The Association Between Hospital Volume and Processes, Outcomes, and Costs of Care for Congestive Heart Failure

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Background: Congestive heart failure (CHF) is common and costly, and outcomes remain suboptimal despite pharmacologic and technical advances.

Objective: To examine whether hospitals with more experience in caring for patients with CHF provide better, more efficient care.

Design: Retrospective cohort study.

Setting: 4095 hospitals in the United States.

Patients: Medicare fee-for-service patients with a primary discharge diagnosis of CHF.

Measurements: Hospital Quality Alliance CHF process measures; 30-day, risk-adjusted mortality rates; 30-day, risk-adjusted readmission rates; and costs per discharge. National Medicare claims data from 2006 to 2007 were used to examine the relationship between hospital case volume and quality, outcomes, and costs for patients with CHF.

Results: Hospitals in the low-volume group had lower performance on the process measures (80.2%) than did medium-volume (87.0%) or high-volume (89.1%) hospitals ($P < 0.001$). In the low-volume group, being admitted to a hospital with a higher case volume was associated with lower mortality, lower readmission, and higher costs. Similar, though smaller, relationships were found between case volume and both mortality and costs in the medium- and high-volume hospital groups.

Limitations: Analysis was limited to Medicare patients 65 years or older. Risk adjustment was performed by using administrative data.

Conclusion: Experience with managing CHF, as measured by an institution's volume, is associated with higher quality of care and better outcomes for patients but a higher cost. Understanding which practices employed by high-volume institutions account for these advantages can help improve quality of care and clinical outcomes for all patients with CHF.

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Congestive heart failure (CHF) is the most common cause of hospitalization in the Medicare program, and led to nearly 1.4 million hospitalizations and $17 billion in total spending in 2007 alone (1, 2). Despite pharmacologic and technical advances in the diagnosis and management of CHF, outcomes remain suboptimal: 1 in 10 patients dies in the first 30 days after hospitalization for CHF, and of those who survive, 1 in 4 is readmitted (3). The high clinical and financial burden of this disease, especially among elderly persons, has led to great interest in both improving outcomes and decreasing the costs of care.

It is important to understand why some hospitals perform better than others on both processes and outcomes of care for CHF, and why some hospitals can do so at a lower cost. One possibility is that experience, as measured by volume, drives performance. A large body of literature suggests that hospitals that perform a higher volume of procedures have better outcomes for surgeries, such as coronary artery bypass grafting, esophagectomy, or pancreatectomy (4–7), and cardiovascular procedures, such as percutaneous coronary intervention (8–10)—often with both lower complication rates and, consequently, lower costs. However, studies that have examined the volume–outcome relationship for such medical conditions as CHF, acute myocardial infarction, chronic obstructive pulmonary disease, or pneumonia have yielded mixed results (11–14), and none (to our knowledge) has examined the effect of volume on costs for medical illness—which is particularly important in an increasingly cost-conscious health care environment.

We sought to examine the relationship between the volume of patients with CHF at a hospital and the performance of that hospital in terms of CHF processes, outcomes (mortality and readmission), and costs of care. We hypothesized that hospitals with a high volume of patients with CHF would have higher adherence to quality process measures, lower mortality rates, lower readmission rates, and lower costs of care than those with a low volume of such patients. We also hypothesized that the effect of volume would be independent of other factors, such as the size of the hospital or its teaching status.

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METHODS

Data

We used the Medicare Provider Analysis Review 100% files from 2006 and 2007, which include all hospitalizations for Medicare fee-for-service enrollees, and exam-

ined hospitalizations for patients 65 years or older with a primary discharge diagnosis of CHF (International Classification of Diseases, Ninth Revision, Clinical Modification, codes 398.91, 404.x1, 404.x3, or 428.0 to 428.9) between 1 January 2006 and 30 November 2007. Discharges that occurred in December 2007 were excluded because of the lack of 30 days of follow-up to determine clinical status. Because the Centers for Medicare & Medicaid Services methodology for classifying index admissions (15) was followed, patients could be included in the sample more than once. Thus, although our analysis was carried out at the discharge level, individual discharges are referred to as patients for ease of presentation. Federal hospitals and those located outside the 50 U.S. states and the District of Columbia were excluded. On the basis of recommendations from The Joint Commission on appropriate sample size for performance analysis (16), 441 hospitals with fewer than 25 Medicare CHF discharges over the 23-month period were also excluded. Our final sample consisted of 4095 hospitals and 1 029 497 discharges (>99.5% of eligible CHF discharges).

