedure was therefore considered available at these hospitals. The mean ICD implantation volume of implanting hospitals was 22.7 (SD 28.5), and the mean CRT-D implantation volume was 17.7 (SD 25.6). The majority of devices were implanted at not-for-profit hospitals (76.9%), and one third of devices were implanted at academic medical centers. All regions of the United States were represented, and nearly half of all implantations occurred in urban areas (47.9%). The median household income of hospital ZIP codes ranged from $21,315 to $93,581, with a mean of $43,019. Just over one quarter of implantations (25.8%) were performed at hospitals with a median household income < $40,000 (Figure 2). The preponderance of hospitals (76.4%) received disproportionate share payments from the Federal government to account for uncompensated care. Nearly all hospitals that offered ICD and CRT-D therapy also offered more established cardiovascular technologies, such as diagnostic heart catheterization, coronary stenting, and cardiothoracic surgery. Hospital- and community-level variables are described in detail in Table 2.

All patients in the cohort were eligible to receive CRT-D therapy and received either an ICD or a CRT-D; however, there was wide variability in the rate of CRT-D implantation between hospitals (Figure 3). One hundred hospitals (12%) in the data set implanted CRT-D devices in <50% of CRT-D-eligible patients. Two hundred and six hospitals (25%) in the data set implanted CRT-D devices in >90% of CRT-D-eligible patients. The relationship between hospital ICD volume and likelihood of CRT-D receipt was inconsistent. Patients were more likely to receive CRT-D in low (+5.7%) and medium (+8.1%) volume hospitals than in high-volume ones.

The significance of individual hospital/system-level predictors when added to patient-level variables is presented in Table 3. As one measure of hospital financial resources, we calculated the operating margin for all included hospitals using Medicare Cost Report Data. The 3-year trailing average of profitability was not predictive of CRT-D receipt either independently (\( P=0.10 \)) or in the final hierarchical model. We used median household income of the zip code in which a hospital was located to examine the impact of community wealth on receipt of CRT-D. For this broader measure, there was a consistent and linear relationship between median household income and the likelihood of CRT-D receipt (Figure 4). Hospitals in high-income areas were much more likely to provide CRT-D compared with hospitals in low-income areas, even after accounting for patient insurance status. In fact, insurance status had a relatively small impact in this cohort. Patients with Medicaid insurance were only 2.4% less likely to get CRT-D in comparison with patients with private insurance. The relationship between median household income and receipt of CRT-D persisted in a sensitivity analysis that excluded hospitals with outlying median household income values (ie, median income < $30,000 [\( n=96 \)] or > $80,000 [\( n=27 \)]). The final multilevel model includes patient-level variables as fixed effects and ICD volume and median household income as random effects (Table 4).

In comparison with the large impacts of community wealth and procedure availability on likelihood of CRT-D receipt, patient and provider characteristics had a relatively small impact (Figure 5). There was very little difference in the likelihood of CRT-D receipt by age or sex. Although
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there were racial and ethnic differences in rates of CRT-D implantation, the extent of the inequalities were small when other parameters were considered. Hispanic patients and black patients were 1.9% and 2.2% (respectively) less likely to receive CRT-D than white patients. As expected, a number of clinical variables were significant predictors of the likelihood of CRT-D receipt. In particular, the type and magnitude of delayed electrical conduction in the heart was an important predictor of CRT-D implantation. Patients with better heart function were less likely to receive CRT-D. Patients on dialysis were less likely (−5.5%) to receive CRT-D.

Discussion

Our analysis demonstrates marked variability in use of CRT-D among eligible patients in the NCDR-ICD registry. We show that the wealth of the community in which hospitals are located is associated with the care patients receive. Patients treated at hospitals located in wealthy communities were much more likely to get CRT-D than patients treated at hospitals in poor communities, even when other patient and hospital differences were accounted for. The median household income of the community in which a hospital is located was among the strongest predictors of CRT-D receipt even after accounting for patients’ insurance status, and this relationship persisted when outlying income records were excluded from analysis. Thus, for many patients, the care they received was a function of where they were treated.

