The Effect of Preoperative and Hospital Characteristics on Costs for Coronary Artery Bypass Graft

Shadi S. Saleh, PhD, MPH, Michael Racz, PhD,† and Edward Hannan, PhD**

Objective: This study aimed at exploring the effect of preoperative risk factors and hospital characteristics on costs of coronary artery bypass graft (CABG) hospitalizations.

Background: The considerable investment in hospital-based cardiac programs has not been coupled with comparable efforts to explore cost drivers of associated procedures.

Methods: Data sources included (*a*) New York State's Cardiac Surgery Reporting System, (*b*) New York State's Statewide Planning and Research Cooperative System dataset, (*c*) American Hospital Association dataset, and (*d*) Medicare Hospital Cost Report Public Use files and wage index files. The study population comprised New York state residents who underwent an isolated CABG procedure in a New York State hospital and were discharged in 2003. The outcome measure was inpatient costs. Independent variables included patient (demographic and clinical) and hospital characteristics.

Results: The total number of cases was 12,016. Findings revealed that selected demographic characteristics, including older age, female gender, and being black, were associated with higher costs. Several clinical characteristics were found to affect CABG discharge costs such as lower ejection fraction, the duration between CABG admission and the occurrence of myocardial infarction, number of diseased vessels, previous open heart operations, and a number of comorbidities. Furthermore, larger hospitals were associated with higher CABG discharge costs, while costs significantly decreased with higher CABG volume.

Conclusions: Hospitals should explore ways to address patient (patient management) and hospital (case volume), when possible, associated with higher CABG discharge costs in its efforts to contain costs.

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The number of coronary artery bypass graft (CABG) surgeries in the United States approached half a million per year in 2005.[1] The considerable number of CABG procedures performed combined with the fact that the procedure constitutes a revenue generator have encouraged hospitals to invest in the establishment of cardiac surgery programs.[2–5] However, the considerable investment by hospitals in such programs–which will have/had an impact on public and private health care spending–was not coupled with comparable efforts to explore the associated determinants of costs. Most of the studies that examined costs of CABG procedures were focused on the effect of demographic characteristics,[6–12] the comparison among clinical techniques to perform the procedure (eg, off-pump vs. conventional CABG),[13–17] and the differences in costs among the various coronary revascularization procedures (eg, percutaneous coronary angioplasty vs. stenting; CABG vs. PCI; thrombolytic treatment vs. PCI. etc).[18–27] Few investigations examined the effect of patient clinical risk factors and hospital characteristics on CABG costs.

The aim of this study was to explore the effect of clinical risk factors and hospital characteristics on costs of CABG hospitalization. Such an investigation is merited as the health care delivery system is going into a new phase where the concept of value-based purchasing, in which providers are compared not only based on quality but also efficiency, is a key component. Hospitals that are able to demonstrate favorable efficiency in health care delivery will be rewarded. As such, identifying–and controlling for–the factors that affect performance on efficiency measures, in this case costs, will allow for optimal comparative evaluation.

From the *Department of Health Policy, Management, and Behavior, School of Public Health, State University of New York at Albany, Albany, NY; and †New York State Department of Health, Albany, NY.

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Reprints: Shadi Saleh, PhD, MPH, School of Public Health, State University of New York at Albany, One University Place, Rensselaer, NY 12144. E-mail: ssaleh@albany.edu.

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METHODS

Study Population

The study population was comprised of New York State residents who underwent an isolated CABG procedure in the state during 2003. The cases–total number of cases was 12,016–were derived from hospitals that were certified by the State to perform the procedure in 2003 (33 hospitals).

Data Sources

Data for the study was derived from: (*a*) New York State's Cardiac Surgery Reporting System (CSRS), (*b*) New York State's Statewide Planning and Research Cooperative System (SPARCS) dataset, (*c*) American Hospital Association dataset, and (*d*) Medicare Hospital Cost Report Public Use files (Cost Report) and Medicare wage index files.

The CSRS contains clinical data on patients undergoing CABG in New York State. Information from CSRS that was used included patient characteristics (demographics and preoperative risk factors). This dataset was combined with SPARCS, an administrative dataset which contains information on inpatient acute care services delivered in New York State. The data extracted from SPARCS included diagnostic and procedural codes, department-level (eg, supplies, laboratory, etc.) charges, federal and New York State Diagnosis-Related Groups (DRGs), and facility identifier.

