
Quality of Care

The Trade-Off between Costs and Outcomes: The Case of Acute Myocardial Infarction

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Objective. To investigate and to quantify the relationship between hospital costs and health outcomes for patients with acute myocardial infarction (AMI) in Veterans Health Administration (VHA) hospitals using individual-level data for costs and outcomes.

Data Sources. VHA administrative files for the fiscal years 2000–2006.

Study Design. Costs were defined as costs incurred during the index hospitalization for treatment of AMI. Mortality and readmission, assessed 1 year after the index hospitalization, were used as measures of clinical outcome. We examined health outcomes as a function of costs and other patient-level and hospital-level characteristics using a two-stage Cox proportional hazard model that accounted for competing risks within a multilevel framework. To control for patient comorbidities, we compiled a comprehensive list of comorbidities that have been found in other studies to affect mortality and readmissions.

Principal Findings. We found that costs were negatively associated with mortality and readmissions. Every U.S.\$100 less spent is associated with a 0.63 percent increase in the hazard of dying and a 1.24 percent increase in the hazard to be readmitted conditional on not dying. This main finding remained unchanged after a number of sensitivity checks.

Conclusions. Our results suggest that there is a trade-off between costs and outcomes. The negative association between costs and mortality suggests that outcomes should be monitored closely when introducing cost-containment programs. Additional studies are needed to examine the cost–outcome relationship for conditions other than AMI to see whether our results are consistent.

Key Words. Hospital costs, acute myocardial infarction, trade-off, outcomes, readmission, mortality

Providing high-quality health care services at reasonable costs is the central policy goal in most health care systems. Because of rising health expenditures

in many industrialized countries, a variety of cost-containment measures have been introduced in recent years, including DRGs and diverse managed care instruments. This has led to mounting pressures on hospitals to reduce costs but also to increasing public concerns that these pressures may result in worsened health outcomes.

Previous studies exploring the relationship between hospital costs and health outcomes have reported conflicting results (Fleming 1991; Carey and Burgess 1999; Mukamel, Zwanziger, and Tomaszewski 2001). Most of these studies were conducted at the hospital level using aggregate measures for costs and outcomes. Although this method has certain advantages from a policy perspective, it precludes adequate control for case mix. Our study takes a different approach by focusing on acute myocardial infarction (AMI) as one episode of care. AMI has several important advantages when it comes to investigating the relationship between costs and outcomes. First, because AMI requires immediate medical attention, patient selection between hospitals is less relevant than for other conditions. Second, the incidence of AMI is high, and it is the leading cause of death in the elderly, resulting in a substantial number of hospital cases. Third, hospitals that provide higher quality care can achieve substantially lower mortality rates (McClellan and Staiger 2000; Shen 2002; Landrum et al. 2004).

To overcome problems associated with aggregate measures, we used patient-level measures for costs, outcomes, and comorbidity. Because of the fragmentation of health care systems, patient-level data usually provide information from either (a) the payer perspective (e.g., Medicare), which includes information on posthospitalization outcomes, but not on actual costs per patient, or (b) the hospital perspective, which includes actual costs per patient, but no information on posthospitalization outcomes. With this in mind, the integrated health care system of the Veterans Health Administration (VHA) is well suited to capturing both perspectives. In addition, patient-level data from the VHA databases permit a relatively high level of consistency. VHA hospitals have been subject to budgetary pressures similar to those experienced

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by other providers. Limited global budgets are currently the chief cost-containing measure applied in VHA hospitals (Yaisawarng and Burgess 2006).

In this paper, we investigate the relationship between hospital costs and health outcomes for patients with AMI at index hospitalization in VHA hospitals. To do so, we used mortality and readmission following AMI for 1 year at index hospitalization as health-outcome measures. We examined health outcomes as a function of costs and other patient-level and hospital-level determinants of outcome using random-effects Cox proportional hazard models. We also accounted for competing risk between mortality and readmission.

The paper is structured as follows: the next (i.e., second) section reviews the relevant literature on the relationship between hospital costs and health outcomes. The following section presents the methodology used in this paper to explore this relationship. The next two sections describe the data used in the analysis and the estimated results, respectively. The final section discusses the implications of the results and makes several suggestions for future research.

