Provider and Hospital Characteristics Associated With Geographic Variation in the Evaluation and Management of Elderly Patients With Heart Failure

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**Background:** Rates of guideline-based care for elderly patients with heart failure vary by state, and overall are not optimal. Identifying factors associated with the lack of uniformly high-quality health care might aid efforts to improve care. We therefore sought to determine the extent to which provider and hospital characteristics contribute to small-area geographic variation in heart failure care after controlling for patient factors.

**Methods:** We studied 30,228 Medicare patients who were older than 65 years and hospitalized with heart failure. We mapped rates for 2 quality measures—documentation of left ventricular ejection fraction and appropriate prescription of angiotensin-converting enzyme inhibitors—across the United States, using a Bayesian technique that smooths rates and enhances assessment for significant patterns of small-area variation. We used nonlinear hierarchical models to assess for associations between the quality indicators and provider and hospital characteristics independent of patient characteristics.

**Results:** Smoothed, unadjusted rates of left ventricular ejection fraction documentation ranged from 30.1% to 67.2% and of angiotensin-converting enzyme inhibitor prescription from 55.8% to 87.1% among hospital referral regions; regional patterns were apparent. After patient factors were controlled for, care at hospitals without a medical school affiliation, without invasive cardiac capabilities, or in a rural location, as well as not having a cardiologist as an attending physician, was significantly associated with lower rates of left ventricular ejection fraction documentation. Hospitalization at a non-teaching facility was significantly associated with failure to prescribe angiotensin-converting enzyme inhibitors.

**Conclusion:** Characteristics of providers and hospitals explain in part the geographic variation in guideline-based care for elderly patients with heart failure.

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The causes of geographic variation in the provision of health care services have been debated for more than 25 years. Regional differences in patient demographics, in disease incidence and severity, in specialist and hospital bed availability, and in physician practice patterns have all been implicated. Causes of variation have been most widely studied for surgical procedures, less is known about the causes of variation in treatment for medical conditions. In addition to incomplete understanding of the causes of geographic variation, interpretation of these studies has been plagued by a lack of consensus on the most appropriate levels for the rates studied. It is generally not known whether low rates represent underuse, and thus poor quality of care, or if high rates represent overuse and poor quality of care. Demonstration of systematic variation in a clinical situation in which there is consensus that all patients should receive a given treatment would add significant strength to calls to reduce geographic variation in health services.

Among Medicare beneficiaries, heart failure is the leading cause of hospital admission, has a 6-month readmission rate of 44%, and has a 1-year mortality rate that is estimated at 29% to 36%. Uniform high-quality health care might reasonably be expected to reduce this burden of morbidity and mortality. There is consensus that documentation of ejection fraction (EF) for all patients with heart failure and prescription of angiotensin-converting enzyme (ACE) inhibitors for all patients with heart failure due to left ventricular systolic dysfunction are indicators of quality of care. The Centers for Medicare & Medicaid Services has reported that these services are not provided to all patients for whom they are appropriate.

Against this background, we analyzed geographic variation in heart fail-
ure care. We assessed the degree of small-area geographic variation for these indicators by mapping rates with a Bayesian technique to facilitate the recognition of geographic patterns by hospital referral region (HRR).\textsuperscript{18} Small areas such as HRRs have been judged to be the most valid units for characterizing geographic variation.\textsuperscript{8} We also looked for associations between indicator rates and hospital and physician characteristics after controlling for patient characteristics.

