Measuring the Relationship between Hospital Costs and Quality of Care: An Example of Acute Myocardial Infarction in Edmonton, Alberta, Canada

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Abstract

This study explores the relationship between hospital costs and quality of care for Acute Myocardial Infarction (AMI) in the Edmonton area hospitals. The importance of this relationship is realized when policy makers face decisions about cost minimization and quality maximization during times of health care budget constraints. This study uses regression modelling with increasing specifications as well as various robustness checks to ensure the accuracy of the results. The Model specifications include demographics, AMI risk adjustments, Hospital fixed effects, and year fixed effects. Semi-parametric regression removes the assumption of linearity to determine the true relationship between hospital cost and AMI quality. Higher AMI quality is associated with a 39% increase in hospital costs after adjustments and controls. The semi-parametric regression shows a fairly linear relationship between cost and AMI quality. This study suggests that Canadian policy and decision makers should take caution during budget cuts and implementing cost containment programs. The results suggest that reducing AMI budgets may have a negative effect on the quality of AMI care patients receive in Edmonton, Alberta. The linear relationship suggests that the return on the quality of AMI is consistent for each dollar invested with no economies of scale.

Keywords

Acute Myocardial Infarction, cost-quality trade-off, case-mix groupers, Canada, efficiency, hospital costs

1. Introduction

The relationship between quality of care and cost is essential to all policy makers. This study explores the relationship between hospital costs and quality of care for Acute Myocardial Infarction (AMI) in

the Edmonton area hospitals. This relationship is increasingly important for policy makers who have strict budget constraints and make decisions about cost minimization and quality maximization. To our knowledge this is the first Canadian study on the cost-outcome tradeoff for AMI.

Cost-outcome tradeoff studies are focused on either outcome on cost (Hvenegaard, Arendt, Street, & Gyrd-Hansen, 2011; Gutacker et al., 2013) or cost on outcome (Fisher et al., 2003; Fisher, Wennberg, Stukel, & Gottlieb, 2004 Variations Supplement; Kaestner & Silber, 2010; Schreyögg & Stargardt, 2010; Romley, Jena, & Goldman, 2011; Stargardt, Schreyögg, & Kondofersky, 2014; Häkkinen et al., 2014; Häkkinen, Rosenqvist, Iversen, Rehnberg, & Seppälä, 2015 Supplement). The Canadian health care system is complex where the hospitals receive mainly global funding from the province while physicians bill the provinces after providing their services. Due to this complexity it is unclear on which methodology should be applied to the Canadian system.

Recent observational outcome-cost tradeoff studies have tried to control for unobservable variable and reverse causality bias through Instrumental Variable (IV) regression modelling (Kaestner & Silber, 2010; Stargardt, Schreyögg, & Kondofersky, 2014; Häkkinen, Rosenqvist, Iversen, Rehnberg, & Seppälä, 2015 Supplement; Schreyögg & Stargardt, 2010). The IV models require a variable (the instrument) that is highly correlated with the dependent variable (hospital costs) and must have no relationship with the explanatory variable (quality of AMI care) to ensure a non-bias estimate of causal effects. Instruments from previous studies include: total inpatient spending per decedent (Kaestner & Silber, 2010), average hospital costs in federal state and price per square meter in hospitals in the country (Stargardt, Schreyögg, & Kondofersky, 2014), Hospital level average cost of unstable angina (Häkkinen, Rosenqvist, Iversen, Rehnberg, & Seppälä, 2015 Supplement), and Hospital occupancy rate (Schreyögg & Stargardt, 2010). However, these previous IV's cannot be used in this study due to this studies small and well-defined sample population.

This study focuses on the quality and cost of AMI care for Edmonton, Alberta, Canada. There are several advantages in this well-defined population. The first reason is that AMI requires immediate medical attention, which removes problems with patient selections between hospitals. The second is that hospitals that provide better care can substantially improve the quality relating to AMI (Stargardt, Schreyögg, & Kondofersky, 2014). The third is that the quality of care can be measured by mortality in well-defined patient groups (Häkkinen, Rosenqvist, Iversen, Rehnberg, & Seppälä, 2015 Supplement). Lastly, the existence of any possible relationship between quality and cost may differ between different heterogeneous sample groups such as the difference between cities, provinces, and countries, which may explain the inconsistent findings in existing literatures.