PREVIOUS RESEARCH

Previous studies examining the relationship between hospital costs and health outcomes have reached divergent conclusions. Whereas some studies have found a positive association between hospital costs and health outcomes (Mukamel, Zwanziger, and Tomaszewski 2001), others have concluded that low hospital costs and excellent health outcomes are not mutually exclusive (Fleming 1991; Carey and Burgess 1999). Weech-Maldonado, Shea, and Mor (2006) examined the cost/outcome relationship for nursing homes and found that the pattern of the relationship depended on the choice of outcome measures. Different studies examining the relationship between inefficiency and health outcomes have also yielded contradictory results. Morey et al. (1992) and Deily and McKay (2006) found that a hospital's inefficiency score was positively associated with the observed in-hospital mortality rate, whereas McKay and Deily (2008) did not find any consistent association.

There are generally two ways of approaching the cost/outcome relationship. Some studies have used cost functions with costs as the dependent variable, where outcome measures were explanatory variables in a given cost function (Fleming 1991; Carey and Burgess 1999; Weech-Maldonado, Shea, and Mor 2006). This cost function usually has a hybrid functional form following Grannemann, Brown, and Pauly (1986). However, Mukamel, Zwanziger, and Tomaszewski (2001), Deily and McKay (2006), and McKay

and Deily (2008) used outcomes as the dependent variables, where hospital cost was one explanatory variable.

A common feature of these studies is their use of aggregate measures for costs and health outcomes. Most studies use mortality (i.e., usually in-hospital mortality) as the only outcome measure (Morey et al. 1992; Mukamel, Zwanziger, and Tomaszewski 2001; Deily and McKay 2006). Using both readmissions and mortality, Fleming (1991) found that the association with costs was positive at low outcome levels, negative at intermediate outcome levels, and positive again at high outcome levels for both outcomes measures. However, McKay and Deily (2008) also used readmissions in addition to mortality and found no systematic pattern. Carey and Burgess (1999) used posthospitalization outcomes for mortality and readmission, as well as outpatient follow-up rates. They found that all three outcome measures were positively associated with hospital costs (i.e., high levels of mortality were associated with high costs). Weech-Maldonado, Shea, and Mor (2006) used pressure ulcers and mood decline as outcome measures in nursing homes.

METHODOLOGY

Empirical Model

The goal of the present study was to explore and to quantify the relationship between costs and outcomes of treatment for AMI while controlling for comorbidity, input quality, and organizational hospital characteristics. We used individual-level data for costs, outcomes, and comorbidity from the VHA. Costs were defined as costs incurred during the index hospitalization for treatment of AMI. Mortality and readmission, each assessed 1 year after the index hospitalization, were used as measures of clinical outcome.

We hypothesized that outcome would be a function of age, comorbidities, costs, and hospital organizational characteristics. While age, comorbidities, and costs can differ for each treated patient, hospital organizational characteristics remain identical for all patients treated in a given hospital. As a result, observations across patients violate assumptions such as independence and common variance. Significance tests are thus not robust and would overestimate the precision of information provided by the hospital-level variables. To avoid this problem, we applied random-effects proportional hazard models, also known as frailty models (Yamaguchi et al. 2002; Glidden and Vittinghoff 2004).

In our study, we took a two-level multilevel modeling approach, nesting treated patients as microunits within hospitals, which were, in turn, considered

to be macrounits. We used the following model:

$$\begin{aligned}
 h_{ij}(t) &= h_0(t) \times \exp(\beta X_{ij} + \gamma Z_j + \lambda_{0j}) \\
 &= \xi_{0j} \times h_0(t) \times \exp(\beta X_{ij} + \gamma Z_j)
 \end{aligned}$$

where $h_{ij}(t)$ is the hazard for the i th patient in the j th hospital at time t . $h_0(t)$ is the unspecified baseline hazard. X_{ij} is a vector of explanatory variables at the patient level, while Z_j is a vector of explanatory variables at the hospital level. β and γ are two vectors that measure the effects of X_{ij} and Z_j , respectively. λ_{0j} or ξ_{0j} ($= \exp(\lambda_{0j})$), if interpreted as a factor, represent the deviation of hospital j from the overall baseline hazard. λ_{j0} is assumed to follow a normal distribution.