We obtained hospital characteristics from the 2007 American Hospital Association annual survey, including hospital size, nurse-to-census ratio, ownership, proportion of patients who had Medicare or Medicaid insurance, membership in a hospital system, membership in the Council of Teaching Hospitals, presence of a cardiac intensive care unit, location, and census region. Nurse-to-census ratio was calculated by dividing the number of full-time equivalent nurses on staff by 1000 patient-days.

Outcomes

We used the September 2008 release of Hospital Quality Alliance (HQA) data, which provides performance data on clinical quality process measures from 2007. An overall CHF summary performance score was calculated for each hospital on the basis of its score on each of the 4 HQA CHF quality measures: percentage of patients with CHF who received discharge instructions, an evaluation of left ventricular systolic function, an angiotensin-converting enzyme inhibitor or angiotensin-receptor blocker for left ventricular systolic dysfunction, and smoking cessation advice and counseling.

Our analysis had 4 primary outcomes: processes of care (HQA score), outcomes of care (30-day all-cause mortality and readmission rates), and costs of care. Because we lacked patient-level HQA data, we examined the relationship between case volume and HQA performance at the hospital level; for the remaining outcomes, the unit of analysis was the individual discharge. Each patient's likelihood of death or readmission was adjusted for patient characteristics by using the Elixhauser comorbidity adjustment scheme, which has been derived and validated on administrative data (17–19). Each patient's costs were adjusted by using an approach, described elsewhere by us and others (20, 21), that regresses costs on the basis of patient-level factors (age, sex, race, and comorbid conditions); hospital-level factors that might be expected to cause cost differences but are not within the hospital's control (Medicare Wage Index and income and poverty rate in the community); and the pursuit of costly missions, including teaching (as measured by the intern- and resident-to-bed ratio) or caring for the poor (as measured by the Disproportionate Share Hospital Index). The **Appendix** (available at www.annals.org) details our approach to risk adjustment.

Context

Heart failure is among the most common reasons for hospital admission in many developed countries.

Contribution

Among patients with heart failure in the United States, being admitted to a hospital with a higher volume of patients with heart failure was associated with lower mortality, fewer readmissions, and higher costs.

Caution

The study used administrative data, limiting the ability to determine care practices that drove the findings.

Implication

Understanding which practices account for the outcome advantages in high-volume hospitals might improve outcomes for all patients with heart failure.

—The Editors

Statistical Analysis

We examined associations between our primary predictor (hospital volume of patients with CHF, as a continuous variable) and each of the 4 outcomes, first with all outcomes aggregated at the hospital level. Because the relationships between volume and outcomes were thought to be nonlinear, risk-adjusted nonparametric curves were created to examine them by using the Loess locally weighted scatterplot smoothing method. On the basis of these curves, patients were divided into 3 groups according to discharge volume in our 23-month study period of the discharging hospital: low (25 to 200 discharges), medium (201 to 400 discharges), and high (>400 discharges). Although the natural cut points varied across outcomes, a single set of cut points was used for ease of presentation. Models that used the alternative cut points were also performed; these results are described qualitatively, and the full results are shown in **Appendix Table 1** (available at www.annals.org).

We created unadjusted linear regression models for continuous outcomes (HQA score and cost) and logistic regression models for binary outcomes (30-day mortality and 30-day readmission) at the hospital level for HQA score and at the discharge level for mortality, readmission,

and cost. To quantify the effect of volume on outcomes within each group of hospitals, we performed linear spline analyses by using the number of discharges from each hospital during the study period as the primary predictor, with knots at the break points used to define the groups (200 and 400 discharges). Analyses for each outcome were subsequently further adjusted for the previously identified key hospital characteristics. Because of the significant collinearity between case volume and number of hospital beds (which we hypothesized would occur), number of beds was excluded from our primary models. Results with number of beds are included in the models in **Appendix Table 2** (available at www.annals.org).