Some studies in the United States have found a positive association where higher cost leads to a better outcome (Timbie, Newhouse, Rosenthal, & Normand, 2008; Schreyögg & Stargardt, 2010; Romley, Jena, & Goldman, 2011) while other studies from United States found no association (Fisher et al., 2003; Fisher, Wennberg, Stukel, & Gottlieb, 2004 Variations Supplement; Jha, Orav, Dobson, Book, & Epstein, 2009; Yasaitis, Fisher, Skinner, & Chandra, 2009; Kaestner & Silber, 2010; Hussey,

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Wertheimer, & Mehrotra, 2013). Besides our neighboring country, these inconsistent results also exist across the globe where a positive relationship was found in Sweden (Häkkinen et al., 2014), Hungry, Finland (Häkkinen, Rosenqvist, Iversen, Rehnberg, & Seppälä, 2015 Supplement) and Germany (Stargardt, Schreyögg, & Kondofersky, 2014). No clear evidence of any association was also found for Finland, France, Germany, and Spain (Häkkinen et al., 2014).

2. Data and Method

2.1 Data

In this study all micro-costing data comes from the Management Information System (MIS) from Alberta Health Services (AHS). These costs include all functional costs such as hospital direct cost, hospital drug cost, patient supply cost, patient drug cost, and hospital indirect cost. Hospital discharge data were available for 4802 AMI (ICD-10 code I21) patients in the Edmonton area hospitals between fiscal periods of April 1, 2006 to March 30, 2009. Patients were excluded if they were discharged as a transfer to an acute care facility, left against medical advice, or had a Length of Stay (LOS) greater than 90 days (3988 patients remaining). We also excluded patients who were hospitalized for AMI within one-year prior the index day to restrict our analysis to only new AMI hospitalization (3554 patients remaining). All functional costs are aggregated for each patient. The data set also contains Resource Intensity Weights (RIW's) and the Case Mixed Group Plus (CMG+) which allows a linkage to the Canadian Institute for Health Information (CIHI) costing proxy. This is used as a robustness check and is further explained in the robustness check section.

Similar to previous studies (Häkkinen, Rosenqvist, Iversen, Rehnberg, & Seppälä, 2015 Supplement), the quality indicator is a binary variable measured by a 30-day survival where it takes a value of 1 if the patient is alive after 30 days and 0 if the patient died during the 30 days. It has been argued and shown that within a well-defined patient group such as AMI, the quality or outcome of hospital care is measureable by hospital mortality in many countries such as Canada, Denmark, United Kingdom, United States, Sweden, and Finland (Häkkinen, Rosenqvist, Iversen, Rehnberg, & Seppälä, 2015 Supplement). Risk adjustment is controlled with binary variables for 15 comorbidities (Note 1). Demographic controls include both age and sex. Hospital fixed effects will account for hospital heterogeneity such as teaching or university status. Year fixed effects will account for any annual fluctuations in policy or economic conditions.

2.2 Methods

2.2.1 Parametric Analysis

Hospital costs were regressed with increasing model specifications starting with a simple linear regression of just hospital costs and quality (equation 1). The second model has additional demographic controls (equation 2). The third model includes risk adjustments (equation 3). The last two models include hospital fixed effects (equation 4) and year fixed effects (equation 5). Where i is the ith patient treated at time t, $COST$, is the micro-costing data from MIS, Q is the respective quality measurement

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as defined above, $\boldsymbol{X}$ is a vector of demographic controls, $\boldsymbol{R}$ is a vector of risk adjustments, $\boldsymbol{Hos}$ is hospital fixed effects, $\boldsymbol{Year}$ is year fixed effects, and $\boldsymbol{\varepsilon}$ is the residuals. All costs are logarithmically transformed to create a normal distribution and make easier interpretation of the results for policy makers and layman research users.

$$lnCOST_{i,t} = \beta_1 Q_{i,t} + \varepsilon_{i,t} \tag{1}$$

$$lnCOST_{i,t} = \beta_1 Q_{i,t} + \beta_2 X_{i,t} + + \varepsilon_{i,t} \tag{2}$$

$$lnCOST_{i,t} = \beta_1 Q_{i,t} + \beta_2 X_{i,t} + \beta_3 R_{i,t} + \varepsilon_{i,t} \tag{3}$$

$$lnCOST_{i,t} = \beta_1 Q_{i,t} + \beta_2 X_{i,t} + \beta_3 R_{i,t} + \beta_4 Hos_{i,t} + \varepsilon_{i,t} \tag{4}$$

$$lnCOST_{i,t} = \beta_1 Q_{i,t} + \beta_2 X_{i,t} + \beta_3 R_{i,t} + \beta_4 Hos_{i,t} + \beta_5 Year_{i,t} + \varepsilon_{i,t} \tag{5}$$

