Use of Cardiac Resynchronization Therapy in Patients Hospitalized With Heart Failure

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Background—The frequency and characterization of patients receiving cardiac resynchronization therapy (CRT) are largely unknown since the publication of pivotal clinical trials and subsequent incorporation of CRT into the American College of Cardiology/American Heart Association guidelines for heart failure.

Methods and Results—We analyzed 33,898 patients admitted from January 2005 through September 2007 to 228 hospitals participating in the American Heart Association’s Get With the Guidelines–Heart Failure program. There were 4,201 patients (12.4%) discharged alive with CRT, including 811 new implants. Patients discharged with CRT were older (median age, 75 versus 72 years) and had lower median left ventricular ejection fraction (30% versus 38%), more frequent ischemic cardiomyopathy (58% versus 45%), more history of atrial fibrillation (38% versus 27%), and higher rates of β-blocker and aldosterone antagonist use ($P<0.0001$ for all) than those without CRT. We found that 4.8% of patients with left ventricular ejection fraction $\leq 35\%$ were discharged with a new CRT implant, which varied greatly by hospital. Ten percent of patients discharged with a new CRT implant had a left ventricular ejection fraction $>35\%$. Major factors associated with lower rates of new CRT placement were treatment in the northeast (odds ratio, 0.40; 95% confidence interval, 0.30 to 0.53), black race (odds ratio, 0.45; 95% confidence interval, 0.36 to 0.57), increasing left ventricular ejection fraction per 10% (odds ratio, 0.56; 95% confidence interval, 0.52 to 0.60), and increasing age per 10 years in those $>70$ years of age (odds ratio, 0.56; 95% confidence interval, 0.48 to 0.65).

Conclusions—Although CRT is a recent evidence-based therapy for heart failure, patterns of use differ significantly from clinical trials and published guidelines. Important variations also exist for CRT therapy based on race, geographic region, comorbidities, and age and need to be addressed through further study and/or quality-of-care initiatives.

Key Words: heart failure ■ pacemaker ■ registries

Poor outcomes are common after hospitalization for heart failure (HF), with 1-year readmission rates $>50\%$ and 1-year mortality $>30\%$. To address these poor outcomes, improved use of existing HF therapies and new treatments for HF have been sought. When used in combination with optimal medical therapy, cardiac resynchronization therapy (CRT) is associated with a 50% reduction in hospitalization for HF and a 36% reduction in mortality. In 2005, the American College of Cardiology/American Heart Association (ACC/AHA) HF guidelines were updated to recommend CRT in patients with systolic dysfunction (left ventricular [LV] ejection fraction [LVEF] $\leq 35\%$), evidence of electrical dyssynchrony (QRS $>120$ ms), and moderate to severe HF (New York Heart Association functional class III or ambulatory class IV) despite optimal medical therapy (Class I; Level of Evidence A).

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Despite the significant improvements in clinical outcomes observed with CRT in randomized trials and the current recommendations for CRT, few data are available regarding CRT use outside clinical trials. Given the cost of these devices and the significant benefit associated with CRT, there is a great need to define which patients are and are not receiving CRT in clinical practice. To characterize predictors of CRT implantation, disparities in CRT use, regional variation, and potential areas of non–guideline-based application
of CRT, we examined CRT use in the AHA’s Get With the Guidelines—Heart Failure (GWTG-HF) registry.

Methods

Data Collection

Data were abstracted from the GWTG, a national, ongoing, prospective, observational data collection and quality improvement initiative started in 2000 under the aegis of the AHA. The GWTG program and its component data elements have been described previously.6,7 Hospitals participating in the registry submit clinical information regarding the medical history, hospital care, and outcomes of consecutive patients hospitalized for coronary artery disease, stroke, or HF using an online, interactive case report form and patient management tool (Outcome Sciences, Inc, Cambridge, Mass). Beginning in January 2005, patients hospitalized with HF were enrolled in the program regardless of their LV function. Participating institutions are instructed to submit consecutive eligible HF patients to the GWTG-HF database.