To provide information about differences between the groups, we also examined volume group as a categorical variable in a secondary analysis and used it as our primary predictor in both bivariate and multivariate analyses for each of the outcomes.

A 2-sided *P* value of less than 0.05 was considered to be statistically significant. All analyses were performed by using SAS, version 9.2 (SAS Institute, Cary, North Carolina). The Harvard School of Public Health institutional review board, within the Office of Human Research Administration, granted this study as exempt from full human subjects research review.

Role of the Funding Source

An American Heart Association Clinical Research Program grant provided funding for the study. The funding source had no role in the design, analysis, or interpretation of the study or in the decision to submit the manuscript for publication.

Table 1. **Characteristics, by Hospital CHF Volume Group***

Characteristic	Low Volume (25–200 Discharges)	Medium Volume (201–400 Discharges)	High Volume (>400 Discharges)
Patient characteristics			
Patients, *n*	176 981	248 251	604 265
Median age (25th, 75th percentiles), *y*	81 (74, 87)	80 (74, 86)	80 (74, 86)
Women, %	59	57	55
Race, %			
White	87	84	84
Black	9	10	12
Hispanic	2	2	2
Other	3	3	2
Diabetes without complications, %	30	28	26
Diabetes with complications, %	5.4	6.0	5.8
Hypertension, %	54	57	58
Renal failure, %	8	12	14
Valvular heart disease, %	1.8	2.6	3.4
Peripheral vascular disease, %	6.5	7.0	7.4
Chronic pulmonary disease, %	35	37	36
Hospital characteristics			
Hospitals, *n*	2133	970	992
Median CHF discharges in 23 mo (25th, 75th percentiles), *n*	85 (51, 132)	284 (236, 339)	602 (493, 1160)
Median hospital beds (25th, 75th percentiles), *n*	54 (25, 102)	164 (114, 237)	330 (234, 455)
Hospital size, %			
Small (6–99 beds)	73	19	2
Medium (100–399 beds)	25	74	64
Large (≥400 beds)	2	7	34
Median length of stay for CHF (25th, 75th percentiles), *d*	4.0 (3.5, 4.6)	4.8 (4.3, 5.4)	5.2 (4.7, 5.7)
Median nurse-to-census ratio (25th, 75th percentiles)	7.0 (4.5, 9.9)	6.2 (4.9, 7.8)	6.1 (5.1, 7.4)
Cardiac intensive care, %	16	37	69
Ownership, %			
For-profit	16	21	12
Nonprofit	54	64	80
Public	31	15	8
Median proportion of Medicare patients (25th, 75th percentiles)	51 (43, 59)	45 (40, 52)	45 (40, 51)
Median proportion of Medicaid patients (25th, 75th percentiles)	16 (9, 20)	17 (13, 22)	16 (11, 20)
Member of hospital system, %	40	52	54
Major teaching hospital, %	2	6	18
Urban location, %	61	93	100
Region, %			
Northeast	8	17	24
Midwest	34	23	26
South	38	41	41
West	21	19	8

CHF = congestive heart failure.
* Groups may not sum to 100% because of rounding.

RESULTS

We divided the 1 029 497 discharges that met our inclusion criteria into 3 groups by the case volume of the discharging hospital. **Table 1** shows the clinical characteristics of these patients, as well as the structural characteristics of the hospitals from which patients in each of the groups were discharged. Hospitals in the low-volume group were mostly small (75%); only 16% of these hospitals had cardiac intensive care capabilities, and only 2% were major teaching hospitals. Hospitals in the high-volume group were mostly medium or large (64% and 34%, respectively), and most (69%) had cardiac intensive care units. Nearly 20% of the hospitals in the high-volume group were major teaching hospitals, and all were in urban locations.

