Ten-Year Trends in Hospital Care for Congestive Heart Failure

Improved Outcomes and Increased Use of Resources

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**Background:** Scarce data are available on long-term trends in hospital mortality, length of stay (LOS), and costs in congestive heart failure (CHF).

**Objective:** To assess 10-year trends in the outcomes of patients hospitalized with CHF.

**Methods:** We studied all 6676 patients with a primary discharge diagnosis of CHF hospitalized from January 1, 1986, through July 31, 1996, at an academic tertiary care center. Hospital mortality, LOS, and costs were adjusted for sociodemographic characteristics, comorbidities, invasive procedures, hospital disposition, and LOS where appropriate.

**Results:** The mean (±SD) age of patients was 70 ± 13 years; 54.1% were male; 87.0% were white. There was a significant increasing trend in heart failure severity as assessed by a CHF-specific risk-adjustment index. The proportion of patients who underwent invasive procedures (eg, cardiac catheterization, coronary angioplasty, coronary artery bypass surgery, defibrillator and pacemaker implantation) was significantly higher in the 1994-1996 period. The standardized mortality ratio (observed mortality/predicted mortality) progressively fell during the study period. Compared with patients admitted before 1991, those admitted after 1991 had a 24% lower observed than predicted mortality. Adjusted LOS exhibited a downward trend, ie, 7.7 days in 1986-1987 to 5.6 days in 1994-1996 (P<.001). Unadjusted cost peaked during 1992-1993 and declined thereafter. Adjusted costs in 1994-1996 were not significantly different from those in 1990-1991.

**Conclusions:** After risk adjustment for sociodemographic characteristics, comorbidities, and disease severity, a significant decrease in in-hospital mortality was observed during the study decade. This decline in hospital mortality occurred in parallel with decreasing LOS and increasing use of cardiac procedures and costs.

**RESULTS**

A total of 6676 hospital admissions occurred at MGH with the ICD-9-CM codes for CHF during the last 2 decades. In 1989, 2% of all hospital discharges carried a principal diagnosis of CHF, and an additional 4% of all discharges carried a secondary diagnosis of heart failure. It is estimated that more than $10 billion in resources is used each year in the treatment of patients with heart failure, and about 75% of this cost is spent on hospitalization.

Thus, trends in hospital mortality and use of resources constitute a useful instrument for observing possible changes in the process of hospital health care for CHF. Since 1987, several studies demonstrated improved survival and lower rates of hospital readmission in patients with heart failure, but few data examine secular trends in hospital mortality in this common condition. In addition, there are limited studies examining the changes in the use of health care resources over time. Gehlbach et al recently reported a 34% increase in the use of common diagnostic tests overall in patients with heart failure from 1985 through 1990. Our purposes were to describe trends in hospital mortality, length of stay (LOS), and total hospital cost for patients primarily admitted for decompensated CHF in an academic medical center from January 1, 1986, through July 31, 1996.
MATERIALS AND METHODS

DATA SOURCE AND PATIENT SELECTION

We reviewed data from all patients aged 18 years or older admitted to the Massachusetts General Hospital (MGH), Boston, from January 1, 1986, to July 31, 1996, using the hospital administrative database. Massachusetts General Hospital is an urban tertiary care teaching hospital with approximately 1000 beds and has active heart transplantation and CHF clinical trial programs. Patients for the study were identified by screening the database for International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) principal discharge diagnoses of CHF (ICD-9-CM codes 428, 428.1, and 428.9). Each record in the database has an ICD-9-CM primary discharge diagnosis, up to 10 ICD-9-CM codes as secondary discharge diagnoses, and 10 ICD-9-CM codes for procedures, as well as patient demographics, insurance payer, LOS, diagnosis-related group, charges, discharge status, and disposition data. All 6676 patients in the database with a principal ICD-9-CM discharge diagnosis of CHF were identified and constitute the study population. Data abstraction and ICD-9-CM coding was performed by trained hospital nonphysician professional coders and verified by physician attending staff. During the study decade, there was no substantial incentive or policy change in the data abstraction or ICD-9-CM coding process at MGH.