Two models were estimated, one model for time to death and one model for time to readmission. As the event “death” is a competing risk for the event “readmission,” that is, death at a specific point in time thereafter excludes readmission, we treated observations that died as censored at the time of death in the readmission model (Allison 2005; Sá, Dismuke, and Guimaras 2007). The event of “readmission,” however, is not a competing risk for the event “death” because the data allowed a follow-up for 365 days after index admission.

We also assumed that costs were endogenous to health outcomes, which we confirmed using the Hausman test (Hausman 1978). Thus, we subsequently used two-stage residual inclusion (2SRI) based on Terza, Basu, and Rathouz (2008). The two-stage approach is less efficient than full information maximum likelihood but yields consistent estimates. 2SRI has been used before for survival outcomes in a health care context by Lindrooth and Weisbrod (2007). The method requires the use of instrumental variables, that is, variables that are highly correlated with the endogenous variable (costs), but not with unobserved determinants of the main outcome variable of interest (time to readmission conditional on not dying, time to death). These assumptions are often satisfied by variables that are correlated with the endogenous variable but have no direct effect on the outcome variable (Cameron and Trivedi 2005). We believe that the Medicare Wage Index and general overhead costs per day at the hospital level meet these criteria. The Medicare Wage Index adjusts hospital costs for regional differences in medical wages across the United States. One could argue that higher wages may represent an extrinsic incentive for staff to perform better and deliver higher quality care. However, the Medicare Wage Index only covers wage differences between, and not within, regions and thus is unlikely to have a direct effect on health outcomes. General overhead costs per day at the hospital level include cost elements

from the nonmedical infrastructure of a hospital, for example, costs for activities such as housekeeping, engineering, and administration. Note that we excluded medical department overhead from overhead costs. The variable "General overhead costs per day" thus acts as a proxy for the price level a hospital faces to purchase certain activities excluding prices for medical personnel. The costs are allocated by charging the same amount for each patient day irrespective of the reason for admission. Thus, this is a specific type of overhead costs, which does not relate to the actual hospital stay of each patient. These overhead costs are predominantly fixed in the short term and are not related to AMI treatment and severity of disease. It should also be pointed out that this type of overhead costs is not related to either hospital size or angiography, because we control for both of these in the analysis at both stages of the estimation. Given our definition of general overhead costs per day at the hospital level, the variable is highly correlated with individual level costs per case but is unlikely to be associated with health outcomes.

Several other variables may have been theoretically suitable as instruments. In particular we also included the hospital's occupancy rate and the overall hospital's case mix. However, their explanatory power was calculated to be low (i.e., with an F -value < 10). Because the use of weak instruments can be problematic in statistical analysis, we ultimately decided to use only two instruments (Bartels 1991).

Estimation Issues

We first estimated a generalized linear mixed model with cost as the dependent variable and all variables at the patient and hospital levels, including the Medicare Wage Index and general overhead costs per day at the hospital level, as explanatory variables. We assumed a gamma distribution for the variable "cost" and used a log-link function. The gamma procedure of the *mgcv* package of *R* was used. The functional form of the cost function incorporates variables used in structural cost functions and variables on an ad hoc basis (Grannemann, Brown, and Pauly 1986). We dropped explanatory variables in cases of multicollinearity.

Subsequently, we estimated two separate random-effects proportional hazard models for mortality and readmission using the survival package of the statistical program *R*, which allows for frailty models. Actual costs and residuals from the first-stage regression were used in the second stage (Terza, Basu, and Rathouz 2008). We also reestimated including polynomials of the residuals. To adjust standard errors of the second-stage regression for including estimated residuals from the first stage, Murphy–Topel adjustment was used

(Murphy and Topel 1985). To assess the validity of the proportional hazards assumption, we plotted scaled Schoenfeld residuals against event time. In addition, according to a test suggested by Grambsch and Therneau (1994), we regressed scaled Schoenfeld residuals on event time for each covariate and tested for zero slope.

