Procedure Intensity and the Cost of Care

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Background—The intensive practice style of hospitals with high procedure rates may result in higher costs of care for medically managed patients. We sought to determine how costs for patients with heart failure (HF) not receiving procedures compare between hospital groups defined by their overall use of procedures.

Methods and Results—We identified all 2009 to 2010 adult HF hospitalizations in hospitals capable of performing invasive procedures that had at least 25 HF hospitalizations in the Perspective database from Premier, Inc. We divided hospitals into 2 groups by the proportion of patients with HF receiving invasive percutaneous or surgical procedures: low (≥0%–10%) and high (≥10%). The standard costs of hospitalizations at each hospital were risk adjusted using patient demographics and comorbidities. We used the Wilcoxon rank sum test to assess cost, length of stay, and mortality outcome between the 2 groups. Median risk-standardized costs among low-procedural HF hospitalizations were $5259 (interquartile range, $4683–$6814) versus $6965 (interquartile range, $5981–$8235) for hospitals with high procedure use (P < 0.001). Median length of stay was 4 days for both groups. Risk-standardized mortality rates were 5.4% (low procedure) and 5.0% (high procedure) (P = 0.009). We did not identify any single service area that explained the difference in costs between hospital groups, but these hospitals had higher costs for most service areas.

Conclusion—Among patients who do not receive invasive procedures, the cost of HF hospitalization is higher in more procedure-intensive hospitals compared with hospitals that perform fewer procedures. (Circ Cardiovasc Qual Outcomes. 2012;5:308-313.)

Key Words: costs and cost analysis ■ hospitals ■ heart failure ■ utilization

The costs of health care are at the center of national attention. A particular focus has been on hospital care, which was estimated to cost $800 billion in 2010 and to represent approximately one third of total healthcare costs. Previous studies have described variation in costs across hospitals, indicating that there may be opportunities to reduce costs without sacrificing care quality. In particular, specialty-driven, procedure-intensive, high-volume hospitals tend to provide care that is more expensive but it has been difficult to identify whether this higher-intensity care is the result of their greater use of procedures or other hospital-specific practices.

In the present study, we examined whether hospitals that perform more invasive cardiovascular procedures for patients with heart failure (HF) also had a greater tendency to provide higher-cost care to the larger subset of these patients who did not receive procedures. We first grouped hospitals by the proportion of patients who received invasive cardiovascular procedures, excluding hospitals that did not perform such procedures. We then compared risk-standardized cost (RSC) among the subset of patients with HF who did not receive invasive cardiovascular percutaneous or surgical procedures. Because hospitals that perform a high volume of procedures may have a more-intensive style of care, we hypothesized that resource utilization would be, on average, higher in hospitals with a high proportion of patients undergoing procedures. To help us to understand drivers of cost, we examined length of stay and costs according to service areas (eg, room and board, pharmacy). As a secondary outcome, we examined in-hospital mortality outcomes between hospital groups.

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WHAT IS KNOWN
- Hospitalization costs totaled nearly $800 billion in 2010, representing >30% of total US healthcare spending.
- Hospitals that are procedure intensive and specialty driven have been associated with higher costs of hospitalization.
- Whether the pattern of greater resource use at hospitals that are procedure intensive extends to those hospitalizations where patients do not receive procedures has yet to be explored.

WHAT THE STUDY ADDS
- Hospitals with a higher proportion of patients with heart failure undergoing invasive cardiovascular procedures had higher standard costs with similar lengths of stay for patients who did not undergo procedures.
- We did not identify any single service area that explained the cost difference between hospital groups, but overall costs, in the majority of service categories, were higher at high-procedure hospitals.

Methods
Data Source
We conducted a cross-sectional study using the Perspective database, a voluntary, fee-supported, data collection developed by Premier, Inc, to measure quality and resource use. As of 2010, the Perspective database contained information from >300 US hospitals, representing >130 million hospital discharges. These inpatient discharges comprise ~20% of acute care hospitalizations nationwide. For each episode of hospitalization, the Perspective database contains information standard to hospital discharge files as well as date-stamped logs of all billed items, including medications, laboratory tests, diagnostics, and therapeutic services. The Perspective database also contains costs at the item level as well as total costs of hospitalization. In ~75% of the hospitals, these item costs are calculated using internal cost accounting systems based on relative value units. The remaining hospitals provide cost estimates based on Medicare cost-to-charge ratios.