All participating institutions were required to comply with local regulatory and privacy guidelines and to submit the GWTG protocol for review and approval by their institutional review board. Because data were used primarily at the local site for quality improvement, sites were granted a waiver of informed consent under the common rule. The Duke Clinical Research Institute served as the data analysis center and analyzed the aggregate deidentified data for research purposes. Trained personnel abstracted the data using standardized definitions for all data fields, including HF, ischemic versus nonischemic origin, and comorbidities. Patients were assigned to race/ethnicity categories using options defined by the electronic case report form. Other variables included demographic and clinical characteristics, medical history, previous treatments, contraindications for evidence-based therapies, and in-hospital outcomes. Data collection regarding CRT included prior implantation or new implantation during the HF admission. Data on QRS duration and/or mechanical dyssynchrony were not collected. Using an internet-based system, we monitored data quality to ensure the completeness and accuracy of the submitted data. The analysis was restricted to hospitals submitting data with a high degree of completeness, defined as >95% of baseline demographics and >75% of past medical history.

Study Population

From January 2005 through September 2007, 58 502 patients admitted with HF were discharged from 238 hospitals participating in GWTG–HF. We excluded 13 176 patients who were transferred to another acute care facility (n=1 1578) or were discharged to hospice (n=7541), or rehabilitation center (n=1095), a skilled nursing facility (n=8541), or other facility (n=962). We excluded 4581 patients with new-onset HF because they were not eligible for CRT therapy. We excluded 6847 patients for whom there was no documentation of LVEF. The final overall study population included 33 898 HF patients at 228 hospitals.

Outcome Measures

The main outcome measure was CRT status at discharge. For the purposes of the analysis, we included those patients with prior CRT device implantation and those with new CRT device implantation during the current HF admission. We also evaluated factors associated with new CRT device implantation because patients with prior CRT and new CRT may differ.

Additional outcome measures of interest were discharge quality indicators, including the provision of HF-specific discharge instructions, use of an angiotensin-converting enzyme inhibitor or angiotensin receptor blocker in patients with LV systolic dysfunction, and smoking cessation counseling for eligible patients, which are the core measures of quality used by the Centers for Medicare and Medicaid Services. Additional indicators of evidence-based care included in the analysis were the use of β-blockers in LV systolic dysfunction, use of 1 of the 3 specific guideline-recommended β-blockers for HF, anticoagulation for atrial fibrillation, and aldosterone antagonists for LV dysfunction, which are class I therapies in the AHA/ACC HF guidelines.5

Statistical Analysis

Using χ² tests for categorical variables and Wilcoxon rank-sum tests for continuous variables, we compared baseline characteristics between patients who did and did not receive CRT. Medians and 25th and 75th percentiles are given for continuous variables; percentages are given for categorical variables. We also examined the characteristics of those patients who received CRT implants during their HF admission (new CRT). Multivariable logistic regression was used to identify important factors associated with overall and new CRT use. Generalized estimating equations were used to adjust for clustering within hospitals.8 The initial model included variables for age, sex, race, geographic region, hospital type, systolic blood pressure, heart rate, body mass index, LVEF, anemia, atrial fibrillation, cerebrovascular disease (stroke or transient ischemic attack), chronic obstructive pulmonary disease, coronary artery disease, depression, diabetes mellitus, hyperlipidemia, hypertension, nonischemic cardiomyopathy, peripheral vascular disease, renal insufficiency, smoking, chronic dialysis, and a prior history of revascularization (coronary bypass grafting or percutaneous intervention). In addition, we tested for interactions between sex and race. Using backward elimination, we removed factors with values of P≥0.05 from the logistic regression model.

All tests were 2 tailed, and statistical significance was declared at α=0.05. All analyses were performed with SAS software version 9.0 (SAS Institute, Cary, NC).

The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.

Results

Among 33 898 patients admitted for HF who met the study criteria, 4201 (12.4%) were discharged with CRT. The median frequency of CRT use in patients with LVEF ≤35% by hospital was 14.3% (25th and 75th percentiles, 5.6% and 25.4%). As shown in Table 1, patients with CRT were older compared with HF patients without CRT. Nearly 70% of CRT recipients were Medicare beneficiaries. CRT use was greater in white patients compared with black patients and those of other races. CRT patients had higher rates of renal insufficiency, and most had ischemic cardiomyopathy. Patients with CRT devices had a median LVEF of 30%; however, a significant proportion of CRT patients had relatively preserved LV function.