DATA

The primary data source in this study was a set of VHA administrative files for the fiscal years 2000 through 2006. For each AMI patient, we selected the index hospitalization during which a primary diagnosis of AMI was made. Readmission and mortality were assessed 1 year after discharge from the index hospitalization. We excluded all patients who were admitted and discharged on the same day, because we assumed that these patients were transferred to other hospitals or ruled out for AMI. Moreover, we excluded patients who had been admitted with AMI in the previous year, as well as those whose AMI was coded as an in-hospital complication. Ultimately, a total of 115 VHA hospitals with 35,279 patients remained in the sample.

For measuring costs, the VHA database offers several advantages over the American Hospital Association data commonly used in U.S. hospital cost estimation, because the former is based on the requirement that hospitals provide information to a standardized internal accounting system that is subject to extensive periodic audits. The VHA accounting system was established in the 1990s and has been continuously improved since then. It provides detailed cost information for hospitalization episodes and thus individual-level cost data. Moreover, it includes the costs of physicians while, at the same time, excluding capital costs. We eliminated the costs of postacute care, a component usually included in VHA hospital costs, from the total costs, and we excluded patients whose total treatment costs were recorded as being <U.S.\$100, interpreting this as an obvious accounting error. Finally, costs were deflated to reflect year 1999 values.

To control for patient comorbidities, we compiled a comprehensive list of comorbidities that have been found in other studies to affect mortality. In doing so, we relied on the Ontario Acute Myocardial Infarction Mortality Prediction Rules (Tu et al. 2001) and the Charlson Comorbidity Index (Sundararajan et al. 2004). Because Evans et al. (2007) have shown that comorbidities associated with mortality in AMI patients are also associated with resource use, we hypothesized that these and other predictors of mortality risk

would also be associated with inpatient costs. We thus also included the full set of comorbidities for the first-stage cost estimation. For coding diagnoses, the VHA uses ICD-9 codes.

We obtained data on hospital organizational characteristics that we judged to be potentially associated with outcomes. The number of treated AMI patients per hospital was included to control for volume effects, because a larger number of treated cases has been found to be associated with superior outcomes for specific indications (Birkmeyer et al. 2002). Following an approach taken in previous studies, we used the number of beds to control for the size of the hospital (Carey and Burgess 1999; Dudley et al. 2000).

We also included variables for hospital characteristics to control for input quality. One of these was a dummy variable for a hospital's teaching status, which we used as a proxy for staff qualification and equipment. Each VHA hospital was classified as a teaching-affiliated hospital if it was a member of the Council of Teaching Hospitals (COTH). As a proxy for labor intensity, we included the ratio of nurses per bed for each hospital (Needleman et al. 2002; Kovner et al. 2002). For the nursing ratio, full-time equivalents were calculated. Following Landrum et al. (2004), we also included a dummy variable for a hospital's capability to perform coronary angiography; we counted five or more claims for coronary angiography as evidence of a hospital's capability to perform this procedure. All hospital characteristics were also included in the first-stage cost equation. To control for regional effects, we included regional dummies into first- and second-stage equations.

As discussed previously, we estimated a cost equation in the first stage. The additional variables included in this equation are the Medicare Wage Index obtained from the Centers for Medicare and Medicaid Services and general overhead costs per day on hospital level. Finally, we controlled for years in each equation.

RESULTS

Table 1 shows the sample characteristics for all variables. Table 2 presents coefficient estimates and *p*-values for the first-stage cost equation. The signs of the estimated coefficients were generally in line with our expectations, and the variables for Medicare Wage Index and general overhead costs per day were highly significant.

Table 3 shows the results of the second-stage regression models, with mortality and readmission conditional on not dying as dependent variables.