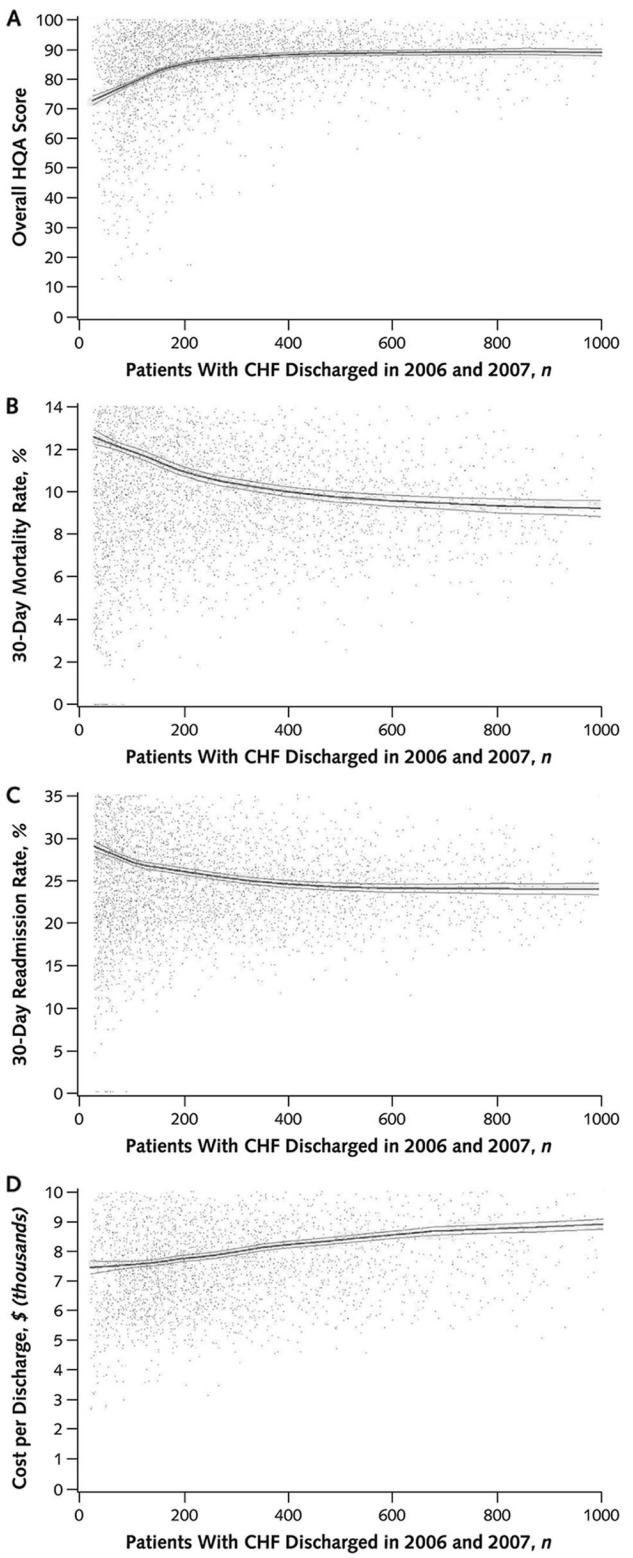
We first examined outcomes aggregated at the hospital level and found a positive relationship between volume and HQA scores and a negative relationship between volume and both 30-day mortality and readmission rates (**Figure**, *A* to *C*). For each, an initial linear relationship was followed by a plateau in the effect of volume on outcomes; this plateau appeared between 200 and 400 discharges over the 23-month study period. Higher-volume hospitals had higher costs than lower-volume ones, and this relationship had no obvious plateau effect (**Figure**, *D*).

Linear Relationship Between Case Volume and Outcomes

Using spline models with adjustments for patient characteristics, each 10-patient increase in volume was associated with a 0.75-point increase in HQA score in the low-volume group of hospitals and a 0.13-point increase in the medium-volume group of hospitals; no significant relationship was seen in the high-volume group, which reflects the plateau effect seen in the Loess curves (**Table 2**). After further adjustment for hospital characteristics (**Table 2**), volume correlated only with HQA score in the low-volume group.