To explore differences between those patients with prior CRT and those with new CRT use, we identified those patients who underwent CRT implantation during their admission for decompensated HF. Of 4201 patients with CRT devices, 811 (19.3%) were new CRT device implants during hospitalization for HF. Shown in Table 1 are the baseline and clinical characteristics of the patients according to prior versus new CRT implantation. In general, patients with new CRT were admitted to hospitals with larger bed capacities. Nearly one third of the new CRT patients had a history of atrial fibrillation, and a fifth had chronic pulmonary disease. Most had prior coronary revascularization with a median LVEF of 25%; 4.8% (733 of 15 197) with LVEF ≤35% received new CRT implantation during their HF hospitalization. Although 90.4% (733 of 811) of the new CRT patients had an LVEF ≤35%, 9.6% (78 of 811) had an LVEF >35%, and 6.4% (52 of 811) had an LVEF ≥40% (Figure 1). Compared with all patients with CRT, the new CRT cohort was a younger population with fewer septuagenarians and octogenarians. Non–guideline-based new CRT implantation was spread widely among hospitals, with up to one third of our
hospitals implanting at least 1 patient with LVEF >35% (n = 35 of 87). Using patient-level data, we found no significant differences in hospital characteristics between new CRT implants in patients with LVEF ≤35% and those patients with LVEF >35% except that patients who received new CRT with an LVEF >35% were less likely to be treated in a hospital with interventional cardiology capabilities (71.8% versus 87.5%; *P* = 0.0147). Analysis of site-level data revealed no significant differences in hospital characteristics between sites implanting new CRT in patients with LVEF >35% compared with those implanting only in patients with LVEF ≤35%.

Discharge quality-of-care measures were ascertained in patients with and without CRT and are detailed in Table 2. Overall, the rates of evidence-based therapies were fairly similar in those patients with and without CRT. Patients with CRT were more likely to receive an aldosterone antagonist, anticoagulation for atrial fibrillation, β-blocker at discharge, evidence-based β-blocker at discharge, appropriate HF-specific discharge instructions, and lipid-lowering therapy; however, these differences were small (although highly statistically significant).

Because patient characteristics and factors associated with CRT use are likely to be different between those patients with...
new and those with prior CRT implantation, we analyzed predictors of overall CRT use and new CRT implantation during an admission for HF (Table 3). A binary relationship was observed with new CRT implants and age. Patients <70 years of age were more likely to receive CRT (odds ratio [OR], 1.44; 95% confidence interval [CI], 1.28 to 1.60), whereas advancing age was associated with decreased CRT use in those >70 years of age (OR, 0.56; 95% CI, 0.48 to 0.65). New CRT use decreased with increasing LVEF per 10% (OR, 0.56; 95% CI, 0.52 to 0.60). The presence of diabetes, chronic pulmonary disease, and renal insufficiency was associated with decreased CRT use in those with new CRT implants.

We also examined the variation in CRT use across hospitals. There was marked variation in new CRT placement by hospital site in potentially eligible patients with LVEF ≤35% (Figure 2). To determine whether new CRT use was influenced by the availability of implanting physicians, we conducted a sensitivity analysis in which all excluded sites that did not implant an implantable cardioverter-defibrillator (ICD) during the study period. When we restricted our model to include only those sites with known device implantation capability, factors with new CRT implantation were essentially unchanged except that admission to an academic hospital was significantly associated with new CRT implantation, with an OR of 1.30 (95% CI, 1.07 to 1.58). The previously observed region differences remained significant (Table 3). After accounting for device implanting capabilities, we found continued evidence of intersite variance for new CRT implantation.

