Underutilization of β-Blockers in Patients Undergoing Implantable Cardioverter-Defibrillator and Cardiac Resynchronization Procedures

Paul J. Hauptman, MD; Jason P. Swindle, MPH, PhD; Frederick A. Masoudi, MD, MSPH; Thomas E. Burroughs, PhD

Background—Current guidelines emphasize the need for optimal medical therapy before implantation of cardiac devices (implantable cardioverter-defibrillator, cardiac resynchronization therapy). Our objective was to evaluate use of β-blockers (BB) among patients with heart failure undergoing a cardiac device procedure.

Methods and Results—We used a large, multistate, managed-care database (January 2003 to December 2006) to identify adults admitted with an International Classification of Diseases, Ninth Revision (ICD-9) procedure code for cardiac device, continuous enrollment for 180 days before and 180 days after device procedure, and a primary or secondary ICD-9 diagnosis code for heart failure during that period. Our primary measures were use of BB before device procedure and changes after discharge. A total of 2766 beneficiaries (78.8% men; median age, 61 years) underwent a device procedure for primary prevention. The median number of days on BB therapy in the 90 days before device procedure was 46. Beneficiaries who did not have a pharmacy fill for BB during that time (n=925, 33.4%) were more elderly and had fewer antecedent outpatient visits with a cardiologist. There was a shift toward greater use of BB after device procedure; 83.4% had at least 1 pharmacy fill for a BB during follow-up.

Conclusions—BB are underused before and after cardiac device procedures. There is a modest increase in use after the procedure. Strategies are required to ensure that patients are on optimal medical therapy before device therapy is selected.

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Key Words: heart failure ■ drugs ■ prevention ■ sudden death
WHAT IS KNOWN

- Current guidelines emphasize the need for optimal medical therapy prior to implantation of cardiac devices (implantable cardioverter-defibrillator, cardiac resynchronization therapy) in patients with heart failure.
- β-Blockers in particular may decrease the incidence of sudden cardiac death and may lead to clinically important improvements in left ventricular ejection fraction.

WHAT THE STUDY ADDS

- β-Blockers are underused in the 90 days before cardiac device procedures.
- There is a modest increase in use after the procedure, but underuse remains.
- This highlights the need for strategies geared toward ensuring maximal use of β-blockers in patients undergoing implantation of implantable cardioverter-defibrillators or cardiac resynchronization therapy.

Methods

We used administrative claims data from a large managed-care organization within the United States. The extracted dataset includes more than 218 million medical claims, 243 million pharmacy claims, and 306 million laboratory records across 6.1 million individuals during the period of January 1, 2003, to December 31, 2006. All beneficiaries had concurrent continuous medical and pharmacy coverage provided through the insurer within this time frame.

Variables in the database include patient demographic information (age, sex, and geographic location but not race), admission and discharge dates, start and end dates for medical and pharmacy coverage, primary and secondary International Classification of Disease, Ninth Revision (ICD-9) diagnosis and procedure codes, pharmacy fill information (ie, drug type, fill date, days supplied) organized by the National Drug Code system, and provider information (type of visit and physician specialty).

The key inclusion criteria for this study were (1) an ICD-9 procedure code for device procedure (supplemental Appendix 1), (2) continuous coverage for 180 days before the day of admission for the index hospitalization that included the device procedure and 180 days after discharge for device procedure, (3) a primary or secondary ICD-9 diagnosis code for HF (a detailed list is available on request) during the coverage period, and (4) age 18 years or older at the beginning of the coverage period. Individuals were excluded when contraindications for BB therapy were identified (using ICD-9 diagnosis codes listed at any time during the 180 days before hospitalization) and included hypertension, diabetes mellitus, lung disease (chronic airway obstruction, emphysema, chronic bronchitis), chronic renal failure, and acute cerebrovascular disease. Although chronic lung diseases do not necessarily represent absolute contraindications to therapy, a secondary analysis was performed in which the sample was limited to beneficiaries without an ICD-9 diagnosis code for any chronic lung disease and/or any prescribed days for medications listed as appropriate for asthma treatment according to the National Committee for Quality Assurance.