The implication of this association is that wealthier hospitals are more able to adopt newer and more expensive technologies, such as CRT-D, regardless of patients’ personal financial or insurance factors. If a poorer hospital lacks the resources needed to offer a more sophisticated procedure, patients will not receive it. Although the equipment required to implant an ICD and CRT-D is similar, more training is required for CRT-D implantation, and hospitals in poorer
communities may lack the resources to provide such training. This could result in uneven technical skills for physician staff at poorer hospitals. Communities in low-income areas may have difficulty recruiting the most highly trained providers for several reasons. Poorer communities may be less desirable places to work because of concerns with neighborhood safety, quality of hospital support staff, quality of medical equipment, or even perceived challenges regarding the patient population served. Hospitals with constrained resources may also have difficulty offering competitive

Table 2. Hospital- and Community-Level Variables Stratified by Device Type

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>ICD (n=4694)</th>
<th>CRT-D (n=17 511)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Small</td>
<td>840 (18.28)</td>
<td>2489 (14.62)</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>1236 (26.90)</td>
<td>4813 (28.26)</td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td>2518 (54.81)</td>
<td>9728 (57.12)</td>
<td></td>
</tr>
<tr>
<td>Ownership</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Government</td>
<td>513 (11.17)</td>
<td>1559 (9.15)</td>
<td></td>
</tr>
<tr>
<td>Not-for-profit</td>
<td>3452 (75.14)</td>
<td>13 175 (77.36)</td>
<td></td>
</tr>
<tr>
<td>For-profit</td>
<td>629 (13.69)</td>
<td>2290 (13.48)</td>
<td></td>
</tr>
<tr>
<td>Academic</td>
<td>1490 (32.43)</td>
<td>5524 (32.44)</td>
<td>0.997</td>
</tr>
<tr>
<td>Urban</td>
<td>2059 (44.82)</td>
<td>8296 (48.71)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Region</td>
<td></td>
<td></td>
<td>0.046</td>
</tr>
<tr>
<td>West</td>
<td>560 (12.19)</td>
<td>2145 (12.60)</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>1984 (43.19)</td>
<td>7064 (41.48)</td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>1365 (29.71)</td>
<td>5029 (29.53)</td>
<td></td>
</tr>
<tr>
<td>Northwest</td>
<td>685 (14.91)</td>
<td>2792 (16.39)</td>
<td></td>
</tr>
<tr>
<td>Technology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnostic catheterization</td>
<td>4593 (99.98)</td>
<td>17 030 (100.00)</td>
<td>0.054</td>
</tr>
<tr>
<td>Interventional catheterization</td>
<td>4507 (98.11)</td>
<td>16 843 (98.90)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cardiovascular surgery</td>
<td>4530 (98.82)</td>
<td>16 966 (99.62)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ICD volume (mean [SD])</td>
<td>53.32 (42.30)</td>
<td>57.94 (40.85)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CRT-D volume (mean [SD])</td>
<td>43.94 (42.31)</td>
<td>52.98 (44.07)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Disproportionate share payment</td>
<td>3633 (79.08)</td>
<td>12 888 (75.68)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Household income (mean [SD])</td>
<td>42 871 (9057)</td>
<td>43 951 (9336)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

ICD indicates implantable cardioverter-defibrillator; CRT, cardiac-resynchronization therapy with defibrillation.
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compensation packages to recruit and retain the most advanced providers. It is also possible that resource constraints in low-income hospitals limit the procedural time and clinical expertise necessary to implant a CRT-D compared with implanting a simpler ICD.

Marked treatment variations attributable to community wealth persisted despite accounting for hospital- and community-level characteristics. A host of hospital and community characteristics were statistically associated with receipt of CRT-D when considered alone, but were no longer associated once median household income was included in the model. These factors include hospital size, ownership, academic affiliation, urban location, and geographic region. Despite the importance of community wealth in predicting CRT-D receipt, there was no significant association in the final model with receipt of disproportionate share payments from Centers for Medicare and Medicaid Services. These extra payments are made to offset care provided to underserved patient populations, especially the uninsured.