Table 1: Characteristics of the Study Sample

	Mean	SD
Costs (U.S.\$)	8,035	9,553
Length of stay (days)	7.89	8.17
Medicare Wage Index	26.12	4.09
Overhead per day (U.S.\$)	513	246
Hospital characteristics		
AMI cases (no.)	72.8	39.4
COTH (%)	49.1	
Beds (no.)	175.5	87.5
Nursing ratio per bed (no.)	2.7	0.7
Angiography capability (%)	86.1	
Outcome variables (%)		
Mortality 30 days*	1.1	
Mortality 60 days*	1.7	
Mortality 90 days*	2.2	
Mortality 365 days*	3.5	
Readmission 30 days	2.7	
Readmission 60 days	3.7	
Readmission 90 days	4.4	
Readmission 365 days	6.8	
Age and comorbidities		
Age	65.2	11.4
Gender (%) (= female)	1.7	
Acute renal failure (%)	2.1	
Angina pectoris (%)	1.9	
Cancer (%)	3.8	
Cardiac dysrhythmias (%)	8.6	
Cerebrovascular disease (%)	2.4	
Chronic ischemic heart disease (%)	67.3	
Chronic renal failure (%)	7.1	
Congestive heart failure (%)	6.6	
Diabetes (%)	24.6	
Diabetes complications (%)	3.4	
Hypertensive heart disease (%)	0.4	
Liver (%)	0.1	
Peripheral vascular disease (%)	3.8	
Pulmonary disease (%)	16.1	
Shock (%)	0.4	
Region (%)		
Northeast	20.4	
Southeast	37.7	
Central	30.5	
West coast	11.4	

*Values for mortality do not include cases who died during index hospitalization.
AMI, acute myocardial infarction; COTH Council of Teaching Hospitals.

Table 2: Results of the First-Stage Cost Equation

<i>Variable</i>	<i>Coefficient</i>	<i>SD</i>	<i>p-Value</i>
Intercept	2.7182	0.1815	<.0001
Overhead per day	0.0006	0.00007	<.0001
Medicare Wage Index	0.0318	0.0059	<.0001
Hospital characteristics			
AMI cases	0.1007	0.0681	.1395
COTH	0.0357	0.0435	.4120
Beds	0.0067	0.0353	.8493
Nursing ratio per bed	-0.0297	0.0292	.3098
Angiography capability	0.1631	0.0458	.0004
Years (2006 = reference year)			
Year 1999	-0.1966	0.0356	<.0001
Year 2000	-0.1895	0.0253	<.0001
Year 2001	-0.1335	0.0253	<.0001
Year 2002	-0.0708	0.0245	.0039
Year 2003	-0.0193	0.0248	.4368
Year 2004	0.0126	0.0249	.6147
Year 2005	0.0282	0.0253	.2645
Regions (central = reference region)			
Northeast	0.0982	0.0471	.0372
Southeast	0.0759	0.0463	.1010
West coast	0.0687	0.0634	.2781
Comorbidities, age, and gender		Included	

Note. The dependent variable is costs in U.S.\$100 per index hospitalization with AMI. The coefficients for AMI cases (no.) and beds were multiplied by 100.

AMI, acute myocardial infarction; COTH Council of Teaching Hospitals.

For the mortality equation, the majority of coefficients had the expected signs and the equation showed a highly significant negative association between costs and mortality. Every U.S.\$100 less spent is associated with a 0.63 percent increase in the hazard of dying. The risk for mortality also decreased significantly as the number of treated AMI cases per hospital increased (each additional AMI case treated decreased the hazard of dying by 0.32 percent). Other hospital-level variables were not significant. The readmission equation also yielded expected results for most coefficients. Costs are, again, negatively associated with readmission conditional on not dying. Every U.S.\$100 less spent is associated with a 1.24 percent increase in the hazard to be readmitted conditional on not dying. Except for angiographic capability that was positively associated with readmission conditional on not dying, hospital-level variables were not significant. Regional fixed effects were not significant in both equations.