Patient and hospital data were deidentified by Premier, Inc, in accordance with the Health Insurance Portability and Accountability Act. The Yale University Human Investigation Committee reviewed the protocol for this study and determined that it is not considered to be human subjects research as defined by the Office of Human Research Protections.

Study Cohort and Hospital Groups by Procedure Volume
We included hospitalizations between January 1, 2009, and December 31, 2010, with a principal discharge diagnosis of HF (International Classification of Diseases, Ninth Revision, Clinical Modification, codes 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, and 428.xx) or respiratory failure (518.81) with a secondary discharge diagnosis of HF. A patient could contribute multiple hospitalizations. We excluded patients aged <18 years at the time of admission, were transferred into or out of an acute care facility, had a pediatric attending physician, or received a heart transplantation or implantation of a ventricular assist device.

To further define the study cohort, 2 investigators (K.D., S.I.C.) identified a comprehensive list of 228 invasive cardiovascular percutaneous and surgical procedures, including percutaneous coronary intervention, carotid artery stenting, coronary artery bypass surgery, various valve replacements, and aortic surgery (online-only Data Supplement Table I). We only included hospitals that had at least 25 HF admissions and performed at least 1 of the included invasive cardiovascular percutaneous and surgical procedures during the study period. All other hospitals were excluded. For the remaining hospitals, we calculated the proportion of HF hospitalizations with at least 1 of these 228 procedures at each hospital in the cohort. We divided hospitals into 2 groups based on the proportion of their patients receiving at least 1 invasive cardiovascular procedure. The high-procedure group included hospitals with a proportion of patients who received procedures that was greater than the all-hospital median (Figure 1). The remaining hospitals were placed into the low-procedure group. Patients who were treated with any of the 228 procedures during the course of the hospitalization were excluded, so the final study cohort included only nonprocedural patients with HF.
Primary Outcome
The primary outcome was RSC of hospitalization. Because cost varies by many factors (eg, region, local wage index), we assessed use by standard costs. To calculate standard cost, we calculated the median cost of each item in the database. This median was calculated using data from both included and excluded hospitals. We then applied this median as the standard cost of that item at every hospital. For example, if the median cost of a chest radiograph was $150, the standard cost assigned for a chest radiograph to every patient at every hospital was $150. Once standard costs were assigned at the item level, we summed the standard costs of all items billed to each patient and calculated the standard cost per hospitalization at each hospital.

Secondary Outcomes
To help us to understand differences in cost between hospital groups, we also calculated median length of stay and percentage of hospital use attributable to each charge category, such as room and board, laboratory testing, and pharmaceuticals. As an additional secondary outcome, we examined the in-hospital risk-standardized mortality rate (RSMR), using an approach analogous to those used for the publicly reported Centers for Medicare & Medicaid Services measures.13–18

Statistical Analysis
We calculated frequencies for categorical variables and medians and interquartile ranges (IQRs) for continuous variables. To probe cost differences and their potential drivers, we used the Wilcoxon rank sum test to assess differences in length of stay between hospital groups. Statistical significance was set at \( P < 0.05 \). To calculate the proportion of total cost associated with each standard charge category, we divided the total standard cost of each standard charge category by the total standard cost for the hospital group. We used a Spearman correlation to assess agreement between the 2 groups. We also calculated the average cost per patient by standard charge category. Costs were calculated for the combined years of 2009 and 2010.

We estimated RSCs by using a hierarchical generalized linear model with a logarithmic link and Poisson distribution to account for skewing of cost data to the left, heteroscedasticity of the variance, and the clustering effect within hospitals. We calculated the final RSC for each hospital as the observed average hospital cost minus the average expected hospital cost from the hierarchical generalized linear model plus the national median hospitalization cost. We calculated in-hospital RSMR for each hospital using a hierarchical logistic regression. In-hospital mortality was the binary dependent variable for this model. Adjusted mortality rates were risk standardized by taking the ratio of the predicted mortality to the expected mortality for each hospital multiplied by the population mortality rate. We adjusted costs and mortality for age, sex, and Elixhauser comorbidities19 classified using software (versions 3.4, 3.5, and 3.6 for federal fiscal years 2009, 2010, and 2011, respectively) provided by the Healthcare Costs and Utilization Project of the Agency for Healthcare Research and Quality. A Wilcoxon rank sum test was used to assess the statistical difference in RSC and RSMR between groups. \( P < 0.05 \) was considered statistically significant.