We also examined inpatient admissions with primary ICD-9 diagnosis codes for HF and acute myocardial infarction (AMI) and outpatient cardiology visits with a physician provider (described as “cardiac electrophysiologist,” “cardiologist,” “cardiovascular disease specialist,” “diagnostic cardiology,” or “interventional cardiologist”) during the entire study period.

In a secondary analysis, background oral BB therapy was categorized as either evidence-based or non–evidence-based, according to the results of randomized clinical trials and contemporary HF practice guidelines. Evidence-based BB therapy was defined as use of carvedilol, metoprolol, or bisoprolol. Non–evidence-based BB therapy consisted of acebutolol, atenolol, betaxolol, labetalol, nadolol, pindolol, propranolol, or sotalol. Although bisoprolol fumarate and the tartrate formulation of metoprolol are not approved by the Food and Drug Administration for use in HF, we included these drugs under the evidence-based label (the latter because its selection may have been influenced by lower copays as a generic drug and the former because its use can be supported by the results of a large randomized clinical trial).

Statistical Analyses

To assess how patient characteristics and clinical course were related to BB use, we examined the distributional characteristics of each variable to check for outliers and to test the underlying assumptions for each of the formal statistical tests that followed. We used χ² tests to identify the individual beneficiary factors associated with drug use before and after the hospitalization for device procedure. Tests used to identify differences in variables before versus after hospitalization for device procedure were the Wilcoxon signed-rank test for ordinal variables (such as drug use, HF hospitalization, and outpatient cardiology visits) and McNemar test for AMI hospitalization (yes/no). Correlations between levels of drug use for specific time periods were evaluated using Spearman’s ρ.

Logistic regression with stepwise selection was performed to model BB use in the 90 days before hospitalization for device procedure and changes in BB use from the 90 days before the 180 days after hospitalization for device procedure. However, the relevant time period for a pharmacy fill extended to 180 days, so that prescriptions filled before 90 days before the device procedure were included if the projected end date of the prescription overlapped with the 90 days before the hospitalization. For all other pharmacy fills, the number of days supplied was added to the pharmacy fill date to project start and end dates for the period covered by the prescription.

We excluded the period of hospitalization for device procedure from the analysis; therefore, prescription fills before the procedure were carried over to the date after discharge as appropriate. If prescriptions were refilled before the projected end date, the projected start date for the new fill was shifted to the day after the projected end date of the earlier fill.

Use of BB therapy was classified into 4 groups according to a modification of prior published definitions: high (proportion of days on evidence-based therapy >80%), intermediate (40% to 79%), low (<40% but >0%), and none (no prescribed days for the drug during the period under observation).

Beneficiary characteristics at hospitalization for the device procedure were age, sex, geographic location, device type, and length of stay. Length of stay was calculated from the day of admission to the day of discharge inclusive; any calendar day change added a day to the value.

Coexisting illnesses were identified by primary or secondary ICD-9 diagnosis codes listed at any time during the 180 days before hospitalization and included hypertension, diabetes mellitus, lung disease (chronic airway obstruction, emphysema, chronic bronchitis), chronic renal failure, and acute cerebrovascular disease. Although chronic lung diseases do not necessarily represent absolute contraindications to therapy, a secondary analysis was performed in which the sample was limited to beneficiaries without an ICD-9 diagnosis code for any chronic lung disease and/or any prescribed days for medications listed as appropriate for asthma treatment according to the National Committee for Quality Assurance.

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days after hospitalization. One analysis modeled improvement in use among individuals in the none, low, and intermediate categories to any higher level of use, whereas another analysis modeled decline in use among individuals in the high use category. Covariates included age at admission for device procedure (18 to 64, 65 to 74, >75 years), sex, geographic location, any prescribed days for angiotensin-converting enzyme (ACE) inhibitors and/or angiotensin receptor blockers (ARBs) in the 90 days before device procedure, coexisting illnesses (hypertension, diabetes mellitus, lung disease, chronic renal failure, and acute cerebrovascular disease), any hospitalizations for AMI or HF before device implantation, and any outpatient cardiology visits.