Table 3: Results of Second-Stage Equations

	Mortality Equation			Readmission Equation				
	Hazard Ratio	Coefficient	SD	p-Value	Hazard Ratio	Coefficient	SD	p-Value
Costs in U.S.\$100	0.9937	-0.0063	0.001754	.0003	0.9876	-0.0125	0.001561	<.0001
Residents from 1st stage	0.9926	-0.0074	0.001764	<.0001	0.9872	0.0129	0.001567	<.0001
Hospital characteristics								
AMI cases	0.6813	-0.3838	0.160961	.0171	1.0265	0.0261	0.144728	.8568
COTH	1.0803	0.0772	0.099752	.4389	1.1127	0.1068	0.089508	.2329
Beds	1.1202	0.1135	0.085991	.1869	1.0418	0.0409	0.076865	.5945
Nursing ratio per bed	1.0088	0.0087	0.077480	.9103	0.9564	-0.0446	0.068855	.5170
Angiography capability	1.2180	0.1971	0.122981	.1089	1.2399	0.2150	0.106443	.0434
Years (2006 = reference year)								
Year 1999	2.5340	0.9298	0.165985	<.0001	2.1033	0.7435	0.116768	<.0001
Year 2000	2.0481	0.7169	0.137848	<.0001	1.6842	0.5213	0.097103	<.0001
Year 2001	1.6172	0.4807	0.139946	.0006	1.6820	0.5200	0.095563	<.0001
Year 2002	1.3325	0.2870	0.140296	.0041	1.5069	0.4101	0.094204	<.0001
Year 2003	1.4859	0.3960	0.138246	.0042	1.4643	0.3814	0.095110	<.0001
Year 2004	1.2500	0.2232	0.142573	.1175	1.2967	0.2598	0.097182	.0075
Year 2005	1.5085	0.4111	0.139888	.0033	1.2483	0.2217	0.099248	.0254
Regions (central = reference region)								
Northeast	1.0604	0.0587	0.115901	.6176	1.1943	0.1775	0.103473	.0862
Southeast	0.9535	-0.0587	0.108475	.6604	0.8874	-0.1194	0.098253	.2421
West coast	0.8212	-0.1970	0.153096	.1981	1.0975	0.0930	0.130650	.4765
Comorbidities, age, and gender			Included				Included	

Note. Dependent variables: time to death and time to readmission within 1 year of discharge. The coefficients for AMI cases (no.) and beds were multiplied by 100.

AMI, acute myocardial infarction; COTH Council of Teaching Hospitals.

We tested the robustness of our findings in five ways. To begin with, we reestimated the first- and second-stage regressions using readmission and mortality assessed 1 year after admission from the index hospitalization instead of discharge. Thus, in these reestimated models mortality and readmission are dated from the admission to the hospital because one could argue that if dated from discharge some individuals would be observed shorter than others due to longer hospitalization. The coefficients for costs remained almost throughout the reestimated equations and were highly significant. Second, we ran the models by excluding cases that were transferred between different hospitals during index hospitalization (3,131 cases). The modification had very little impact on the coefficient of the cost variable, which remained highly significant in both equations. Third, we reestimated both models without a multilevel approach dropping the higher level variables. In doing so, we made a correction for clusters of the variance-covariance matrix to obtain a robust estimate in the second stage. The size of the coefficients decreased slightly in both equations, but it remained highly significant. Fourth, we ran the models with an extended observation period of 2 years instead of 1 year for both outcomes. Again the modification had very little impact on the coefficient of the cost variable, which remained highly significant in both equations. Fifth, we obtained *F*-statistics to test the reliability of our instrument (i.e., whether our instrument was correlated with the costs). Because the *F*-statistics for the Medicare Wage Index and general overhead per day were 23.69 and 58.91, respectively, weak correlation is unlikely to be a source of bias (Bound, Jaeger, and Baker 1995; Staiger and Stock 1994).

When plotting scaled Schoenfeld residuals against event time for the survival models, the mortality model appeared to be a good fit to the data. According to the regressions, the proportional assumption seems to have been violated for the variable "Chronic renal failure," and some of the dummy variables for year of treatment. However, this might also be due to the OLS regression being heavily influenced by outliers (Thompson et al. 2003) that could be identified in the plots. In the readmission model, however, the proportional hazard assumption seems to have been violated more often. Therefore, and as an additional sensitivity analysis, we also fitted a Weibull model for mortality and readmission, respectively. The results in both models, that is, the sign of the coefficient for the variable cost and the *p*-value, remained robust. If parameter estimates of the Weibull models are transformed to hazard ratios, every U.S.\$100 less spent is associated with a 0.64 percent increase in the hazard of dying and a 1.27 percent increase in the hazard of a readmission conditional on not dying.