We found a significant negative relationship between volume and the odds of death for patients discharged from hospitals in each of the 3 groups; the decrease in mortality per 10-patient increase in volume was largest in the low-volume group, intermediate in the medium-volume group, and smallest in the high-volume group. For readmissions, volume and odds of readmission had a significant negative relationship in the low- and medium-volume groups of hospitals, but no relationship in the high-volume group. Volume had a significant effect on costs per discharge in all groups, although the magnitude of the effect was smallest in the high-volume group. When these models were adjusted for additional hospital characteristics, the effects of volume on mortality and costs remained largely unchanged; however, the effect of volume on readmissions diminished significantly, and the associations were no longer statistically significant. The results were qualitatively similar when cut points of 100 and 400 cases were used, except that the effect of volume on readmissions was neg-

Figure. **Relationship between CHF volume and processes, outcomes, and costs of care.**



CHF = congestive heart failure; HQA = Hospital Quality Alliance.

Table 2. **The Relationship Between CHF Case Volume and Processes, Outcomes, or Costs of Care, by Hospital CHF Volume Group**

Variable and Volume Group	Patients, *n*	Hospitals, *n*	Unadjusted Analysis			
			Change per 10-Patient Increase in Volume (95% CI)	*P* Value	Mean Value	*P* Value
Process of care measures						
Overall Hospital Quality Alliance score						
Low	–	1388	0.75% (0.64% to 0.87%)	<0.001	80.2%	<0.001
Medium	–	964	0.13% (0.06% to 0.20%)	<0.001	87.0%	<0.001
High	–	991	0.00% (−0.02% to 0.02%)	0.84	89.1%	Reference
ACE inhibitor or ARB for patients with left ventricular systolic dysfunction						
Low	–	378	−0.19% (−0.33% to −0.06%)	0.005	89.3%	0.122
Medium	–	866	0.08% (0.02% to 0.14%)	0.004	89.0%	0.004
High	–	989	0.00% (−0.02% to 0.02%)	0.98	90.1%	Reference
Assessment of left ventricular function						
Low	–	1388	0.80% (0.69% to 0.91%)	<0.001	86.1%	<0.001
Medium	–	964	0.16% (0.09% to 0.22%)	<0.001	93.6%	<0.001
High	–	991	0.01% (−0.00% to 0.03%)	0.23	96.3%	Reference
Discharge instructions						
Low	–	1161	0.69% (0.49% to 0.89%)	<0.001	70.9%	<0.001
Medium	–	964	0.12% (0.00% to 0.23%)	0.043	76.6%	0.130
High	–	991	−0.02% (−0.06% to 0.01%)	0.174	78.0%	Reference
Smoking cessation counseling						
Low	–	168	0.33% (0.18% to 0.48%)	<0.001	92.3%	<0.001
Medium	–	510	0.10% (0.03% to 0.15%)	0.003	95.8%	0.004
High	–	889	0.01% (−0.01% to 0.02%)	0.45	97.0%	Reference
Outcome of care measures						
30-day mortality†						
Low	176 985	2129	−0.009 (−0.012 to −0.007)	<0.001	10.5%	<0.001
Medium	248 251	970	−0.006 (−0.007 to −0.004)	<0.001	9.3%	<0.001
High	604 265	992	−0.0008 (−0.001 to −0.0004)	<0.001	8.5%	Reference
30-day readmission†						
Low	146 671	2133	−0.009 (−0.01 to −0.006)	<0.001	27.7%	<0.001
Medium	214 024	970	−0.003 (−0.004 to −0.0009)	0.002	26.0%	<0.001
High	545 405	992	0.0001 (−0.0002 to 0.0004)	0.40	25.5%	Reference
Costs per discharge‡						
Low	125 300	1181	$21.78 ($1.92 to $41.61)	0.032	$7189	<0.001
Medium	253 205	956	$35.76 ($24.94 to $46.59)	<0.001	$7579	<0.001
High	621 913	987	$10.13 ($6.67 to $13.59)	<0.001	$8382	Reference