Data management and analyses were performed using SAS version 9.1 (SAS Institute, Inc, Cary, NC). Differences were considered statistically significant at a 2-sided P<0.05 level. The study was approved by the Saint Louis University Institutional Review Board.

## Results

### Demographics and Clinical Course

A total of 2766 beneficiaries were identified as having a device procedure for primary prevention during the period under study and continuous enrollment for 180 days before and after the hospitalization with a diagnosis of HF during that period. Of this number, 78.8% were male with a median age of 61 years (mean, 60.4; SD, 11.8). Prevalent coexisting illnesses were hypertension (65.0%), diabetes mellitus (35.6%), and lung disease (20.4%) (Table 1). Device procedures were categorized as implantation, revision or replacement of ICD (n=1846), CRT-D (n=814), or CRT-P alone (n=106). The median length of stay was 2 days (mean, 4.3; SD, 4.6).

More than 1 in 5 patients (n=610, 22.1%) had an HF admission in the 180 days before hospitalization for device procedure. In the 180 days after the device procedure, hospitalizations for HF and AMI occurred in 540 (19.5%) and 73 (2.6%) patients, respectively. The majority of patients had an outpatient encounter with a cardiologist before (86.8%) and after (95.4%) the hospitalization for device procedure; however, the median number of outpatient visits to a cardiologist, per beneficiary, increased from 3 visits to 4.

### BB Use Before Hospitalization for Device Procedure

The median number of covered days in the 90 days leading up to hospitalization for device procedure was 46 (mean, 44.6; SD, 38.6). Use increased gradually peaking at 54.5% on the day before hospitalization (Figure 1). When we limited the HF population to those subjects with a prior documented ICD-9 diagnosis code for HF (n=2213), we found that the daily percentage of patients on a BB increased slightly to a peak of 56.8% (or 43.2% without a pharmacy fill covering the day before the device procedure). The percentage without at least 1 day of prescribed BB therapy at any time was 33.4% (n=925). There was a gradient according to age, which was apparent when we removed the small percentage (3.5%) of patients with no pharmacy fills during the entire period of observation (Figure 2). There was also an increase in use of BB by calendar year (of the device procedure) in the 7 days leading up to the device procedure (from 50.8% to 62.7%).

Among those with a prescribed day (n=1841), 1049 beneficiaries (57.0%) were in a high use group for BB, whereas 435 (23.6%) and 357 (19.4%) individuals were in intermediate and low use groups, respectively. On any given day, evidence-based BB accounted for at least 84.6% of total BB use.

We compared patients with any prescribed days for a BB in the 90 days before device procedure with beneficiaries who had no fill. Individuals without a pharmacy fill were more often elderly; they also had fewer outpatient office visits with a cardiologist and fewer hospitalizations for HF or acute myocardial infarction (Table 1). When the group with a pharmacy fill was analyzed by specific level of use, these differences remained (Table 2).

There were slight differences in BB use according to cardiac device (Figure 3A); the percentage of subjects on BB was greatest for CRT-D. Subjects who had a primary ICD-9 diagnosis code for HF were more likely to be on a BB in the
BB Use After Hospitalization for Device Procedure

The use of a BB increased immediately after discharge and was sustained during the entire follow-up period (Figure 1). In the 180 days after hospitalization for device procedure, 83.4% of patients had at least 1 day prescribed for a BB; the median number of days on therapy was 155 (mean, 120.5; SD, 69.5). A moderate positive correlation existed between level of BB use before and after device procedure ($r=0.569$, $P<0.001$).