DISCUSSION

In this paper, we investigated and we quantified the relationship between hospital costs and health outcomes for patients with AMI using a two-step random intercept Cox proportional hazard model to obtain consistent estimates of the effects of costs on outcomes. We followed a more refined approach than previous studies investigating this relationship by (a) focusing on one episode of care, (b) using patient-level data, and (c) applying a survival model. Our results are also clearer than that of previous studies. We found that costs were negatively associated with mortality and with readmission conditional on not dying. Thus, the cost–outcome relationship appears to be very clear in both cases, although costs were more significant in the readmission equation compared with the mortality equation.

The finding that the relationship between costs and outcomes is negatively correlated for both outcome measures is at odds with the results obtained by Carey and Burgess (1999), who also based their analysis on VHA data. They found that both 1-year mortality and 1-year readmissions were positively associated with hospital costs. They suggested that differences in severity of illness unmeasured by the case mix were a likely explanation for this result. However, comparability to our study is limited by the fact that Carey and Burgess (1999) did not concentrate solely on AMI as one episode of care and by that they used aggregate hospital costs instead of patient-level costs. In addition, they did not use a survival model and did not control for competing risks. In general, none of the previous studies used a survival model to investigate the cost–outcome relationship, making any comparison with our study difficult.

The negative association between costs and the risk for mortality/readmission conditional on not dying confirms the often-stated hypothesis that increased resource input for patients should clearly lead to better outcomes. Some of the hospital-level variables had unexpected signs, although most of them (e.g., COTH) were not significant. However, the positive coefficient for the variable for capability of angiography in both equations suggests that the risk for an event, that is, readmission conditional on not dying or death, increases significantly with capability of angiography. One potential explanation for this pattern may be that certain measures for case mix are not included. Thus, the positive coefficients for angiography capability may reflect higher severity rather than input quality.

Our study has a number of strengths. To begin with, it is the first study, to our knowledge, to examine the trade-off between costs and outcomes using

patient-level cost and outcome data. The use of patient-level data enabled us to obtain more consistent estimates on the relationship between costs and outcomes. Second, we focused on AMI as one episode of care, which allowed us to control appropriately for case mix. Third, we are the first study exploring this trade-off using a Cox proportional hazard model and considering the competing risk nature of the data. Fourth, the rich data sample containing information at the patient and hospital levels allowed us to use a multilevel model combined with a 2SRI model. This is likely to yield more consistent estimates than conventional statistical methods.

Our study also has several important limitations. First, certain undocumented health-related conditions or factors may explain part of the variation in our outcome variables, thus potentially affecting the relationship between costs and outcomes. Also, the validity of the instruments relies on the assumption that the error structure follows a random effects model. Another limitation may be this study's focus on mortality and readmissions as opposed to clinical-outcome measures.

Although the VHA has a standardized internal accounting system, certain variations in costs may be explained by the different accounting systems used in different VHA hospitals, which is a factor we were unable to control for. Finally, our study uses only VHA data, which raises the question of generalizability beyond the VHA. It is likely that the relationship between costs and outcomes varies according to the health care context, differing, for example, between fragmented and integrated health care systems. For instance, an integrated delivery system with managed care elements, such as the VHA, is more likely than fragmented health care systems to avoid or substitute readmissions. Thus, in the VHA context, it is conceivable that patients with multiple conditions—for which acute hospital treatment was not appropriate—were less likely to be readmitted.

In spite of the clear findings, care must be taken when drawing policy implications. Certainly, the negative association between costs and mortality and costs and readmission conditional on not dying does not mean that every clinical intervention is justified, especially if the costs of the intervention are greater than the benefits. However, this negative association does suggest that reductions in costs may indeed lead to poorer outcomes. Because of this, outcomes should be monitored closely when introducing cost-containment programs. Moreover, linking reimbursement rates to outcomes, as is practiced in reimbursement programs such as “Pay for Performance” in the United States or “Payment by Results” in the United Kingdom, might represent a promising approach to overcoming the trade-off between costs and outcomes,

supplying providers with incentives to keep outcomes stable in spite of decreasing costs.

Research on the relationship between costs and outcomes is still in its infancy. Additional studies are needed to examine the cost–outcome relationship for conditions other than AMI to see whether our results are consistent. With this in mind, examining the various treatment processes within organizations would also seem a fruitful way of gaining a greater understanding of this relationship.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Appendix SA1: Author Matrix.

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