DATA COLLECTION AND OUTCOMES

The hospital outcomes of interest were observed, and risk-adjusted mortality, LOS, and total hospital costs associated with the index admission. Multivariable models were used to adjust the outcomes of interest for differences across years in sociodemographic variables, comorbidity, disease-specific indicators of severity of illness, process of care, and hospital disposition, where appropriate.

The sociodemographic variables identified were age, sex, race, insurance coverage, and type of admission (emergency, elective, or transferred from another facility). Seventeen comorbidity variables were identified using an ICD-9-CM discharge diagnosis coding scheme derived by Deyo et al,8 which is a validated translation of the Charlson comorbidity index.7 These variables were evaluated and modeled individually, rather than combined in a single score, because the original Charlson index does not reflect accurately the prognosis of patients hospitalized with CHF.8 The CHF-specific index, which is a score that accounts for the presence of sociodemographic variables, comorbidities, and disease-specific variables, was also computed.7 In addition, all ICD-9-CM discharge diagnosis codes with a frequency greater than 1% in the entire study population were tabulated and considered potential predictors of in-hospital mortality, LOS, and total hospital costs.

Process of care was determined across the years evaluated by searching the principal procedure code and up to 10 secondary codes for each patient. Similar procedures with related codes were combined to yield clinically relevant composite rates of technical services. For example, procedure code 96.71 (mechanical ventilation less than 96 hours) was combined with procedure codes 96.72 (mechanical ventilation more than 96 hours) and 96.74 (insertion of endotracheal tube) to estimate total prevalence of mechanical ventilatory support.

Costs were determined by computing cost-to-charge ratios. First, total charges for all hospital services and procedures were tabulated. Second, direct and indirect costs (including the costs of provision of unreimbursed care) were tabulated for each particular hospital service, procedure, and department. Costs for procedures were calculated by assessing the true utilization of space, manpower, equipment, and time of services for procedures. Third, summary cost-to-charge ratios were determined by the MGH Finance Department based on the tabulated costs and charges for each respective hospital department. Cost data retrieved from the hospital administrative database were expressed in US dollars in the year of discharge from the hospital.

Table 1. The study population had a mean (±SD) age of 71 ± 13 years; 3615 (54.1%) were male; 866 (13.0%) were nonwhite; and most were admitted through the emergency department.

In the entire 10 years, there was no significant difference in the age or sex of the patients with CHF. There was a progressive increase in the number of patients transferred from other hospitals. Fewer patients were discharged with routine care. Most patients were insured under Medicare, and the relative proportions of insurance carriers exhibited only small changes. The CHF-specific index increased in a stepwise fashion over time. The prevalence of associated comorbidities did not differ across the years, except for a trend toward an increasing prevalence of chronic obstructive lung disease and diabetes mellitus with end-organ damage among the last 2 cohorts (Table 2). However, the cardiovascular conditions associated with CHF (eg, myocardial infarction and ventricular arrhythmias), potential markers of disease severity, showed an increase in prevalence during the study period.

PROCESS OF CARE

Processes of care data are shown in Table 3, stratified by year of admission. Overall, the number of patients who underwent invasive procedures in this population was relatively low, except for cardiac catheterization, which averaged approximately 15%. Comparing the period 1986-1987 with 1994-1996 (Table 3), the proportion of patients with heart failure who underwent any revascularization procedure increased significantly from 0.5% to 2.6% (P < .01 for trend). The proportion of patients undergoing permanent pacemaker and automatic cardioverter or defibrillator implantation also increased significantly from 0.2% to 1.8% (P < .01 for trend). In addition, the number of patients admitted to the intensive care unit receiving mechanical ventilation and invasive hemodynamic monitoring doubled from 4% to 8%.

IN-HOSPITAL MORTALITY

By 2-year periods, observed in-hospital mortality decreased from 8.4% in 1986-1987 to 7.1% in 1990-1991 to...
hospital. Cost data were inflated and are expressed in 1996 US dollars, using a 4% inflation rate per year. In addition, costs were discounted to represent true 1996 US dollars using a discount rate of 3% per year, after correcting for inflation.