2.2.2 Semi-Parametric Analysis

If evidence of an association exists, then it is important for policy makers to know the true functional form of the relationship between quality and hospital costs. Semi-parametric regressions allowed us to relax the assumption of linearity from multi-linear regression analysis. Our model will resume the use of the linearity assumption on all parameters except the quality measurement as shown in equation 6, where F is an unknown function and the $\boldsymbol{Q}_{i,t}$ coefficient remains linear. This function will be depicted in a graphical form to allow the interpretation of its true functional form.

$$lnC_{i,t} = F(Q_{i,t}) + \beta_1 X_{i,t} + \beta_2 R_{i,t} + \beta_3 Hos_{i,t} + \beta_4 Year_{i,t} + + \varepsilon_{i,t} \tag{6}$$

3. Results

Table 1 contains descriptive statistics broken down by sex for selected variables. The average age was 69 and 77 for males and females, respectively. There were approximately twice as many males than females. Male patients have increased drastically from fiscal year 2007 to fiscal year 2009. There were 1377 male and 470 female patients who received Percutaneous Coronary Intervention, which is a non-invasive and less expensive procedure compared to a Coronary Artery Bypass Grafting (CABG). 11 male patients received CABG compared to only 1 female. 43 male patients signed-out against medical advice compared to 11 female patients.

Table 1. Descriptive Statistics

		Fiscal Year[1]		
	Male (n=2421)	2006/2007	2007/2008	2008/2009
(1)	Age	72 (14)	70 (14)	68 (13)
(2)	Length of Stay	7.8 (6.7)	7.3 (6.6)	6.7 (5.6)
(3)	Cost	$11,463 (10496)	$10,684 (9554)	$11,650 (11109)
(4)	CABG (#)	11	0	0
(5)	PCI (#)	277	515	585
	Female (n=1133)			

(6)	Age (mean)	81 (14)	76 (14)	76 (14)
(7)	Length of Stay (mean)	10.2 (10.8)	8.9 (8.9)	8.2 (7.80
(8)	Cost (mean)	$12,287 (13175)	$11,026 (8450)	$12,377 (9804)
(9)	CABG (#)	1	0	0
(10)	PCI (#)	91	191	188

Note. [1] Fiscal period starts in April Ends in March.

Standard Deviation in Brackets when applicable.

All the results from the regression models with increasing regression specifications are shown in table two. The results suggest that the quality of AMI care as measured by hospital mortality is positively associated with hospital costs after controlling for demographics, comorbidities, and fixed effects. These results suggest that higher AMI quality of care is associated with approximately 39% higher hospital costs.

Table 2. Select AMI Quality Regression Coefficients

		(1)	(2)
	Model Specifications	Quality Coefficents[1]	Survival Coefficients
(1)	No Risk adjustment	.393***	0.087***
(2)	+ Risk adjustments	.391***	.093***
(3)	+ Hospital Fixed Effects	.399***	.091***
(4)	+ Year Fixed Effects	.388***	0.092***
(6)	Instrumental Variable regression	-8.308	1.918
(7)	1st Stage F-Stat	20.97	52.91
(8)	Instrumental Variable regression[2]	-2.440	-0.654
(9)	1st Stage F-Stat	17.54	43.67

Note. *, **, *** indicates 1%, 5%, 10%, significance levels respectively.

[1] Based on patient mortality.

[2] Controlled for: average household income, prevalence of current smoking, average HUI3 index, and average number of drinks per day.

The semi-parametric regression results (Figure 1) show a fairly linear and positive relationship between the numbers of days survived and hospital costs. This provides additional support for the positive association found under the parametric approach.
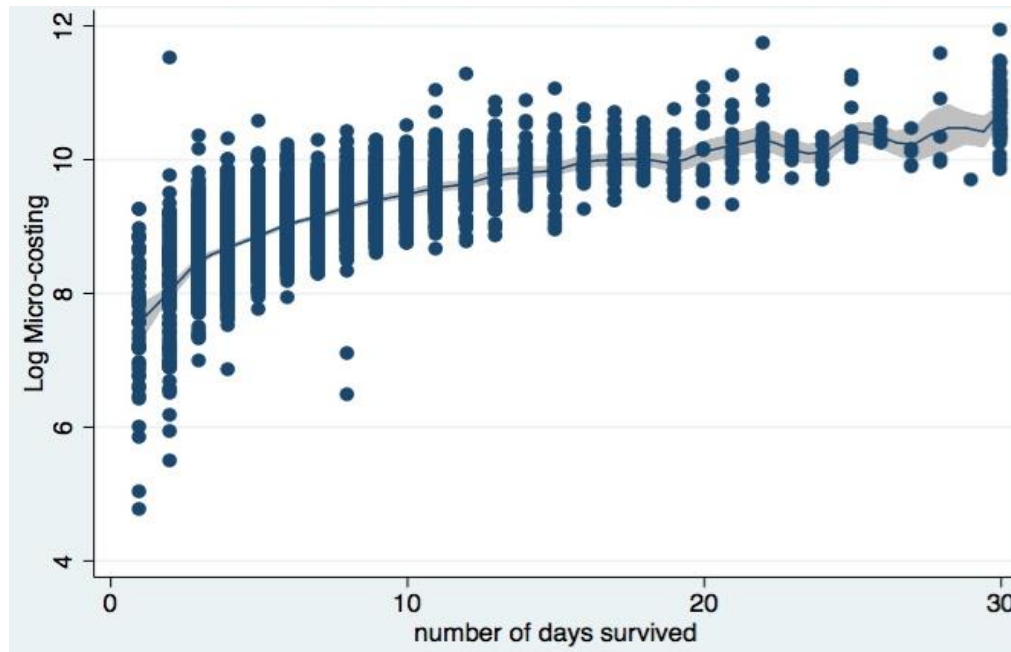
Figure 1. Functional Form of Quality vs. Cost from Semi-Parametric Regression with 95% Confidence Interval