After adjusting for patient demographics, hospital characteristics, LV function, and geographic region, we identified an interaction between race and sex in overall CRT use (black women interaction, \( P=0.009 \)). When examining the specific race-sex interactions, we found that black women were more likely to receive CRT than black men (OR, 1.24 [95% CI, 1.04 to 1.48]; \( P=0.018 \)), whereas white women and other (nonwhite, nonblack) women were less likely to receive CRT relative to their male peers. Among male patients, white men were more likely to receive CRT relative to black men (OR, 1.53; 95% CI, 1.33 to 1.77; \( P<0.0001 \)). When restricting the analysis to only new CRT implants, black race was again associated with decreased CRT use (OR, 0.45; 95% CI, 0.36 to 0.57; \( P<0.0001 \)), but no race-sex interaction was observed.

Our analyses used general estimating effects modeling to account for clustering. To further examine the influence of hospital effects, we performed a hierarchical model to ascertain if there is a site-level effect influencing the observed differences in new CRT use. Hierarchical modeling identified a small but demonstrable hospital effect. When sites are accounted for, the regional differences in new CRT implant use are no longer significant; however, the previously observed racial disparities persisted. To further explore the influence of hospital effects on the observed racial disparity in new CRT implantation, we investigated the incidence of new CRT implantation during admissions for HF according to the percent of black patients at each hospital. CRT use was consistent across sites according to the percent of black patients. Sites with <5% black patients had 0.89% new CRT use among those with an LVEF ≤35% compared with 2.03% at sites with 5% to 15% black patients and 1.99% at sites with ≥15% black patients (\( P=0.70 \)).

**Discussion**

We investigated the use of CRT, an emerging therapy, in a real-world HF population. There are three main findings in this study. First, patients with CRT in clinical practice are sicker and differ significantly from those enrolled in randomized controlled trials. Second, a small but significant proportion of patients receive new CRT placement with a documented LVEF >35%, outside current clinical trial evidence and guideline recommendations. Finally, CRT use varies by age, race, hospital site, and geographic region.

Our study has several advantages compared with other registries. Unlike device-based observational studies, our population included all patients hospitalized with HF and was not limited to...

![Figure 1. Distribution of LV function among new CRT recipients.](image-url)

**Table 2. Discharge Quality-Of-Care Measures for Patients With and Without CRT**

<table>
<thead>
<tr>
<th>Quality Measure</th>
<th>Overall, %</th>
<th>CRT, %</th>
<th>No CRT, %</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACE inhibitor or ARB in those with LV dysfunction (n=14 985)</td>
<td>86.6</td>
<td>86.8</td>
<td>86.6</td>
<td>0.8591</td>
</tr>
<tr>
<td>Aldosterone antagonist in those with LV dysfunction (n=16 335)</td>
<td>28.7</td>
<td>34.7</td>
<td>27.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Anticoagulation for atrial fibrillation (n=8284)</td>
<td>66.1</td>
<td>68.3</td>
<td>65.6</td>
<td>0.0478</td>
</tr>
<tr>
<td>Any β-blocker in those with LV dysfunction (n=16 335)</td>
<td>89.4</td>
<td>91.5</td>
<td>89.0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Evidence-based β-blocker in those with LV dysfunction (bisoprolol, carvedilol, metoprolol succinate) (n=16 335)</td>
<td>71.4</td>
<td>77.0</td>
<td>70.3</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Discharge instructions (n=29 493)</td>
<td>82.0</td>
<td>83.7</td>
<td>81.8</td>
<td>0.0053</td>
</tr>
<tr>
<td>Lipid-lowering therapy if atherosclerotic vascular disease or diabetes (n=22 572)</td>
<td>58.6</td>
<td>61.8</td>
<td>58.1</td>
<td>0.0001</td>
</tr>
<tr>
<td>Smoking cessation counseling (n=5506)</td>
<td>91.3</td>
<td>91.3</td>
<td>91.3</td>
<td>0.9732</td>
</tr>
</tbody>
</table>

ACE indicates angiotensin-converting enzyme; ARB, angiotensin receptor blocker.
those patients who actually received an intracardiac device. This allowed us to identify independent predictors of CRT use in addition to the characteristics of those patients with CRT. To the best of our knowledge, our study is the largest description of CRT use in potentially eligible patients with HF.