RISK ADJUSTMENT

The predicted risk for in-hospital mortality (0%-100%), LOS (in days), and total costs (in 1996 US dollars) of all patients were measured by using multivariate models that were developed separately for each outcome. All models were based on sociodemographic characteristics and comorbidities. Procedures coded and hospital disposition were also considered potential predictors of LOS and total hospital costs. In addition, to adjust for total costs across the years evaluated, LOS was included in the cost model. The models used in our analysis were based on the entire 10-year period of data collection.

We screened the data set to identify variables at least weakly associated (P < .15) with the outcomes using χ² or Fisher exact test for categorical variables and unpaired, 2-tailed t test for continuous variables. The variables identified in the univariate analysis were then entered in stepwise logistic regression models designed to predict hospital mortality. Variables remained in the model if their adjusted P values were less than .10. The ability of the model to predict in-hospital mortality across the years was compared by calculating the respective model c statistics, equivalent to comparison of areas under the model receiver-operating characteristic curves for each year. The c statistic of the mortality model in the entire population was 0.79, and ranged from 0.77 to 0.89 across the years evaluated.

Length-of-stay analyses were based on logarithm-transformed data because of skewness in the distribution of LOS. Linear regression modeling was used to estimate the predicted LOS in each year. Because associations of predicted variables are influenced by the disposition from the hospital, death and transfer to another health care facility were included in the analyses. The explained variance (adjusted R²) of the LOS model in the whole population was 0.23, and ranged from 0.16 to 0.29 in the years evaluated. The model satisfied the assumption of the normality distribution of the residuals.

Cost data were not normally distributed, even after several attempts to transform the data. Therefore, to estimate the predicted cost data according to demographic characteristics, comorbidities, process of care, LOS, and hospital disposition, general linear models were applied. To avoid the impact of extreme values on the final results, cost data were trimmed at the 99th percentile value ($116,401). The explained variance (adjusted R²) of the cost model in the whole population was 0.49, and ranged from 0.49 to 0.58 in the years evaluated.

The ratio of observed-to-expected mortality was referred to as the standardized mortality ratio (SMR) and provided a measure of relative mortality changes over time. The same standardized ratio was calculated for LOS and costs.

In addition, the continuous outcomes (LOS and costs) were adjusted using general linear models for all variables significantly identified in the multivariate analysis plus the year of admission. Using this method, number of hospital days and costs attributable to each year were expressed as the least squares mean value for each year, adjusting for all other variables.

DATA ANALYSIS

In the evaluation of trends across the 10-year study period in hospital outcomes for CHF, analyses were performed separately considering each year and each 2-year period in the study decade (1986-1987, 1988-1989, 1990-1991, 1992-1993, and 1994-1996). Because these analyses yielded similar results for each outcome, most of the data and results of the study are presented in 2-year periods. We assessed trends in baseline characteristics, comorbidities, and procedure rates across the entire 10 years using χ² tests for categorical variables and analysis of variance for continuous variables; P < .05 was considered statistically significant.

LENGTH OF STAY

Observed LOS exhibited a significant downward trend in the 10 years studied (Figure 2). Mean observed LOS was 6.8 days in 1986-1987, 7.4 days in 1990-1991, and 5.8 days in 1994-1996 (P < .01 for trend) (Table 5). On the contrary, mean predicted LOS, based on sociodemographic characteristics, comorbidities, use of invasive procedures, and hospital disposition, was longer for the last 6 years of the study period (Table 5). The observed-to-expected LOS ratios showed a significant decline across the years (P < .01 for trend) (Table 5). For example, in the 1986-1987 and 1994-1996 periods, the standardized LOS were 1.13 and 0.84, respectively, indicating a 13% higher and a 16% lower than expected LOS, respectively.

Multivariate analyses were performed to adjust LOS and estimate-attributable values for each 2-year period. Adjusted LOS was significantly lower after 1990 (Figure 2). Compared with 1986-1987, adjusted LOS was 5.6% lower in 1990-1991 (equivalent to −0.4 days; P = .08),
18.3% lower in 1992-1993 (equivalent to −1.4 days; \( P < .001 \)), and 27% lower in 1994-1996 (equivalent to −2.1 days; \( P < .001 \)).