ACE = angiotensin-converting enzyme; ARB = angiotensin-receptor blocker; CHF = congestive heart failure.
* The adjusted model accounts for the presence of a cardiac intensive care unit, hospital ownership, teaching status, hospital system membership, proportion of patients with Medicare in the overall hospital population, proportion of patients with Medicaid in the overall hospital population, urban location, and region.
† Change in the log odds of death (or readmission), per 10-patient increase in case volume.
‡ Change in dollars per discharge, per 10-patient increase in case volume.

ative and significant in the low-volume group, even after adjustments for hospital characteristics.

Between-Group Comparisons

When we examined whether average performance varied across the 3 groups of hospitals, our results were similar to those from the linear spline models. For HQA measures, hospitals in the high-volume group had better performance than those in the medium- or low-volume group (89.1% vs. 87.0% or 80.2%; $P < 0.001$ for each) (**Table 2**). The low-volume group continued to have worse performance even after further adjustment for other hospital characteristics.

At 30 days, patients admitted to the hospitals in the high-volume group had lower mortality rates on average than those admitted to hospitals in the medium- or low-volume groups (8.5% vs. 9.3% or 10.5%; $P < 0.001$ for each), with similar results for readmission rates. Per-discharge costs were higher in the high-volume group of hospitals than in the medium- or low-volume groups ($8382 vs. $7579 or $7189; $P < 0.001$ for all comparisons). Our findings remained similar to the linear models even after further adjustment for other hospital characteristics; the relationships between volume group and mortality or cost remained largely unchanged, whereas that between volume group and readmission rates was smaller and not significant.

DISCUSSION

We examined the relationship between volume of patients with CHF and clinical processes, outcomes, and

Table 2—**Continued**

Adjusted for Hospital Characteristics*			
Change per 10-Patient Increase in Volume (95% CI)	***P* Value**	**Mean Value**	***P* Value**
0.58% (0.47% to 0.69%)	<0.001	82.2%	<0.001
0.04% (−0.03% to 0.11%)	0.29	86.5%	0.55
−0.02% (−0.04% to 0.00%)	0.092	86.9%	Reference
−0.12% (−0.25% to 0.02%)	0.092	89.5%	0.83
0.04% (−0.02% to 0.09%)	0.21	89.4%	0.54
−0.02% (−0.03% to 0.00%)	0.057	89.6%	Reference
0.59% (0.49% to 0.70%)	<0.001	88.4%	<0.001
0.04% (−0.02% to 0.10%)	0.20	92.9%	0.109
0.00% (−0.02% to 0.02%)	0.91	93.8%	Reference
0.55% (0.35% to 0.75%)	<0.001	72.3%	<0.001
0.06% (−0.05% to 0.18%)	0.29	76.5%	0.96
−0.04% (−0.08% to 0.00%)	0.028	76.6%	Reference
0.28% (0.13% to 0.42%)	<0.001	93.1%	<0.001
0.07% (0.01% to 0.14%)	0.029	96.1%	0.162
0.00% (−0.01% to 0.01%)	0.99	96.7%	Reference
−0.009 (−0.01 to −0.006)	<0.001	10.2%	<0.001
−0.005 (−0.007 to −0.004)	<0.001	9.3%	<0.001
−0.0007 (−0.001 to −0.0003)	0.001	8.6%	Reference
−0.003 (−0.006 to 0.0004)	0.086	26.1%	0.34
−0.0001 (−0.002 to 0.001)	0.87	25.9%	0.73
0.00 (−0.0004 to 0.0003)	0.76	25.8%	Reference
$29.88 ($9.81 to $49.95)	0.004	$7321	<0.001
$28.83 ($18.07 to $39.59)	<0.001	$7702	<0.001
$8.59 ($5.13 to $12.05)	<0.001	$8320	Reference

costs, and found that patients with CHF discharged from hospitals with a higher volume of such patients received higher-quality care, on average, and had better outcomes, but at modestly higher cost. These relationships were independent of other key hospital characteristics, including teaching status and hospital size. The strongest effect of volume on outcomes was seen in the group of hospitals with the lowest volume (those with a case volume less than 200 over the 23-month study period). The effects of volume on outcomes seemed to diminish beyond 200 to 400 discharges over the study period. Our findings suggest that the volume–outcome relationship previously observed for procedure-based conditions also exists for CHF and may extend more broadly to chronic medical conditions.