4. Robustness Check

Following the CIHI methodology for CMG+ cost estimation each patient's RIW was multiplied with the provincial CPWC from years 2006/2007 to 2008/2009. However due to changes in CIHI procedures these CPWC are no longer publicly available. This study will include these CPWC for future references (Note 2). To ensure further robustness of our results, this study replaces all micro-costs used in the previous analysis with the CMG+ cost estimates. The association under all specification were consistent with the previous findings when using the CMG+ cost estimates. All robustness check results are available upon request from the corresponding author.

5. Conclusion and Discussion

This study cautions Canadian policy and decision makers on budget cuts and cost containment programs relating to AMI. Our model finds evidence of a robust positive association between the level of AMI care and hospital cost. In other words, reducing hospital expenditure is associated with a decrease in AMI quality for Edmonton, Alberta. These results suggest that policy makers should take extreme caution when implementing any cost containment program as it may have a negative effect on patient health.

These results have undergone various robustness checks including increasing model specifications and replacing the micro-costing data with CMG+ cost estimates. These variations ensured the robustness of a positive association between the quality of AMI care and hospital costs. Similar positive association between AMI quality and hospital costs can be found in studies from California (Romley, Jena, &

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Goldman, 2011), Germany (Stargardt, Schreyögg, & Kondofersky, 2014), Sweden (Häkkinen et al., 2014), and United States Veterans hospitals (Schreyögg & Stargardt, 2010). Interestingly, this study's semi-parametric approach confirms a fairly linear relationship between quality and cost, which suggest that economics of scale and diminishing marginal returns may not be applicable. This means that the return on the quality of AMI is constant for each dollar invested.

Two major strengths of this study lie in the data set used. The first is that the data set is population based and not a sample. This data set contains all patients between fiscal years 2006 to 2009 who were admitted for AMI in Edmonton Alberta. The second, is that all costs came from the Alberta Health Services MIS which contains actual patient costs that remove the need for further estimation of costs.

6. Limitations

A major limitation in all AMI outcome-cost studies is the definition of quality being used. An ideal study would need to incorporate some true measure of AMI quality instead of the quality proxy. To our knowledge, there are no measures of the true quality of AMI and to derive such measurement would require the help of experts and physicians in AMI care. Other limitation includes that AMI treatment like PCI and CABG may be done after the initial hospitalization and in another hospital and increasingly also as outpatient operation. This may have impact to our cost and procedure outcomes of the study.

This study is restricted to the Edmonton area hospitals, which may reduce the variations between cost and quality indicators. A higher-level provincial study would be needed to provide more insight on the nature between hospital cost and AMI quality. This study also suffers from the inability to control for unobservable variable bias and reverse causality. This study has explored all previously proposed IV's as well as health area-based instrumentations (Chu & Ohinmaa, 2016), which were not possible to use since the majority of patients were from the same health region.

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Notes

Note 1. Hypertension, Diabetes Mellitus, Cancer, COPD (Chronic Obstructive Pulmonary Disease) and Asthma, Dementia, Depression, Parkinson's disease, Mental Disorders, Renal Insufficiency, Alcoholism, Coronary Artery disease, Atrial Fibrillation, Cardiac Insufficiency (heart failure), Atherosclerosis, and Stroke.

Note 2. Provincial CPWC values for fiscal years 06/07, 07/08, and 08/09 are $5541.24, $6152.33, and $5769.08, respectively.