### ESTIMATED COST

By single-year periods, observed total hospital costs exhibited a significant upward trend over time. However, costs plateaued in 1992 and began to decrease slightly after 1994 (Figure 3). By 2-year periods, predicted costs peaked during 1990-1991, largely resulting from differences in sociodemographic characteristics, comorbidities, use of invasive procedures, hospital disposition, and LOS as presented in the predicted values for those years. Adjusted costs were highest in 1992-1993, but fell slightly in 1994-1996 (Table 5). The inclusion of medical dis-
We described 10-year trends in the clinical characteristics, processes of care, and hospital outcomes of patients with CHF who were admitted to an academic tertiary care urban medical center. Although the demographics and clinical characteristics of the patients did not change appreciably, heart failure severity, as measured by the CHF-specific index and predicted in-hospital mortality, increased. Despite care of sicker pa-

position, invasive CHF-related procedures, and LOS to the model for hospital costs left residual variation in the adjusted costs, suggesting that the performance of these selected procedures did not explain the variation over time in hospital costs. The estimated cost per day was not different in the first three 2-year periods evaluated ($1302 for 1986-1987, $1259 for 1988-1989, and $1333 for 1990-1991), but increased significantly in the last 2 periods ($1726 for 1992-1993 and $1781 for 1994-1996) (P<.001).

### Table 3. Procedures Reported in Patients Primarily Hospitalized for CHF According to Year of Admission*

<table>
<thead>
<tr>
<th>Year</th>
<th>Cardiac Catheterization</th>
<th>PTCA</th>
<th>CABG</th>
<th>Other Cardiac Surgery</th>
<th>Permanent Pacemaker Implantation</th>
<th>AICD</th>
<th>Critical Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986-1987</td>
<td>(n = 942)</td>
<td>141</td>
<td>5</td>
<td>12</td>
<td>2</td>
<td>0</td>
<td>Mechanical Ventilation</td>
</tr>
<tr>
<td></td>
<td>(15.0)</td>
<td>0.5</td>
<td>1.3</td>
<td>1.5</td>
<td>0.2</td>
<td>0.2</td>
<td>2.0</td>
</tr>
<tr>
<td>1988-1989</td>
<td>(n = 1126)</td>
<td>184</td>
<td>2</td>
<td>24</td>
<td>6</td>
<td>1</td>
<td>20.1</td>
</tr>
<tr>
<td></td>
<td>(16.3)</td>
<td>0.2</td>
<td>2.1</td>
<td>0.5</td>
<td>0.5</td>
<td>0.1</td>
<td>1.8</td>
</tr>
<tr>
<td>1990-1991</td>
<td>(n = 1302)</td>
<td>253</td>
<td>5</td>
<td>36</td>
<td>22</td>
<td>2</td>
<td>15.2</td>
</tr>
<tr>
<td></td>
<td>(19.4)</td>
<td>0.4</td>
<td>2.8</td>
<td>1.7</td>
<td>0.3</td>
<td>0.3</td>
<td>1.1</td>
</tr>
<tr>
<td>1992-1993</td>
<td>(n = 1411)</td>
<td>289</td>
<td>4</td>
<td>30</td>
<td>21</td>
<td>4</td>
<td>17.2</td>
</tr>
<tr>
<td></td>
<td>(20.5)</td>
<td>0.3</td>
<td>2.1</td>
<td>1.5</td>
<td>0.3</td>
<td>0.3</td>
<td>1.0</td>
</tr>
<tr>
<td>1994-1996</td>
<td>(n = 1896)</td>
<td>301</td>
<td>12</td>
<td>33</td>
<td>25</td>
<td>10</td>
<td>5.2</td>
</tr>
</tbody>
</table>

*CHF indicates congestive heart failure; PTCA, percutaneous transluminal coronary angioplasty; CABG, coronary artery bypass graft; AICD, automatic implanted cardioverter and/or defibrillator; and IAPB, intra-aortic pump balloon.
†P<.01 for trend.
‡Observed to expected ratio.