QUALITY OF HEART FAILURE CARE

Our principal outcomes were 2 indicators of the quality of heart failure care. The first indicator assessed whether patients had documentation in the medical record of left ventricular EF assessment performed either before or during the index admission. The second indicator assessed whether patients with left ventricular systolic dysfunction (EF <40\% or the narrative equivalent) were prescribed an ACE inhibitor at the time of discharge or had a documented reason why ACE inhibitors were not used. Both measures are widely supported in evidence-based guidelines for heart failure care.\textsuperscript{16}

STATISTICAL METHODS

Variation in rates among small areas is the result of both random variation within areas around the true rate for that area and systematic variation in true rates across areas. The literature on small-area variation has produced a number of measures that describe this variation across areas but has not produced clear consensus on the best measure. Recently, empirical Bayesian techniques, originally developed to solve image reconstruction problems, have been applied to problems of spatial epidemiology.\textsuperscript{21} This technique revises the estimate of the dependent variable for a given region using the mean value of the estimates for the adjacent regions. The empirical Bayesian techniques has advantages over traditional maximum likelihood techniques in that it includes more reliable accounting for variation in areas of low incidence or of relatively high or low population and it produces more easily interpretable maps. We used a nonlinear mixed-effects model\textsuperscript{22} with HRR designated as the random effect to produce the empirical Bayesian estimates of the rates by HRR. The parallel between mixed-effects models, also known as hierarchical models, and Bayesian statistics is the result of the correspondence between the random coefficients in the mixed-effects models and the random parameters essential to Bayesian statistics.

The null model includes random effects but no covariates. From this, we estimated the unadjusted rates by HRR. The smoothing is the result of shrinkage toward the mean, since the posterior means are a weighted combination of the population estimates and the observed data, where the weights are a function of the variance of the random effects (in this case, a random intercept for each HRR) and the residual error.\textsuperscript{22} The emphasis is on the population component for HRRs with few observations and shifts toward the observed component as the number of observations increases.

We added covariates to the null hierarchical models to describe the relationships between rates of EF documentation or ACE inhibitor prescription and characteristics of patients, hospitals, and providers. These covariates were chosen from the 192 patient-level data elements in the National Heart Failure database as well as from the provider variables available in the American Medical Association Physician Masterfile and the hospital variables from the American Hospital Association annual survey as noted above. Patient-level data elements included demographic data, heart failure symptoms, comorbid conditions, physical examination findings, and laboratory data, including electrocardiographic and chest radiograph findings. Variables associated in univariate analysis with a P value of less than .05 were candidates for the multivariable models; we chose the relatively stringent criterion of P<.05 because of the large number of observations in our sample. We included variables identified as clinically important from prior studies without subjecting them to univariate analysis. These variables included attending physician specialty, teaching hospital status, and the presence of cardiac catheterization facilities. We estimated the parameters for the covariates in models that included a ran-
dom intercept for hospital characteristics as well as HRR. We checked for multicollinearity for all variables in the final model. Rates for each HRR were calculated using probability weights (inverse sampling fraction for each state) to obtain an estimate that is representative of the total number of heart failure admissions nationwide during the sampling period. We assessed model calibration with the Hosmer-Lemeshow goodness-of-fit statistic; statistical significance indicates that the model is poorly calibrated.

We generated maps and computed unadjusted rates with SAS (Version 8.2; SAS Institute, Cary, NC) and STATA (Version 7.0; STATA Corp, College Station, Tex) software. Final model parameters were estimated with MLwiN software (Version 1.1; Institute of Education, University of London, London, England).

RESULTS

There were 37,423 unique patients in the analysis sample. After the inclusion and exclusion criteria were applied, 30,228 patients aged 65 years or older were eligible for the EF documentation indicator, and 8475 patients aged 65 years or older were eligible for the ACE inhibitor prescription indicator. Exclusions are shown in Figure 1. The initial subset of 30,817 had an age distribution typical for Medicare patients (29.6%, 65-74 years; 43.5%, 75-84 years; and 26.9%, >85 years) and was 59.7% female. The patients were 85.0% white, 11.4% black, and 3.1% other; 4.1% of patients were identified as Hispanic. Details of the baseline characteristics of the National Heart Failure Project population have been published.23

Variation in heart failure care by HRR is illustrated in Figure 2 and Figure 3. The median number of cases per HRR was 36; the interquartile range was 13 to 77. Figure 2 shows smoothed unadjusted rates of EF documentation. Figure 3 shows smoothed unadjusted rates of ACE inhibitor prescription at discharge. The national raw rates are 66.6% for EF documentation and 66.3% for ACE inhibitor prescription.