Although we cannot definitively address underuse of CRT owing to a lack of QRS duration and New York Heart Association classification, use of CRT in our cohort was less than expected on the basis of recent reports. In the GWTG registry, use of CRT in potentially eligible patients with HF was less common than observed in ambulatory patients. Moreover, one third of patients who receive an ICD for primary prevention of sudden cardiac death also have indications for CRT.12,13 In fact, a recent analysis of Medicare ICD recipients demonstrated that more than half also received CRT.14 Further studies that incorporate QRS duration and functional classification are needed to determine whether CRT is underused in the HF population documented to be eligible.

**Patient Characteristics**

Patients in clinical practice often differ from patients enrolled in randomized controlled trials,15,16 including those hospitalized with HF.17 In accordance with these prior observations, new CRT patients in the GWTG registry were much older than patients in randomized trials of CRT (age, 71 versus 64

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### Table 3. Factors Associated With CRT in Patients Admitted With HF

<table>
<thead>
<tr>
<th></th>
<th>All CRT</th>
<th>New Inpatient CRT Implant</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, per 10-y increase</strong></td>
<td>OR (95% CI)</td>
<td>Wald χ²</td>
</tr>
<tr>
<td>Age, per 10-y increase</td>
<td>1.26 (1.20–1.31) when &lt;75 y of age; NS when ≥75 y of age</td>
<td>100.29</td>
</tr>
<tr>
<td>70y of age</td>
<td>0.56 (0.48–0.65) when &gt;70 y of age</td>
<td>56.91</td>
</tr>
</tbody>
</table>

**Sex and race**

<table>
<thead>
<tr>
<th></th>
<th>OR (95% CI)</th>
<th>Wald χ²</th>
<th>P</th>
<th>OR (95% CI)</th>
<th>Wald χ²</th>
<th>P</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Sex and race</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black vs white</td>
<td>0.45 (0.36–0.57)</td>
</tr>
<tr>
<td>White vs white</td>
<td>0.51 (0.38–0.69)</td>
</tr>
<tr>
<td>White vs black</td>
<td>0.45 (0.36–0.57)</td>
</tr>
<tr>
<td>White vs other women</td>
<td>0.51 (0.38–0.69)</td>
</tr>
<tr>
<td>White vs other women</td>
<td>0.51 (0.38–0.69)</td>
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</tbody>
</table>

**Geographic region**

<table>
<thead>
<tr>
<th></th>
<th>OR (95% CI)</th>
<th>Wald χ²</th>
<th>P</th>
<th>OR (95% CI)</th>
<th>Wald χ²</th>
<th>P</th>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Geographic region</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest vs West</td>
<td>0.91 (0.72–1.14)</td>
</tr>
<tr>
<td>Northeast vs West</td>
<td>0.40 (0.30–0.53)</td>
</tr>
<tr>
<td>South vs West</td>
<td>0.76 (0.61–0.95)</td>
</tr>
<tr>
<td>No insurance</td>
<td>0.39 (0.23–0.67)</td>
</tr>
<tr>
<td>Systolic blood pressure, per 10-mm Hg increase</td>
<td>0.95 (0.92–0.98)</td>
</tr>
<tr>
<td>LVEF, per 10% increase</td>
<td>0.56 (0.52–0.60)</td>
</tr>
<tr>
<td>Anemia</td>
<td>0.42 (0.30–0.59)</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>0.71 (0.55–0.92)</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>0.69 (0.59–0.81)</td>
</tr>
<tr>
<td>Depression</td>
<td>0.74 (0.63–0.87)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>0.69 (0.59–0.81)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>0.73 (0.61–0.88)</td>
</tr>
<tr>
<td>Nonischemic cardiomyopathy</td>
<td>0.67 (0.53–0.86)</td>
</tr>
<tr>
<td>Pulmonary disease</td>
<td>0.67 (0.53–0.86)</td>
</tr>
<tr>
<td>Renal insufficiency (creatinine &gt;2.0 mg/dL)</td>
<td>0.32 (0.23–0.45)</td>
</tr>
<tr>
<td>Smoking history</td>
<td>0.33 (0.23–0.45)</td>
</tr>
<tr>
<td>Chronic dialysis</td>
<td>0.33 (0.23–0.45)</td>
</tr>
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</table>