### Table 4. Observed and Predicted In-hospital Mortality in Patients Primarily Hospitalized for CHF According to Year of Admission*

<table>
<thead>
<tr>
<th>Year</th>
<th>Observed†</th>
<th>Predicted†</th>
<th>Standardized Mortality Ratio‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986-1987</td>
<td>8.4</td>
<td>6.4</td>
<td>1.32</td>
</tr>
<tr>
<td>1988-1989</td>
<td>8.5</td>
<td>6.8</td>
<td>1.25</td>
</tr>
<tr>
<td>1990-1991</td>
<td>7.1</td>
<td>7.3</td>
<td>0.98</td>
</tr>
<tr>
<td>1992-1993</td>
<td>6.3</td>
<td>7.6</td>
<td>0.83</td>
</tr>
<tr>
<td>1994-1996</td>
<td>6.1</td>
<td>7.1</td>
<td>0.86</td>
</tr>
</tbody>
</table>

*CHF indicates congestive heart failure.
†P<.01 for trend.
‡Observed to expected ratio.

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tients, the SMR and LOS decreased significantly over time. Procedure use, with the exception of cardiac catheterization, increased, although rates of overall procedural use remained low. Adjusted costs were higher after 1992.

PATIENTS

Although no significant differences in demographics, comorbidities, or the Charlson comorbidity index were observed during the 10-year study, heart failure severity, as measured by the CHF-specific index and predicted in-hospital mortality in general, increased. Thus, sicker patients were cared for during the later years of the study. At least 3 factors partially may account for these findings. First, changing practice patterns in the hospital phase of care for heart failure likely have occurred between 1986 and 1996. Improvements in the ambulatory care of heart failure, the availability of home-based care services, and increasing payer constraints on hospital reimbursement likely have biased physician decision making toward the hospitalization of progressively sicker patients with heart failure. Second, the expansion within our center during the study period of clinical programs targeting patients with heart failure (cardiac transplantation, investigational heart failure drug studies, high-risk cardiac surgery, cardiac electrophysiology) likely contributed to the modest increase in patients transferred to our center from other institutions and the greater severity of heart failure among patients admitted from the emergency department (since these patients were observed by cardiologists at MGH). Third, from 1986 to 1996, the indications for invasive cardiac procedures such as cardiac catheterization, revascularization, and defibrillator implantation have expanded in patients with heart failure. This may have led to the elective admission of increasing sicker patients for the evaluation of the appropriateness and/or performance of such procedures.

PROCESS OF CARE

During the study period, we observed a relatively constant use of cardiac catheterization (approximately 15%) and a small but progressive increase in the use of revascularization and critical care procedures. The increased use of revascularization likely stems from the increasingly recognized role of revascularization in patients with heart failure, including high-risk angioplasty and coronary artery bypass surgery. This use paralleled our center’s growing interest in and experience with several diagnostic and therapeutic modalities requisite for the provision of such care, including the detection of myocardial viability using thallium scintigraphy and positron emission tomography, high-risk coronary artery bypass surgery, mechanical circulatory support devices, and cardiac transplantation.

HOSPITAL MORTALITY

The SMR decreased significantly during the decade. This finding is striking, given the progressive increase in risk-adjusted CHF severity as assessed by the CHF-specific index. This decline in hospital mortality was thus not explained by differences in patient characteristics and associated comorbidities, since patients with more medically complex disease and sicker patients

| Table 5. Unadjusted and Adjusted LOS and Cost in Patients Primarily Hospitalized for CHF According to Year of Admission* |
|-----------------|------------------|------------------|------------------|------------------|------------------|
| LOS, geometric mean, d |
| Observed†       | 6.8              | 7.1              | 7.4              | 6.6              | 5.8              |
| Predicted‡      | 6.0              | 6.2              | 6.8              | 7.0              | 6.9              |
| Observed to expected ratio† | 1.13              | 1.14              | 1.08              | 0.94              | 0.84              |
| Adjusted LOS, geometric mean, d‡‡ | 7.7              | 7.7              | 7.3              | 6.3              | 5.6              |
| Total cost, 1996 $ |
| Observed, mean (median)† | 10 149 (7779) | 11 326 (7491) | 13 599 (7391) | 15 437 (8608) | 13 975 (8996) |
| 25th-75th Percentile | 6841-9098 | 6758-8567 | 7221-9211 | 7743-11 943 | 7307-13 405 |
| Predicted, mean§ | 12 008           | 13 133           | 14 465           | 13 734           | 12 499           |
| Mean adjusted total cost§ | 11 269           | 11 348           | 12 310           | 15 011           | 14 654           |