Previous work has demonstrated that hospital profitability impacts on the type and quality of services patients receive.\textsuperscript{26–28} We hypothesized that hospitals with higher profitability would have more funds available to expand service offerings such as the provision of CRT-D. We tested this hypothesis using Medicare Cost Report data to construct a broad measure of each hospital’s operating margin. However, the 3-year trailing profitability average was not predictive of CRT-D receipt in our models either independently or in the final multilevel model. It is possible that there is no consistent relationship between hospital profitability and receipt of advanced services such as CRT-D. However, assessment of operating margin on technology adoption is challenging because cardiovascular procedures are largely believed to be profitable.\textsuperscript{29,30} Financially troubled facilities might preferentially adopt high-margin services in an attempt to improve profitability; conversely, hospitals may be profitable in part because they offer advanced cardiovascular services. We used Medicare Cost Report data for this analysis because they are the only national data that use standard definitions and have sufficient detail to construct hospital margins.\textsuperscript{31} However, these data have been criticized because they are not audited, some definitions are disputed, and hospitals may manipulate their numbers for a variety of reasons.\textsuperscript{32,33}

Variations in care persisted even after accounting for patient characteristics such as coexisting illnesses, testing results, symptom severity, and duration of symptoms. Our model included much more clinical detail than is typically available outside prospective clinical trials. Patient preferences were unlikely to account for observed differences in care because all patients received either an ICD or CRT-D, and patients are likely to perceive these device implantations similarly. Patient insurance status provided only a small contribution to care variations in this analysis.

Our findings illustrate how context has a much more profound effect than any 1 socioeconomic or demographic factor. If minority patients are more likely to present to hospitals with limited resources, observed disparities in treatment are not attributable to racial or ethnic factors but are more a function of economics and limited hospital resources. In this study, availability of CRT-D had a much greater impact on treatment variations than any patient- or other hospital-specific characteristics. Nonetheless, most hospitals (76.3\%) offered CRT-D at least to some patients. Among hospitals at which CRT-D was available, there was marked variation in rates of ICD versus CRT-D implantation. At some hospitals, >90\% of eligible

\textbf{Figure 3.} Frequency distribution of cardiac-resynchronization therapy with defibrillator implantation rates by facility. Source: 2000 US Census.
patients received CRT-D; at other hospitals, <10% of eligible patients received CRT-D.

Policy Implications
A relationship between socioeconomic status, social context, and health status has been previously described in several different arenas of health. At the individual level, health is in part determined by genetics and personal choices, yet the social context in which people live also impacts health. For example, infant mortality decreases with increasing maternal educational attainment, and life expectancy improves at higher income levels. Community wealth may be associated with the availability of quality education options, healthy food options, and safe public recreational facilities. We extend this observation to the availability of advanced healthcare services. In this study, all patients received an expensive intervention for advanced heart failure, yet a large number of eligible patients did not receive the more beneficial device despite apparent availability and insurance. Our findings suggest that health insurance coverage by itself may not eliminate inequities in care that result from disparate hospital resources. Although evolving health policies may extend insurance coverage to many Americans who are currently uninsured, insurance coverage alone will not eliminate healthcare disparities if patients are cared for at hospitals with limited availability of advanced procedures.

For advanced services, such as ICD or CRT-D therapy, regionalization may offer important benefits. For many technically complex procedures, there is a relationship between volume, care process, and patient outcome. Poor, less educated, and ethnic and racial minority patients may be more likely to receive care at lower volume facilities. However, in this study, the relationship between community wealth and receipt of CRT-D persisted after adjusting for ICD implantation volume. Concentrating complex procedures like ICD or CRT-D implantation at higher volume and more technically advanced hospitals may both improve the quality of care and reduce unwarranted variations in care for underserved patient groups. Alternatively, Centers for Medicare and Medicaid Services could promote recruitment of advanced providers to underserved communities through direct financial incentives to physicians or hospitals. However, to maintain a financially viable practice, providers might be required to serve multiple geographically distant communities. The most appropriate strategy will likely differ depending on the local context.

Table 3. Significance of Individual Hospital/System-Level Predictors When Added to Patient-Level Predictors

<table>
<thead>
<tr>
<th>Description</th>
<th>OR</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital ownership</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government</td>
<td>0.034</td>
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</tr>
<tr>
<td>For profit</td>
<td>0.991</td>
<td></td>
</tr>
<tr>
<td>Academic facility</td>
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</tr>
<tr>
<td>Urban location</td>
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<tr>
<td>Geographic region</td>
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</tr>
<tr>
<td>West</td>
<td>0.944</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>0.107</td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>0.277</td>
<td></td>
</tr>
<tr>
<td>Cardiovascular patient volume</td>
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<td></td>
</tr>
<tr>
<td>Low</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Procedure availability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interventional catheterization</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Cardiothoracic surgery</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>CRT-D</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Procedure volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRT-D volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>&lt;0.001</td>
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<tr>
<td>ICD volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Hospital financial characteristics</td>
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<td></td>
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<tr>
<td>Disproportionate share payments</td>
<td>0.032</td>
<td></td>
</tr>
<tr>
<td>Average medium household income</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>PCOG operating margin</td>
<td>0.095</td>
<td></td>
</tr>
</tbody>
</table>

OR indicates odds ratio; ICD, implantable cardioverter-defibrillator; CRT-D, cardiac-resynchronization therapy with defibrillator; and PCOG operating margin, patient care, other operations, and government appropriations operating margin.