We have known that higher volume is associated with better outcomes for major surgeries (4–7) and cardiovascular procedures (8–10) for nearly 3 decades (22). However, the relationship between volume and outcomes for medical care is less well understood. Our findings suggest that the effects can be substantial for CHF: Patients discharged from hospitals with 200 CHF discharges had, on average, 18% lower odds of death than those discharged from hospitals with 20 CHF discharges. Given the prevalence of CHF, these differences have important clinical and public health implications. The average hospital with 200 discharges would have an HQA score that is 13.5% higher than that of a hospital with 20 CHF discharges, with the average patient having 18% lower odds of readmission. However, the typical stay at a hospital with 200 CHF discharges would cost approximately $400 more per hospitalization. The gains in quality and outcomes would seem to be worth the extra cost, but formal and long-term cost-effectiveness analyses are needed to confirm this.

How might volume lead to better outcomes? Greater knowledge of and adherence to process measures could account for the differences we observed. However, even though high-volume hospitals had higher HQA scores, these measures alone are unlikely to lead to lower short-term mortality or reduced readmissions (23). High-volume hospitals could also have both higher HQA scores and better clinical outcomes as a common result of their greater experience in caring for patients with CHF. Hospitals that have more patients with CHF might have more incentive to retain familiarity with professional society care guidelines or invest in systems to monitor for adherence to quality metrics. High-volume institutions may also be more likely to use standardized admission or discharge forms, be more familiar with CHF-specific patient education, or involve discharge planners in care for patients with CHF, although no data are currently available to assess this directly. In addition, nurses at high-volume centers might be more familiar with CHF-specific patient care and education needs, although we have no data regarding this. High-volume centers might also have specialty inpatient or outpatient CHF services, which would concentrate similar patients under a team of providers; this could improve both the quality and coordination of care. Further work is needed to explore whether these types of services are more often present in high-volume centers and whether they account for some or all of the differences we found.

Finally, it could be that better outcomes lead to higher volume, rather than the other way around. Hospitals that spend more to provide higher-quality services may attract more patients through referral and self-referral, thus increasing case volume. Luft and colleagues (24) examined this possibility by using data from 736 hospitals across the country; on the basis of analyses of referrals in and transfers out, as well as patterns of mortality for different conditions, they concluded that selective referral was important in explaining the volume–outcome relationship. Selective referral requires either that data on hospital quality be available and easy for patients and referring physicians to understand or that high-performing hospitals have a reputation for quality that attracts patients and referring physicians. Previous studies have found that patients rarely use publicly available quality data to select a hospital or clini-

cian (25) and that publishing provider performance has little effect on that provider's market share (26, 27). Therefore, if selective referral is a key part of the mechanism by which high-performing hospitals have higher volume, it is probably a result of having a reputation as a high-quality hospital.

Our finding that higher volume was associated with greater inpatient costs is novel and has important implications for the health policy debate. We could not determine how the extra money was spent or whether extra spending during the index hospitalization led directly to the improved outcomes. Our analysis suggests that the efficiency gains often seen when institutions perform a high volume of surgical procedures may not bear out for such conditions as CHF, at least in the short term, and challenge the assumption that hospitals with more experience in caring for a condition should be able to do so at lower cost. Multiple studies from the Dartmouth Atlas (28–31) have demonstrated that higher Medicare spending is not associated with better health outcomes at either the hospital referral region or the individual hospital level, although their models of costs examine data over a longer period (typically the last 6 months or 2 years of life) and are looking backward after a death. Our costs are episode-based, and our results do not directly contradict the Dartmouth work. Intensive CHF care, although more expensive in the short term, may lead to lower longer-term costs.