Overall, there was a shift toward greater use with BB (Figure 4) after the procedure. Based on a Wilcoxon signed-rank test, a statistically significant difference in level of use was observed in a comparison of the time periods before and after hospitalization ($P<0.001$). Among the 925 patients who had no days prescribed for BB in the 90 days before device procedure, 139 (15.0%) shifted into the low use group, 144 (15.6%) into the intermediate use group, and 234 (25.3%) into the high use group. Conversely, of the 1049 patients in the high use group, 883 (84.2%) remained in that group; 122 (11.6%) shifted into the intermediate use group; 39 (3.7%) shifted into the low use group; and only 5 (0.5%) did not have a day prescribed for BB during follow-up.

Variables significantly related to improvement in use by at least 1 level were any prescribed day of an ACE inhibitor or ARB in the 90 days before hospitalization for device procedure (versus none, OR, 1.38; 95% CI, 1.12 to 1.70; $P=0.002$); hospitalization for AMI in the 180 days before hospitalization (versus none, OR, 1.62; 95% CI, 1.11 to 2.35; $P=0.012$); outpatient visit with a cardiologist in the 180 days before hospitalization (versus none, OR, 0.26; 95% CI, 0.19 to 0.36; $P<0.001$); and age (65 to 74 versus 18 to 64 years, OR, 0.53; 95% CI, 0.42 to 0.69; $P<0.001$; ≥75 versus 18 to 64 years, OR, 0.46; 95% CI, 0.35 to 0.62; $P<0.001$).

Similarly, we examined variables associated with worsening in use by at least 1 level in the group of patients with high use before hospitalization for device procedure. Significant variables were Midwest geographic location (versus South, OR, 1.52; 95% CI, 1.08 to 2.14; $P=0.016$) and age (≥75 versus 18 to 64 years, OR, 3.05; 95% CI, 1.92 to 4.86; $P<0.001$).

BB Use Among Secondary Prevention Patients

Of the patients undergoing a device procedure for secondary prevention (n=433), ICD use alone was more common (82.7 versus 66.7%, $P<0.001$) than in the main primary prevention cohort. In addition, the secondary prevention patients were less likely to have had an antecedent cardiology outpatient visit (80.1 versus 86.8%, $P<0.001$). BB use in the period after the procedure was lower, but the differences were minor (Figure 5): 18.0% did not have a single pharmacy fill for a BB.

Discussion

Underutilization of evidence-based medication has been clearly documented in HF management$^{1-6}$ and may vary according to the type of drug, setting (eg, clinical trial, registry, or clinical practice) and study period. This observation now extends to the growing population of patients undergoing an implantation or revision of an ICD or CRT.
Among patients with a primary prevention indication (absence of an antecedent ICD-9 code for ventricular fibrillation, ventricular flutter, or cardiac arrest), we found that 33.4% of patients did not have coverage for at least 1 or more days with a BB in the 90 days preceding a hospitalization for a device procedure. Less than 40% had prescriptions that covered at least 80% of the 90 days.

These observations are noteworthy because BB can improve ejection fraction and reduce the risk of sudden cardiac death and hence affect device candidacy. Indeed, current clinical practice guidelines state that for primary prevention of sudden cardiac death “consideration of ICD implants should follow documentation of sustained reduction of ejection fraction despite a course of BB,”10 and patients should be on optimal medical therapy before implantation of a cardiac device. These recommendations are based, at least in part, on the observation that improvements in ejection fraction may occur with BB, potentially placing patients outside the window for device therapy. Additionally, the magnitude of effect of device therapy may be lessened if eligible patients are on appropriate medical therapy mediated in part by a reduction in ventricular arrhythmias. As a consequence, the underuse of BB has potential implications for resource utilization and cost-effectiveness. For example, estimates based on primary prevention ICD trials suggest that the cost-effectiveness ratio would exceed $100 000 per quality-adjusted life-year if an ICD placed for primary prevention did not improve mortality for 7 or more years.22 The degree to which increased use of BB would affect this ratio is not absolutely clear, but survival benefit is likely to accrue with BB prescription alone. Although a counterargument could be made that an ICD provides a degree of protection against sudden cardiac death in the absence of β-blockade, this approach to patient care appears to be antithetical to conventional and guideline-driven clinical management.