Odds ratios for the association of patient, physician, and hospital characteristics with rates of EF determination are shown in Table 1. The patient variables associated with documentation of EF before or during hospitalization were female sex, older age, lower income (as assessed by Medicaid eligibility), higher serum creatinine levels, diabetes, chronic obstructive lung disease, history of stroke or dementia, and absence of history of hypertension. The attending physician characteristic of cardiology specialty was associated with more frequent documentation of EF. The hospital characteristics associated with lower rates of documentation of EF were smaller size, absence of catheterization facilities, nonteaching hospital status, and rural location. The univariate relationships for all candidate variables are not shown because of the large number of variables investigated.

Odds ratios for the association of patient, physician, and hospital characteristics with rates of ACE inhibitor prescription are shown in Table 2. The patient variables associated with failure to prescribe ACE inhibitors were older age, nonblack race, higher serum creatinine levels, and chronic obstructive lung disease. No physician characteristics were associated with failure to prescribe ACE inhibitors, but the hospital characteristic of nonteaching hospital designation was associated. Again, univariate relationships for all candidate variables are not shown because of the large number of variables investigated.

Table 3 shows odds ratios for US Census regions (East, Midwest, South, and West) with East as the referent variable. This component of the analysis quantifies the regional patterns evident in Figures 2 and 3, with significantly higher rates of EF determination in the Northeast compared with the rest of the country, and signifi-

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**Figure 1.** Study exclusions. ACE indicates angiotensin-converting enzyme; ARB, angiotensin II receptor blocker; EF, ejection fraction; HRR, hospital referral region; LV, left ventricular; and NHF, National Heart Failure Project.

**Figure 2.** A, Geographic distribution of smoothed unadjusted rates of documentation of left ventricular ejection fraction (LVEF) by hospital referral region (HRR). Alaska is in the 40% to 49% range. B, Frequency distribution of smoothed unadjusted rates of documentation of LVEF by HRR.
significantly lower rates of ACE inhibitor prescription in the South.

Summary statistics for the models are given in Table 4. The statistically significant Hosmer-Lemeshow statistic demonstrates that the model is relatively poorly calibrated and should not be used to predict quality indicators from patient and provider characteristics, a purpose for which it was not intended.

The current study demonstrates small-area variation in rates of EF documentation and ACE inhibitor prescription for hospitalized elderly patients with heart failure in the United States. Variation in rates smoothed with a Bayesian technique is strong evidence that this variation is not the result of chance. Rates of these quality indicators were generally highest in the northeastern states and generally lowest in the Plains and southern states. Rates were lower and variation was greater for EF documentation than for ACE inhibitor prescription.

**Table 1. Multivariable Relationship Between Rates of Ejection Fraction Determination and Patient, Physician, and Hospital Characteristics**

<table>
<thead>
<tr>
<th></th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>0.86 (0.82-0.91)</td>
</tr>
<tr>
<td>Age, y</td>
<td>75-84 0.88 (0.83-0.94)</td>
</tr>
<tr>
<td>Dually eligible</td>
<td>0.78 (0.73-0.83)</td>
</tr>
<tr>
<td>Serum creatinine*</td>
<td>0.87 (0.84-0.91)</td>
</tr>
<tr>
<td>History of hypertension</td>
<td>1.29 (1.22-1.36)</td>
</tr>
<tr>
<td>COPD</td>
<td>0.81 (0.76-0.85)</td>
</tr>
<tr>
<td>History of stroke</td>
<td>0.84 (0.79-0.90)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>0.87 (0.82-0.92)</td>
</tr>
<tr>
<td>Dementia</td>
<td>0.71 (0.66-0.78)</td>
</tr>
<tr>
<td>Cardiac catheterization laboratory present</td>
<td>1.19 (1.10-1.29)</td>
</tr>
<tr>
<td>Teaching hospital</td>
<td>1.12 (1.03-1.22)</td>
</tr>
<tr>
<td>Rural</td>
<td>0.58 (0.53-0.65)</td>
</tr>
<tr>
<td>Hospital size†</td>
<td>1.31 (1.24-1.39)</td>
</tr>
<tr>
<td>Cardiologist as attending physician</td>
<td>1.17 (1.10-1.26)</td>
</tr>
<tr>
<td>Attending physician specialty unknown</td>
<td>1.17 (1.07-1.28)</td>
</tr>
</tbody>
</table>