Data elements derived from the Medicare Cost Report and wage index files included department-level costs, intern and resident to bed ratios and market wage indices, as well as facility identifiers for data linkage. The Medicare Cost Report was linked to the AHA dataset to extract hospital characteristics (ownership, size, teaching status, and operating margin) using the facility identifier. It is worth noting that a one-item survey was conducted with the 33 hospitals in the study to examine whether they use clinical pathways for CABG patients. The study was approved by the State University of New York at Albany Institutional Review Board.

Study Variables

The study outcome measure was costs of CABG discharges. These were derived by applying the ratios of costs to charges for the index claim. This method had shown a correlation of >0.90 with internal accounting costs in previous studies.[28,29] The total costs for each of the claims were standardized based on the hospital that the case was treated in. The costs were standardized based on[1] indirect medical education costs and[2] labor wage index. The Balanced Budget Act of 1997 and subsequent legislation reduced the IME adjustment overtime from 7.7% percent for every 10 percentage point increment in the ratio of residents to hospital beds to 5.5% percent for every 10 percentage point.[30] However, a Medicare Payment Advisory Commission analysis showed that "Inpatient Operating costs increased about 2.7% for every 10% increment in the resident-to-bed ratio." We used this MedPAC analysis with IME to appropriately adjust the costs of teaching hospitals in this study. The PPS statute requires that Secretary of Health and Human Services must adjust the standard PPS payment rate for area differences in hospital wages. Currently, the labor share, as determined by the Centers for Medicare and Medicaid Services, (CMS) is 71.066%. Recent legislation requires that the labor share be set at 62% for hospitals with a wage index of less than 1.0000.[31] In our adjustment of hospital costs, we applied the wage index adjustment only to the empirically determined labor share of 71.066% to adjust a hospital's costs for its wage index.

Independent variables included patient and hospital characteristics. Patient characteristics included age, gender, and preprocedural risk factors (eg, ejection fraction, number of diseased vessels, previous AMI, comorbidities, etc). The use of similar patient characteristics has been employed by others in establishing reimbursement models or examining the utility of clinical risk factors as predictors of hospital charges and costs.[32–35] Hospital characteristics comprised ownership, teaching status, size, operating margin, volume, and use of clinical pathways. The latter was included because of the potential effect of clinical pathways on cost of cardiac procedures.[36–40]

Data Analysis

The bivariate association between each of the independent measures and costs was examined through the use of t-tests and analysis of variance. Multivariate analysis was conducted using a 2-level hierarchical model to examine the effect of patient and hospital characteristics on hospital costs for CABG (patients nested in hospitals). A 2-level hierarchical model was fit to predict log normalized costs. Observations with outlier costs (>$55,000)–246 (2%) were excluded. The level-1 model incorporated patient-level characteristics. The level-2 model investigated the influence of hospital-level factors. First, a stepwise multivariable regression was fit using patient demographics and risk factors to predict log cost. All variables significant at the 0.05 level were then included as level-1 factors and modeled as random effects. The level-1 intercept was modeled as random with hospital factors as fixed effect predictors. Age, gender, race, and clinical risk factors (as individual variables) were level-1 predictors, and ownership, teaching, size, CABG volume, and use of clinical pathways are level-2 predictors.

RESULTS

There were a total of 12,016 patients and 33 hospitals in the study. Table 1 presents the prevalence of patient and hospital characteristics included in the study, as well as the bivariate association between each of these characteristics and costs. More than half of patients (55.8%) were 65 years of age with most patients (72.3%) being men. Approximately nine-tenths of patients (81.8%) were white; a majority of patients (57.5%) had an ejection fraction of 50% or more. Most patients (52.9%) did not have a previous myocardial infarction with a small percentage (4.2%) of patients had undergone a previous open heart surgery. The most common comorbidity was diabetes (34.7%). More than half of patients (52.1%) had 3 diseased vessels. More than four-fifths of hospitals (84.8%) were not-for-profit. The number of teaching hospitals was almost double that of nonteaching hospitals with discharge costs increased by hospital size ($P < 0.001$). Most hospitals had an operating margin that was between 0% and 4.99%; approximately, one-third of hospitals (30.3%) had performed 500 or more CABG procedures during the study period with more than half of the hospitals (51.5%) employing clinical pathways for CABG.