We also found that there were only slight differences according to device type, presence of a primary versus

<table>
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<tr>
<th>Table 2. Beneficiary Characteristics and Clinical Course Before Device Procedure, by Level of BB Use</th>
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<tr>
<td>Variables</td>
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<tr>
<td>Age*, y</td>
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<tr>
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<tr>
<td>Chronic renal failure</td>
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<td>Acute cerebrovascular disease</td>
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*At admission for device procedure.  †High adherence was defined as proportion of days covered at 80% or more; intermediate, 40% to 79%; low, <40% but ≥0%; and none, no prescribed days.
secondary ICD-9 diagnosis code for HF, or inclusion/exclusion of patients with a prescription fill for medications indicated for treatment of asthma. This suggests that the underuse we observed occurs broadly in the device population. Additionally, the variables related to BB use before a device procedure were largely expected: concomitant use of an ACE inhibitor or ARB, outpatient visits with a cardiologist, hospitalization for HF or AMI, acute cerebrovascular disease, and younger patient age. There was also an expected gradient by age group (with younger patients more likely to be prescribed BB) and by year (with greater use in the last 2 years of the period of observation). This latter finding likely reflects secular trends in use, because the major BB trials were already published before 2002.11–14 We cannot exclude the potential influence of guidelines published in 2005,10 2006,8,9 and subsequently; more contemporary data beyond our period of data collection (2003 to 2006) will be needed to establish if the increase in adherence with BB continued.

Finally, we noted that patients with an ICD-9 diagnosis code for ischemic heart disease were more likely to be on a BB compared with patients without a code (data not shown), but whether this can be interpreted to mean that etiology of HF influenced BB prescribing practice is not clear.

The literature offers some insight into the background use of BB. In 5 major device trials published between 2002 and 200523–27 (a period that overlaps with the time frame of the current analysis), baseline BB use varies considerably (from 22.1%26 to 73.8%27). Our results are near the midpoint of this range. The cohort in our study may resemble to some degree the population in the clinical trials; for example, the median age in our cohort (61 years) compares favorably to the average age in these studies (range, 60 to 66 years).

The reasons underlying underutilization cannot be conclusively determined. It is possible that the phenomenon of a risk treatment mismatch28 explains a component of the underutilization of BB. Practitioners may also emphasize technological approaches to HF management over traditional medical therapy or fail to appreciate the impact that BB can have on ejection fraction and prognosis. However, underutilization of evidence-based medication for HF has been previously recognized and led to the development of interventions including an intensive predischarge nurse encounter,29 disease management,30 and other quality initiatives.31

After hospitalization for device procedure, overall use of BB increased. Of the 925 patients without a pharmacy fill for a BB in the 90 days before device procedure, 55.9% had at least 1 fill in the 180 days after hospitalization. This suggests that the hospitalization may have influenced prescribing practice, which is relevant because BB may affect outcomes15–17 and likelihood of ICD discharges15,32 after implantation. In addition, there was a very modest degree of decay in use among patients with the highest levels of use before the procedure; nearly 85% remained in the high use category.

Our findings are consonant with the study by Butler et al,33 which revealed that BB prescription fills after hospitalization for AMI increased shortly after discharge among patients prescribed therapy before discharge. Similarly, Smith et al34 observed that outpatient use of statin therapy was largely

Figure 3. The use of BB varied slightly according to subgroups. A, For device type, use was greater for CRT-D (n=814) than for ICD (n=1846) or CRT-P (n=106). B, The presence of a primary ICD-9 diagnosis code for heart failure (n=2508) was associated with greater use than when only secondary coding was present (n=258). C, Use was lower in the presence of a potential BB contraindication (ICD-9 diagnosis code for chronic lung disease or prescription fill for medications listed as appropriate for asthma treatment, n=676) than in its absence (n=2090), but these differences were small.

Figure 4. A general shift toward higher level of use was observed (see text for definitions). The largest groups remained those at either end of the use spectrum (high and none).