*Because of a significant race-sex interaction in the overall CRT model (black-female, P=0.0009), individual ORs are shown for each race-sex combination in the overall model. There was no evidence of a race-sex interaction in the new CRT use.
The median LVEF at the time of enrollment was 25% in the Cardiac Resynchronization in Heart Failure (CARE-HF) trial, and 25% in the Comparison of Medical Therapy and Cardiac Resynchronization in Heart Failure (COMPANION) trial, and 25% in this clinical practice population at the time of new CRT placement. Furthermore, the cause of HF in our cohort was remarkably similar to that observed in CRT trials: 59.5% had ischemic cardiomyopathy versus 58% in a recent systematic review of CRT trials.

**Comorbidities**

There were more frequent comorbidities among the GWTG cohort receiving CRT compared with randomized controlled trials. An example of the medical complexity observed in this cohort was the prevalence of prior atrial fibrillation. In our analysis, 30% of patients with new CRT implants had a history of atrial fibrillation compared with 22% in COMPANION and 21% in the CARE-HF trial. Although patients with severe renal dysfunction were excluded from the Multicenter InSync Randomized Clinical Evaluation (MIRACLE) ICD trial, >10% of the GWTG patients with new CRT had an estimated creatinine clearance <35 cm³/min. This divergence may be important because impaired renal function has been associated with decreased survival in ICD recipients. Finally, 1 in 5 patients in GWTG with new CRT had a history of chronic obstructive pulmonary disease, which has been associated with a 50% increased risk of death in patients with HF. These findings merit consideration because applying this therapy to a broader, sicker, and older population may not produce the same mortality benefits compared with randomized controlled trials.

**Race and Sex**

Race and sex disparities in ICD use have been well documented. Despite the observed sex disparities in ICD implantation, we did not find a consistent trend of decreased CRT use in women. When we restricted our analysis to new CRT use only, there was no evidence of an interaction between race and sex, and we found that men and women were equally likely to undergo new CRT implantation. Therefore, in this HF population, there was no evidence of sex-based disparity in new CRT use.

Similar to previously published reports, in this study, CRT use was less common in black patients compared with white patients. These findings remained significant after adjusting for LV function and the origin of HF and accounting for the availability of implanting physicians and hospital/site-specific effects. Furthermore, there was no evidence that centers treating more blacks implanted fewer new CRT devices. This disparity is particularly concerning because black patients have a higher incidence of nonischemic cardiomyopathy, which has been shown to be associated with greater rates of clinical response to CRT. Black patients are more likely to develop advanced symptomatic HF and to have a higher rate of rehospitalization. Alternatively, the decreased use may reflect the lower prevalence of QRS delay among blacks with HF. In the Congestive Heart Failure and QRS Duration: Establishing Prognosis (CONQUEST) registry, only 17% of black patients had a QRS >120 ms compared with 26% of white patients. Similarly, QRS delay was less common in black patients (34% versus 43%) in the prospective National Registry to Advance Heart Health (ADVANCEnt). Taken together, our data suggest that black patients are 50% less likely to receive CRT, which is due partially to known racial disparities with invasive procedures such as ICDs and a likely 20% to 30% lower rate of conduction disturbances in black patients.

**Quality of Care**

As expected, the use of evidenced-based therapies such as angiotensin-converting enzyme inhibitors/angiotensin receptor blocker and aldosterone antagonists in this population was less frequent compared with randomized controlled trials of CRT. For example, 86% of eligible patients were receiving angiotensin-converting enzyme inhibitors/angiotensin receptor blocker and 35% were receiving aldosterone antagonists in this population compared with 95% and 54%, respectively, in CARE-HF. Nonetheless, the use of evidence-based HF discharge therapies was fairly prevalent in this cohort. Taken together, these findings suggest that most patients who receive CRT are on guideline-recommended HF medical therapy; however, opportunities may remain to improve optimal medical therapy before CRT implantation.