We conducted a secondary analysis in which we included treatments administered to patients with HF in critical care settings (intravenous vasodilators, vasopressors, inotropes, use of mechanical ventilation, and noninvasive positive pressure ventilation) in addition to age, sex, and comorbidities to calculate the RSC. In the absence of clinical data, such as blood pressure, we considered these treatments to reflect presenting severity of illness if they were administered to patients on hospital days 1 and 2. All analyses were conducted with SAS version 9.2 (SAS Institute Inc) statistical software. Procedure GLIMMIX was used to estimate the hierarchical generalized linear models.

Results
The database contained information from 341 hospitals that contributed >25 hospitalizations with a diagnosis of HF between 2009 and 2010. After excluding 60 hospitals that performed no procedures, we identified a final cohort of 281 hospitals contributing 175 869 HF hospitalizations (Figure 1). In

### Table 1. Characteristics of Hospitals

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All Hospitals (n=281), %</th>
<th>Low-Procedure Hospitals (n=141), %</th>
<th>High-Procedure Hospitals (n=140), %</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of beds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–200</td>
<td>25</td>
<td>39</td>
<td>11</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>201–400</td>
<td>43</td>
<td>47</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>401–600</td>
<td>21</td>
<td>12</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>&gt;600</td>
<td>10</td>
<td>2</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Heart failure volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25–300</td>
<td>19</td>
<td>30</td>
<td>8</td>
<td>&lt;0.001</td>
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<tr>
<td>301–500</td>
<td>22</td>
<td>31</td>
<td>14</td>
<td></td>
</tr>
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<td>501–700</td>
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<tr>
<td>701–900</td>
<td>14</td>
<td>10</td>
<td>17</td>
<td></td>
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<tr>
<td>901–1300</td>
<td>17</td>
<td>9</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>&gt;1300</td>
<td>9</td>
<td>3</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Geographic region</td>
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<td>Midwest</td>
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<td>26</td>
<td>0.5381</td>
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<tr>
<td>Northeast</td>
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<td>16</td>
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<tr>
<td>South</td>
<td>40</td>
<td>38</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>17</td>
<td>20</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Population served</td>
<td></td>
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<td></td>
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<tr>
<td>Urban</td>
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<td>79</td>
<td>91</td>
<td>0.0080</td>
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<tr>
<td>Rural</td>
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<td>21</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Teaching status</td>
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</tr>
<tr>
<td>Teaching</td>
<td>31</td>
<td>18</td>
<td>45</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

the median hospital, 10% of HF hospitalizations involved invasive cardiovascular percutaneous or surgical procedures. Among all hospitals, 141 performed low volumes of procedures (<10% of all HF hospitalizations; median procedure volume, 5% of all HF hospitalizations), and 140 hospitals performed high volumes of procedures (>10% of all HF hospitalizations; median procedure volume, 14% of all HF hospitalizations). Low-procedure hospitals had 65 955 HF hospitalizations, of which 62 262 did not involve any invasive cardiovascular procedures. High-procedure hospitals had 109 914 HF hospitalizations, of which 93 636 did not involve any invasive cardiovascular procedures.

Hospital Characteristics
We observed differences in hospital characteristics between the low- and high-procedure groups (Table 1). Thirty-nine percent of the low-procedure hospitals had ≤200 beds, 47% had between 201 and 400 beds, and the remaining 14% had >400 beds. Only 11% of the high-procedure hospitals had ≤200 beds, whereas 41% had between 201 to 400 beds, and 48% had >400 beds. The volume of HF hospitalizations also varied between hospital groups. More than 61% of the low-procedure hospitals had ≤500 HF hospitalizations, whereas only 22% of the high-procedure hospitals had the same volume. The high-procedure group also had many more hospitals with >900 HF hospitalizations (41%) compared with the low-procedure group (12%). The
2 hospital groups were similarly distributed geographically. The high-procedure group had more hospitals serving an urban population (91%) than the low-procedure group (79%). A greater proportion of high-procedure hospitals were teaching hospitals (45%) compared with low-procedure hospitals (18%).