Figure 5. Comparison of BB use in the 180 days after device procedure between primary and secondary prevention cohorts demonstrates no significant difference.
contingent on use during the hospitalization, and others have noted the role that HF hospitalizations play in improving medication use.35

Limitations
There are a number of limitations to this study that are important to recognize. First, it is possible that some patients received medications outside this managed-care plan (eg, filled medications under a separate insurance plan held by a spouse). However, 96.5% of beneficiaries in the primary and secondary prevention cohorts had at least 1 pharmacy fill during the period under study, which suggests that most beneficiaries used this plan to cover their prescription medications. Second, we cannot account for cases where a prescription was written but not filled by the patient. Nevertheless, if a patient is nonadherent, the argument can be made that candidacy for an implantable device should be reconsidered because frequent device monitoring and/or reprogramming are often required to ensure maximal clinical benefit.

Although there is literature suggesting that cardiologists are more likely to prescribe evidence-based medication in HF,36–39 we were unable to separately analyze the specialty of the prescribing physician because the physician of record may not have been the original prescriber. However, we were able to establish that the majority of patients had an outpatient encounter with a cardiologist, both before and after the hospitalization for the device procedure.

Data on several key patient demographics were deidentified; in particular, race was redacted and therefore we cannot assess this important variable. We have no data on mortality; the absence of defined records might indicate either death or disenrollment from the managed-care plan. Therefore, we required evidence for continuous enrollment as outlined for a period of 180 days after discharge for the device procedure. The study population is selected in that it is derived from a managed care organization rather than a general population of patients with heterogeneous insurance coverage. We also do not address appropriateness of ICD use and cannot delineate symptoms or describe left ventricular ejection fraction in this patient population.

In addition, we relied on ICD-9 codes to establish contraindications to BB and to define the primary prevention cohort; although not ideal, we can point to the OPTIMIZE Registry, which used clinical data to assess for contraindications. Our figure, 85.7% (derived from the originally screened cohort), compares favorably to the 89% eligibility rate described in the registry.40 Although we cannot control for potential undercoding of coexisting illnesses or lack of recognition of conditions such as depression or symptoms such as fatigue that might explain BB underuse, it is unlikely that a full accounting of these factors would translate into a significantly higher figure for use of this class of medication.

Conclusion
Underutilization of BB is significant among patients undergoing implantation or revision of an implantable cardiac rhythm device. Because BB can affect risk of sudden death and overall outcomes, further study is required to delineate the extent of the problem in the non–managed-care setting, to link underuse with poorer outcomes, and to devise strategies to ensure that optimal medical therapy is provided to patients before device implantation.

Sources of Funding
The study was funded through internal sources.

Disclosures
Dr. Hauptman was a site coinvestigator in the SCD-HeFT trial and has received speakers’ bureau and consulting honoraria from GlaxoSmithKline.

References


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Supplemental Data
Appendix 1. *ICD-9* Procedure Codes for Device Procedures

**CRT**
- 00.50 - Implantation of cardiac resynchronization pacemaker without mention of defibrillation, total system [CRT-P]
- 00.51 - Implantation of cardiac resynchronization defibrillator, total system [CRT-D]
- 00.53 - Implantation or replacement of cardiac resynchronization pacemaker pulse generator only [CRT-P]
- 00.54 - Implantation or replacement of cardiac resynchronization defibrillator pulse generator device only [CRT-D]

**ICD**
- 37.94 - Implantation or replacement of automatic cardioverter/defibrillator, total system [AICD]
- 37.96 - Implantation of automatic cardioverter/defibrillator pulse generator only
- 37.98 - Replacement of automatic cardioverter/defibrillator pulse generator only
### Appendix 2. ICD-9 Diagnosis Codes for Beta Blocker Contraindications

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<tr>
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<th>Codes</th>
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<td><strong>Asthma</strong></td>
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<tr>
<td><strong>Second or Third Degree Atrioventricular Block</strong></td>
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<tr>
<td><strong>Autonomic Neuropathy</strong></td>
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<tr>
<td><strong>Bronchiectasis</strong></td>
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