Figure 4. Adjusted probability of CRT-D implantation by median household income of provider ZIP code. The straight line in this figure is the linear trend line, which indicates that there is an increasing linear trend between median household income (MHI) and the predicted rate of receiving CRT-D. CRT-D indicates cardiac-resynchronization therapy with defibrillator. Source: 2000 US Census. The probabilities are the estimated use of CRT-D from the hierarchical (multilevel) logistic regression model for each patient that was described in the Methods section. In this model, MHI is parameterized as a continuous variable with a linear effect on the logit of the probability. We have rounded MHI to the nearest $5000 and found the estimated probability of CRT-D use for each rounded MHI value, and plotted these mean probabilities vs MHI.
Regionalization may also have drawbacks. Some patients might refuse to have a device implanted in an unfamiliar, distant center. Travel to distant hospitals may impose a significant burden on both patients and their families. If patients are unwilling or unable to travel even a relatively short distance, regionalization of ICD/CRT-D implantation may paradoxically exacerbate care disparities. Further, cardiac procedures are widely thought to be profitable. Shifting profitable procedures away from hospitals in poor communities may undermine the financial stability of hospitals caring for underserved patients. Limiting the scope of practice of hospitals in underserved communities may compound the difficulty of recruiting and retaining advanced healthcare providers. Finally, the ability to regionalize care may be particularly challenging in sparsely populated regions or states because of the large distances involved.

### Limitations

NCDR-ICD Registry data provide detailed retrospective information on patients who received an ICD or CRT-D but did not include patients who may have been eligible but did not receive any device. Thirty-seven percent of patients eligible for CRT-D were excluded from the analysis because they had a previous pacemaker or ICD, were not white, black, or Hispanic, or because they presented at hospitals that did not register all ICD implantations. It is possible that these exclusions affected our results. If all heart failure patients were included, variations in care are likely to be far greater than those seen in this analysis because of differential access to diagnostic testing and specialty care. Indeed, an analysis of ICD use in patients with advanced heart failure demonstrated even greater variations in device use than those observed here. In addition, Registry data do not indicate whether CRT-D implantation was attempted but then had to be converted to ICD implantation because of procedural difficulties. Furthermore, the Registry does not include details on some provider-level characteristics, such as level of training. The analysis cannot account for unmeasured variables such as the likelihood of patients receiving optimal drug therapy for advanced heart failure. However, optimizing medical therapy before assessing a patient’s candidacy for a device is important for both ICD and CRT-D implantation. Finally, we used the 2005 published ACC practice guidelines as the basis for our analysis. The guidelines may not have been universally accepted.

### Conclusions

Patients treated in hospitals located in wealthy communities are more likely to receive an advanced heart failure therapy than patients treated in poorer hospitals, despite accounting for other patient and hospital characteristics including insurance status. These findings suggest that health policy targeting insurance coverage alone will be ineffective in resolving inequities in care. Although the most appropriate strategy to improve CRT-D implantation rates in poorer communities will likely depend on local contextual factors, regionalization of care may be a useful strategy to more evenly distribute technical procedures between hospitals.

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Disclosures
None.

References


Figure 5. Average effect of selected patient- and hospital-level variables on the probability of CRT-D receipt. To facilitate interpretation of the multilevel model, we converted patient-, hospital-, and community-level variables to a probability scale. This analysis allows comparison of the predictive change in outcome variable for a unit change in each patient-level and system-level variable whereas holding other inputs constant. Continuous variables have been converted to categories: age per 10-year increment, ejection fraction per 5% increment, QRS duration per 10 ms increment. NICM indicates nonischemic cardiomyopathy; CHF, congestive heart failure; EF, ejection fraction; QRS duration is a measurement on the electrocardiogram which corresponds to the depolarization of the right and left ventricles of the heart; HMO, health maintenance organization; CRT-D, cardiac-resynchronization therapy with defibrillator; and ICD, implantable cardioverter-defibrillator.


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