**Patient Characteristics**
The hospital groups had similar patient characteristics with regard to age, sex, insurance, and comorbidities, although slight differences were present (Table 2). A larger proportion (12%) of nonprocedural patients admitted to high-procedure hospitals were aged 18 to 54 years compared with 10% in low-procedure hospitals. Between groups, the nonprocedural patients were similar with regard to the presence of peripheral vascular disease, hypertension, and obesity. The characteristics of the overall combined procedural and nonprocedural patients by hospital group are included in online-only Data Supplement Table II.

**Primary Outcomes**
There was a significant difference in the cost between hospital groups ($P<0.001$). The median hospitalization RSC was $5259 (IQR, $4683–$6814) at low-procedure hospitals and $6965 (IQR, $5981–$8235) at high-procedure hospitals. We also performed a sensitivity analysis that included more potential HF severity variables (ie, intravenous vasodilators, vasopressors, inotropes, use of mechanical ventilation, noninvasive positive pressure ventilation) to the model. After including these variables, the median hospitalization RSC was $5309 (IQR, $4702–$6810) at low-procedure hospitals and $6907 (IQR, $5889–$8132) at high-procedure hospitals ($P<0.001$).

**Secondary Outcomes**
To better understand the cost differences between hospital groups, we examined the length of stay and the percentage of the total cost by various services areas (eg, room and board, pharmacy). The median length of stay was 4 days for both hospital groups, although the IQR was 3 to 6 days and 2 to 7 days for low- and high-procedure hospitals, respectively ($P<0.001$). The mean ± SD length of stay was 5.6 days at high-procedure hospitals and 5±5 days at low-procedure hospitals.

The spending patterns appeared to be similar between the low- and high-procedure groups; the Spearman correlation between the proportions of the 5 main spending categories was 0.90 ($P<0.001$) (Figure 2). Specifically, room and board made up a large percentage of the total standard cost in both groups but represented a slightly smaller proportion of standard costs at high-procedure hospitals (47%) than at low-procedure hospitals (53%). For most service areas (eg, pharmacy, laboratory), high- and low-procedure hospitals had similar proportions of standard costs. Pharmacy standard costs accounted for 12% and 10% of total standard costs in the high- and low-procedure hospitals, respectively. All other categories of cost, including laboratory testing and diagnostic imaging, contributed <10% of total costs.

![Figure 2. Relative contribution of each service category to the total standard cost of hospital groups (Spearman correlation coefficient, 0.9; $P=0.037$).](http://circoutcomes.ahajournals.org/)}
for both hospital groups. Although the spending patterns were similar between groups, overall spending was greater at the high-procedure hospitals across the majority of service areas. For example, the average standard cost per patient for room and board was $5011 at high-procedure hospitals and $4787 at low-procedure hospitals. Average pharmacy standard cost per patient was $1297 at high-procedure hospitals and $991 per patient at low-procedure hospitals. Average standard cost of supplies per patient was $1064 at high-procedure hospitals and $386 per patient at low-procedure hospitals. The median all-cause in-hospital RSMR was 5.4% (IQR, 4.6%–6.3%) at low-procedure hospitals and 5.0% (IQR, 4.3%–5.9%) at high-procedure hospitals ($P=0.009$).

**Discussion**

In a large sample of US hospitals grouped according to proportion of patients receiving cardiovascular procedures, we found that hospitals with a higher proportion of patients with HF undergoing invasive cardiovascular procedures had higher standard costs with similar lengths of stay for their patients who did not undergo procedures. These findings suggest that relative to hospitals that perform procedures for a smaller proportion of their patients with HF, those that perform procedures for a high proportion of patients with HF also provide higher-intensity care for the large subgroup of patients with HF who are medically managed. We did not identify any single service area that explained the difference in costs between hospital groups, but overall costs in the majority of service categories were higher at high-procedure hospitals.

Because of the large percentage of costs attributed to room and board, differences in hospital costs have been previously reported to be closely associated with differences in length of stay. In the present study, however, we observed higher costs at high-procedure hospitals but similar lengths of stay between high- and low-procedure hospitals. Of note, the length of stay was statistically significant between groups, but this difference was due to the large sample size and was not clinically significant; the mean and median length of stay were the same in both groups.

Rather, we found that average standard cost per patient within most service areas was higher at high-procedure hospitals, indicating that the intensity of care (ie, tests, medications, supplies administered to the patient) was higher at these hospitals. We suspect that differences in intensity and overall costs between groups may be related to differences in the structure and delivery of care and to the culture at high-procedure hospitals. We found that hospitals that performed fewer invasive procedures were more likely to be small, nonteaching institutions, whereas those that performed a higher volume of procedures tended to be urban teaching hospitals that cared for a higher volume of patients with HF. Large hospitals in urban areas with teaching missions may have a greater selection of testing modalities and a higher proportion of specialists and consultations and skilled nursing staff, which may increase costs.