*LOS indicates length of stay; CHF, congestive heart failure.
†P < .01 for trend.
‡Predicted from a model considering sociodemographics, comorbidity, disease-specific indicators of severity of illness, invasive procedures, and hospital disposition.
§Adjusted from a model considering sociodemographics, comorbidity, disease-specific indicators of severity of illness, invasive procedures, hospital disposition, and LOS.
were admitted in the later years of the study. This trend is consistent with nationwide data in nonhospitalized patients showing a rise in CHF mortality for the period 1980 through 1988,5 followed by a slight decline in 1989 and 1990.6 Such results may be partially attributable to temporal changes in the quality of care of patients with heart failure. Increasing use of angiotensin-converting enzyme inhibitors, diuretics, and digoxin; decreasing use of potentially harmful drug therapies (eg, calcium channel blockers); and increasing use of beneficial invasive procedures (eg, revascularization procedures) may have all had an impact on in-hospital mortality.11-13

Although the mortality effects are striking, it is possible that mortality was merely shifted to another setting, given the increasing proportion of patients during the study who were discharged to chronic rehabilitation hospitals and skilled nursing facilities. Unfortunately, because we do not have comprehensive postdischarge follow-up data on the study population, we are unable to assess early postdischarge cumulative mortality. However, in a previous study among Medicare beneficiaries, hospitals with low in-hospital mortality rates had a significant positive correlation with 30- to 180-day mortality, suggesting that hospitals with low in-hospital mortality rates do not simply postpone mortality with aggressive care or shift mortality to another site.14

LENGTH OF STAY

Length of stay decreased significantly during the study period, even after adjustment for sociodemographic characteristics, associated comorbidities, and use of invasive procedures. Although there were no formal incentives to reduce LOS in patients with CHF at our center during the study, improvements in hospital care, increasingly attractive options for postdischarge care, and external economic factors likely played important roles in decreasing LOS during the study period. These and other factors may belay the previously reported 10% shorter LOS in patients with heart failure who were admitted to major teaching hospitals compared with patients with heart failure who were admitted to minor and nonteaching hospitals.15

COST

Adjusted costs increased over time, even after correction for inflation and depreciation. Costs peaked in 1991-1992 and declined thereafter. The rates for use of procedures and LOS accounted for some of the variation in adjusted costs, but did not explain all the observed differences. Our multivariate cost models adjusted only for invasive procedures. Increasing rates of use or increased cost of other noninvasive common diagnostic tests (eg, echocardiography, chest X-rays) or hospital facilities (eg, telemetry monitoring) may have been responsible for some of the incremental increase in cost. Gelbach et al8 recently described an increase of 30% in radiographs of the chest and 23% in electrocardiograms from 1985 through 1990 among Medicare patients admitted with heart failure.

LIMITATIONS

Some methodological limitations of our study should be acknowledged. The study reflects the 10-year cumulative experience of an urban tertiary care academic referral center. The data were collected retrospectively from a hospital-wide administrative data set. The study included only patients discharged with principal ICD-9-CM diagnoses reflective of relatively uncomplicated CHF. Thus, our study results may not be generalizable to patients with other heart failure–related principal ICD-9-CM diagnoses. Disease severity is not fully captured in hospital administrative data sets, as a result of inadequate clinical information pertaining to functional capacity, physical examination findings, and laboratory results.16-18 However, despite well-recognized interhospital differences in discharge coding practices, several studies suggest that the predictive power of models using abstract and administrative data are similar when used to compare aggregated data.18,19 In our study, the performance of the predictive models based only on ICD-9-CM discharge diagnoses coded in the hospital-wide administrative data set was adequate and showed no inconsistency over time.

CONCLUSIONS

In patients admitted to MHG during the study period, the severity of heart failure, as measured by the CHF-specific index and predicted in-hospital mortality, increased. After risk adjustment for sociodemographic characteristics, comorbidities, and heart failure severity, a significant decrease in the in-hospital SMR was observed across the decade. Declining in-hospital mortality occurred in parallel with a decreasing LOS and increasing use of cardiac procedures and cost. Further studies are required to determine whether our findings are generalizable to patients admitted to other centers in other geographic regions.

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