**LV Function and CRT**

Another notable finding in this study was the significant proportion of CRT patients with relatively preserved LV systolic function. In most patients with CRT in place at the time of hospitalization, the LVEF recorded in the registry would be expected to be after CRT placement. However, among patients with new CRT, the LVEF measurement reflects LV function at or before the time of implantation. Nearly 1 in 3 overall CRT patients had an LVEF ≥40%. Observational studies have shown that up to 40% of CRT patients go on to have an improvement in LVEF >10 absolute percentage points at a 1-year follow-up. Similar, though less prominent, improvement has been observed in randomized controlled trials of CRT. When we restricted our analysis to those patients with new CRT implantation, we...
found fewer patients (6.4%) with an LVEF >40% and 9.6% with an LVEF >35% around the time of device implantation. Some CRT implantation in patients with LVEF >35% may represent prophylactic biventricular pacing to prevent right ventricular pacing–induced systolic dysfunction.\textsuperscript{34} However, it is unlikely that nearly 1 in 10 CRT devices were implanted to prevent right ventricular pacing–induced systolic dysfunction in this symptomatic, hospitalized HF cohort. The finding that nearly 10% of patients receiving new CRT have an LVEF >35% suggests that some patients are receiving CRT outside current guideline recommendations.

**Study Limitations**

Our study had several limitations. First, the data were from patients hospitalized with HF at institutions participating in the GWTG-HF Program. Hospitalized patients may differ from patients enrolled in clinical trials that focus on outpatients. Second, the voluntary GWTG program may include hospitals with a higher likelihood of following evidence-based recommendations, making our observations conservative. Previous studies of the Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients With Heart Failure (OPTIMIZE-HF) and other HF registries have shown that patients admitted with HF have baseline characteristics similar to those of patients from national data sets, suggesting that data from registry hospitals are likely to be representative of national trends and practices.\textsuperscript{34,35} Although we controlled for insurance status, we do not have data for out-of-pocket expenses, which could affect patient decisions for CRT placement. Because we do not have access to outpatient follow-up information, we are unable to delineate the adverse consequences of underuse and disparities in the use of CRT. Unfortunately, we did not have data regarding CRT alone versus CRT with defibrillator. However, prior studies suggest that CRT alone has limited use in the US healthcare system, accounting for <20% of all CRT implants.\textsuperscript{36} Finally, we did not have data important for consideration of CRT such as New York Heart Association functional status or QRS duration. Other registries such as the National Cardiovascular Data Registry ICD registry will allow better description of the appropriateness of CRT relative to these factors. Nonetheless, our study represents the largest description of CRT use in a real-world, potentially eligible HF population.

**Conclusions**

HF patients receiving CRT in clinical practice are sicker and differ significantly from those enrolled in randomized controlled trials. Although CRT is a class I recommendation in those patients with LV dysfunction, QRS delay, and class III to IV HF, significant variations exist for CRT therapy by hospital and region of the country and appear to be influenced by patient age and race. Further research is needed to understand the reasons for the variations in CRT use at the patient, physician, and hospital levels and to implement programs to improve the awareness and promotion of evidence-based use of medical devices in HF.

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**Disclosures**

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**References**

Despite the significant improvements in clinical outcomes observed with cardiac resynchronization therapy (CRT) in randomized trials and the current guideline recommendations for CRT, few data are available regarding CRT use outside clinical trials. To explore CRT use in a clinical practice setting, we analyzed CRT implantation in the Get With The Guidelines registry. Among 33,898 patients admitted for heart failure, 12.4% were discharged with CRT. Nearly 10% of new CRT implants occurred in patients with a left ventricular ejection fraction >35%. Major factors associated with an increased likelihood of CRT use included white race, hospitalization in the western United States, decreasing left ventricular ejection fraction, and increasing age up to 70 years of age. CRT use varies by age, race, hospital site, and geographic region. Further research is needed to understand the reasons for the variations in CRT use at the patient, physician, and hospital levels and to implement programs to improve the awareness and promotion of evidence-based use of medical devices in heart failure.

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