In a secondary analysis, we observed that high-procedure hospitals had lower RSMRs than low-procedure hospitals. The literature is mixed on the relationship between hospital spending and patient outcomes, and mortality was not a primary outcome of the present study. The results, therefore, should be interpreted with caution. One interpretation of the slightly lower RSMR (0.4%) in high-procedure hospitals is that more spending improved outcomes, whereas another interpretation is that hospitals that spent more had lower RSMRs, but these better outcomes were not necessarily the result of increased spending. Higher costs may instead be associated with hospital characteristics common to the high-procedure group. These hospitals tend to be large urban teaching hospitals that may have more specialized services, such as HF teams, skilled nursing staff, rapid response teams, and high technology capabilities, and may practice more evidence-based medicine, which has been shown to improve care.

A strength of the present study is our use of standard costs to measure resource utilization. Although the Perspective database includes costs derived from hospitals’ internal cost-accounting systems, representing an improvement over previous cost methods, there are still drawbacks to using these hospital-reported costs. Costs to the hospital include fixed costs, such as overhead and labor. In contrast, standard costs allow us to quantify resource use. It is important to note that resource utilization does not reflect actual costs to hospitals because acquisition and overhead costs (and other factors) vary. Still, we believe that the use of standard cost is more appropriate and superior in comparing hospitals of varying sizes and geographies.

The results should be interpreted in the context of the following assumptions and limitations. A common concern in the comparison of hospitals is the inability to adjust for differences in patient population. We saw few differences in the patient characteristics we examined. Referral centers can attract patients with more complications, but those who travel long distances for admission tend to be more stable (ie, can travel) and tend to receive procedures (an important reason why they might go to a regional center). The exception might be patients who are transferred from another institution who may be critically ill and require higher-level care (which may include a procedure). We managed the issue of differences in case mix in several ways. We adjusted for many factors in our risk-standardized estimates. We were limited to claims, but our prior work suggested that at the hospital level, such adjustment may work as well as clinical data. We excluded patients who received procedures, focusing the study on patients receiving routine medical management. We excluded patients who were transferred into or out of the hospital. Finally, because demographic and comorbidity data may not reflect disease severity on presentation, we conducted an exploratory analysis in which we included additional severity variables (intensive care unit-level treatments received in the first 2 days) in our RSC model. After the addition of these variables, we found that standard costs remained significantly higher in hospitals that performed more procedures.

The study has other limitations as well. First, the use of administrative data limits our ability to detect differences in severity of illness across hospitals. The Perspective database does not contain laboratory results or a clinical measure of HF severity. We calculated RSCs and RSMRs that were adjusted for demographic characteristics and comorbidities. Although we took several steps to address differences in severity of illness between hospital groups, it is still possible that high-procedure
hospitals treat higher-acuity patients, and it is possible that we were not able to adequately adjust for severity for these differences in patient populations. Second, the Perspective database does not record information regarding outpatient follow-up, so we could not assess more-extended outcomes, such as 30-day mortality. Third, because of the nature of the database, we were unable to determine the frequency of consultation of specialist physicians or the makeup of hospital staff, factors that might have provided insight into the cause of higher intensity observed at high-procedure hospitals. Fourth, our application of standard costs is useful for comparing resource utilization between hospitals but may not reflect the actual costs incurred by the treating hospital. Finally, it is possible that low- and high-procedure hospitals had different populations based on selection of patients for procedures. For example, if a particular hospital is more likely to perform procedures on hospitalized patients with HF who are in relatively good health (eg, New York Heart Association functional class II), that hospital’s remaining non-procedure patients with HF are highly likely to have longer average length of stay and higher average cost of hospitalization than patients at a hospital that does not aggressively select healthier patients with HF for procedures.

When compared with hospitals that perform fewer procedures, high-procedure hospitals appear to have higher overall costs among patients who do not receive procedures. This cost difference does not appear to be due to length of stay but to a higher overall intensity of tests, medications, and services, suggesting that there is an opportunity for high-procedure hospitals to reduce use of some of these modalities without having a negative impact on the quality of care they deliver.

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