**Abbreviations:** CI, confidence interval; COPD, chronic obstructive pulmonary disease; OR, odds ratio.

*Odds ratio is for each 1-mg/dL increment in serum creatinine.
†Logarithm of number of beds.

**Table 2. Multivariable Relationship Between Rates of ACE Inhibitor Prescription and Patient, Physician, and Hospital Characteristics**

<table>
<thead>
<tr>
<th></th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black race</td>
<td>1.35 (1.12-1.62)</td>
</tr>
<tr>
<td>Age, y</td>
<td>75-84 0.86 (0.75-0.97)</td>
</tr>
<tr>
<td>Serum creatinine*</td>
<td>0.56 (0.52-0.60)</td>
</tr>
<tr>
<td>COPD</td>
<td>0.79 (0.71-0.89)</td>
</tr>
<tr>
<td>Teaching hospital</td>
<td>1.20 (1.07-1.35)</td>
</tr>
</tbody>
</table>

**Abbreviations:** ACE, angiotensin-converting enzyme; CI, confidence interval; COPD, chronic obstructive pulmonary disease; OR, odds ratio.

*Odds ratio is for each 1-mg/dL increment in serum creatinine.

**Table 3. Odds Ratios (OR) for Ejection Fraction (EF) Documentation and ACE Inhibitor Prescription by US Census Regions**

<table>
<thead>
<tr>
<th></th>
<th>EF Documented</th>
<th>EF Prescribed</th>
</tr>
</thead>
<tbody>
<tr>
<td>East</td>
<td>71.8</td>
<td>83.8</td>
</tr>
<tr>
<td>Midwest</td>
<td>64.1</td>
<td>80.4</td>
</tr>
<tr>
<td>South</td>
<td>64.9</td>
<td>76.5</td>
</tr>
<tr>
<td>West</td>
<td>62.3</td>
<td>82.7</td>
</tr>
</tbody>
</table>

**Abbreviations:** ACE, angiotensin-converting enzyme; CI, confidence interval.

**Table 4. Model Summary Statistics**

<table>
<thead>
<tr>
<th></th>
<th>R², %</th>
<th>c Statistic†</th>
<th>H-L χ²‡ (P Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF documentation</td>
<td>10.5</td>
<td>0.69</td>
<td>36.73 (&lt;.001)</td>
</tr>
<tr>
<td>ACE inhibitor prescription</td>
<td>6.4</td>
<td>0.63</td>
<td>6.37 (.60)</td>
</tr>
</tbody>
</table>

**Abbreviations:** ACE, angiotensin-converting enzyme; EF, ejection fraction.

*Explained variance as a percentage of total variance.
†Area under the receiver operating characteristic curve.
‡Hosmer-Lemeshow goodness-of-fit statistic; χ² with 8 df.

The current study demonstrates small-area variation in rates of EF documentation and ACE inhibitor prescription for hospitalized elderly patients with heart failure in the United States. Variation in rates smoothed with a Bayesian technique is strong evidence that this variation is not the result of chance. Rates of these quality indicators were generally highest in the northeastern states and generally lowest in the Plains and southern states. Rates were lower and variation was greater for EF documentation than for ACE inhibitor prescription.