We found a threshold beyond which additional volume was associated with little additional benefit. The incremental benefit of volume decreased once volume reached approximately 200 Medicare CHF discharges. The fact that roughly one third of all U.S. hospitals, caring for nearly one half of all patients, achieve this level of experience has important implications for quality improvement and regionalization of care. First, our findings suggest that we can get the largest benefit by targeting quality improvement efforts at hospitals with lower volume. Second, policymakers have advocated that patients who need high-risk surgeries should be sent to the few hospitals that achieve very high volumes (4). This degree of centralization may not be necessary with CHF because so many hospitals meet the volume threshold. Of note, although improvement in quality of care and clinical outcomes leveled off, no obvious threshold effect was observed for costs, which suggests that beyond a certain level of spending, additional resource utilization may not be associated with better outcomes. Whether this is due to unnecessary use of expensive tests or procedures at these very high-volume hospitals is unclear, and additional studies are needed to better understand this issue.

Previous studies of the effect of volume on outcomes for medical conditions have demonstrated mixed results. For example, Thiemann and colleagues (11) showed that elderly patients who presented with acute myocardial infarction had lower rates of 30-day and 1-year mortality if they presented to a high-volume hospital. An in-hospital survival benefit in high-volume centers has been seen for patients with AIDS (32–34) and lupus (35), although we know less about longer-term outcomes for these conditions. However, Lindenauer and colleagues (12) found no relationship between volume and outcomes for chronic obstructive pulmonary disease, and demonstrated that hospitals with a high volume of patients with pneumonia actually had both worse performance on process measures and worse clinical outcomes than those with a lower volume (13). A recent analysis by Ross and colleagues (14) found that hospitals with higher volume had lower 30-day mortality rates for acute myocardial infarction, CHF, and pneumonia. Our findings extend this work by both quantifying the benefits of volume on mortality and demonstrating that these benefits include better processes and lower readmissions.

To our knowledge, no previous studies have directly examined the relationship between volume and costs for medical conditions. Hospitals with higher volumes for surgical procedures usually have lower costs, presumably because fewer costly complications occur and length of stay is decreased (36, 37). However, CHF care may fit a different paradigm than a surgical procedure. As policymakers increasingly focus on value (balancing the importance of both outcomes and costs), our findings suggest that no easy solution exists for improving CHF outcomes and that better care might require greater spending. In addition, because CHF is a chronic, relapsing disease, rather than a single episode of care, up-front investment in quality may lead to downstream, rather than immediate, savings. Policy efforts aimed at building greater coordination and accountability among providers may encourage hospitals to invest in better clinical CHF care, provided they create a mechanism by which hospitals could reap the financial benefits of downstream cost savings.

Our study has limitations. First, we lack data about the clinicians who cared for these patients and could not assess the effect of clinician volume or specialty on outcomes. Similarly, because we used administrative rather than clinical data, we could calculate a nurse-to-patient ratio for each hospital but lacked data on the intensity of the nursing care that each patient received. Second, administrative data also presents difficulties in accounting for variations in the severity of illness across hospitals. However, although administrative data are imperfect, they are standardized, validated, and increasingly used, even for public reporting. In addition, high-volume hospitals generally had sicker patients, and inadequate risk adjustment may have led us to underestimate differences in outcomes between these hospitals and their counterparts with less complex populations. Third, we focused on Medicare patients; although these patients make up more than 80% of CHF admissions (38), the applicability of our findings to non-Medicare patients is unclear. Finally, as with any nonexperimental study design, we could not assess whether the

relationships we found were causal or were markers of other factors associated with both volume and outcomes.

We found that hospitals with greater experience caring for patients with CHF provide better care, with better outcomes, to a sicker patient population—but do so at a higher cost. The relationship between volume and outcomes is not fully linear, and the incremental benefits are small beyond a volume of 200 Medicare patients over 23 months. Although further work is needed to better delineate why these relationships exist, our findings suggest that the volume–outcome relationship extends beyond surgical procedures and provide a new avenue to explore for improving the care and outcomes of complex, chronically ill patients.

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