After patient characteristics were adjusted for, both provider and hospital characteristics remained significantly associated with EF documentation but not with...
ACE inhibitor prescription. Contributions of provider and hospital characteristics were quantitatively similar. The effect of adding hospital characteristics was more pronounced in the model for EF measured than in the model for ACE inhibitors, while the addition of patient characteristics caused the single largest reduction in unexplained variation in the ACE inhibitors model.

Obviously, EF documentation and ACE inhibitor prescription are not independent quality indicators; the selection of patients with heart failure for ACE inhibitor therapy depends on first determining the EF. Thus, in areas where the EF is less likely to be documented, opportunities are missed for prescribing proper therapy.

Several of these findings bear further comment. The finding of chronic obstructive pulmonary disease as a predictor of both failure to document EF and failure to prescribe an ACE inhibitor is likely the result of diagnostic overlap between this diagnosis and heart failure. The finding of black race as a predictor of ACE inhibitor prescription is surprising in light of a perception of a lack of efficacy for these agents in African American patients. Although this finding may be the result of African American patients being more likely to have hypertension requiring treatment with multiple agents, further investigation is needed. The finding of lower rates of EF documentation in rural hospitals and in those without invasive cardiac services may imply that echocardiography is unavailable in these settings, although we attempted to compensate for this by excluding from the denominator cases with documentation of a plan to measure EF after discharge.

**COMPARISON WITH PREVIOUS LITERATURE**

Geographic variation in patterns of care for heart failure has not previously been described, to our knowledge. There are parallels in care for ischemic heart disease, however, between the findings in the current study and the findings in studies of geographic variation.

In studies of Medicare patients in the Cooperative Cardiovascular Project, quality of care varied across the country. Higher quality of care after myocardial infarction in Medicare patients has been associated with male sex and higher income, younger age, teaching hospitals, nonrural hospitals, and care by a cardiologist. Rates have been highest in New England.

There is one important way, however, in which our findings differ from those of services for ischemic heart disease. Studies of the relationship between quality of care for ischemic heart disease and the availability of invasive cardiac services have had ambiguous results, and much of the literature has implied that availability of subspecialty services is associated with overuse of services. In the current study, however, facilities with catheterization laboratories and attending physicians whose specialty is cardiology were more likely to provide guideline-based care.

**LIMITATIONS OF CURRENT STUDY**

Our study has several potential limitations. We did not seek to confirm the diagnosis of heart failure. Given that both overdiagnosis and underdiagnosis of heart failure have been documented in hospital charts, restricting the diagnosis to patients with clear evidence of heart failure would necessarily trade lower sensitivity for higher specificity and exclude many patients with heart failure. Ascertaining the patient socioeconomic status is difficult; in our study, the patient-specific variable of dual eligibility for Medicare and Medicaid performed better than a ZIP code level variable accounting for income, occupation, education, and home values. Our study was restricted to hospitalized patients. This group, however, arguably deserves the most attention with regard to quality improvement. We report odds ratios and not relative risks; therefore, the magnitudes of the demonstrated associations should be interpreted with caution.

Finally, important contributors to the variation in quality of care including patient factors were unavoidably omitted from the analysis. This view is supported by the relatively low values for the statistic for both models; taken in toto, patient, hospital, and provider characteristics explain geographic variation modestly. Because quality of care is affected by organizational factors such as the use of data feedback, the influence of opinion leaders, organizational stability, and the presence of administrative support—factors that cannot be measured using nationwide data—unexplained variation should be expected.

**CONCLUSIONS AND IMPLICATIONS FOR POLICY**

Geographic variation in the provision of high-quality heart failure care cannot be completely explained by patient characteristics. Characteristics of the health care system such as availability of cardiology specialty services play important roles. Unmeasured, and for the purposes of this study immeasurable, factors such as the presence of a “culture of quality” within hospitals likely also play important roles. Further understanding of these issues will provide useful context for public reporting of hospital performance. Future research should focus on characterizing these unmeasured factors further and on identifying innovative systems to make the characteristics of the best-performing hospitals available to all facilities.

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