Table 2 presents the results of the multivariate hierarchical linear model of CABG discharge costs. It is worth noting that the effect of patient and hospital characteristics was presented as exponentiated parameter estimates of the model coefficients. The number of years beyond age 65 was associated with higher costs ($P < 0.001$). Being a female was associated with 5% more cost compared with males ($P < 0.001$); so was being black which was associated with 4% more costs compared with other races ($P < 0.05$). The ejection fraction was also significantly associated with costs; lower fraction rates were associated with higher costs. Several comorbidities were found to increase CABG discharge costs; these included carotid/cerebrovascular disease, femoral/popliteal disease, the occurrence of congestive heart failure in the index admission, malignant ventricular arrhythmia, chronic obstructive pulmonary disease, and renal failure. In addition, the presence of left main disease was associated with 5% higher costs ($P < 0.001$), so was having 3 diseased vessels ($P < 0.001$). Having undergone a previous open heart surgery was found to be associated with 10% higher costs ($P < 0.001$).

At the second level of the hierarchical structure, larger hospitals were associated with increased costs. Compared with hospitals with less than 440 beds, CABG discharge costs at hospitals with 440 to 749 were 29% higher ($P < 0.001$), and at hospitals with 750 or more beds even higher by 41% ($P < 0.001$). Conversely, a higher number of CABG procedures performed at the index hospitals was associated with lower CABG discharge costs. Hospitals that performed 250 to 499 CABG procedures during the study year had 15% lower costs ($P < 0.05$) than those with less than 100 procedures performed (reference group). Furthermore, hospitals that had a total CABG volume that was 500 or more procedures were found to be associated with costs that were 19% lower than the reference group ($P < 0.05$).

DISCUSSION

The level of health expenditures on CABG procedures and the financial success of new cardiac programs have led to an increased interest in better understanding the cost determinants of the procedure.[28,29,36–43] However, few studies explored the effect of patient and hospital characteristics on CABG costs. Ferraris et al assessed the association between patient risk factors and hospital costs.[41] The study concluded that certain clinical risk factors such as preoperative congestive heart failure and serum creatinine levels among others were associated with increased CABG costs. However, the study only investigated patient risk factors and did not explore the associated potential effect of hospital characteristics on costs. Other investigations focused more on hospital-based costs; a study exploring the variability in hospital-based costs of CABG reported considerable variations in costs among hospitals, even after controlling for patient clinical risk factors.[42] Similarly, Cowper et al[43] detected considerable variability in hospital costs of CABG among states. However, although these studies examined patient and hospital characteristics, the aim was not to explore their effect on CABG costs. This study was aimed at investigating patient and hospital determinants of CABG discharge costs in an effort to identify significant cost drivers as a first step to potentially better design/enhance cost reducing strategies.

TABLE 1. Prevalence and Average Costs of Patient Demographic and Risk Groups and Hospital Characteristics

Characteristics	Prevalence	%	Average Cost	Standard Deviation	P
Patient characteristics					
All cases	12,016	100.0	19,988	8673	
Age					<0.001
<45	377	3.1	18,343	7619	
45–64	4934	41.1	19,151	8228	
65+	6705	55.8	20,696	8977	
Gender					<0.001
Male	8688	72.3	19,595	8515	
Female	3328	27.7	21,014	8993	
Race					<0.001
White	10,580	88.0	19,808	8585	
Black	829	6.9	22,633	9527	
Other	607	5.1	19,513	8396	
Ejection fraction					<0.001
<20%	194	1.6	27,044	10,574	
20%–29%	731	6.1	23,506	9623	
30%–39%	1444	12.0	21,694	8887	
40%–49%	2647	22.0	20,040	8329	
≥50%	6914	57.5	19,065	8344	
Missing	86	0.7	18,157	8869	
Previous MI*					<0.001
<6 h	68	0.6	23,994	10,619	
6–23 h	97	0.8	22,323	8696	
1–7d	2019	16.8	22,156	8624	
8+ d	3476	28.9	20,869	9314	
None	6356	52.9	18,739	8068	
Previous open heart operations					0.002
Yes	506	4.2	21,261	9593	
No	11,510	95.8	19,932	8627	
Comorbidities					
Previous stroke					<0.001
Yes	944	7.9	21,351	9194	
No	11,072	92.1	19,872	8618	
Aortoiliac disease					<0.001
Yes	543	4.5	21,782	9425	
No	11,473	95.5	19,903	8627	
Carotid/cerebrovascular disease					<0.001
Yes	1580	13.2	21,888	9510	
No	10,436	86.9	19,700	8503	
Femoral/popliteal disease					<0.001
Yes	878	7.3	22,116	9534	
No	11,138	98.4	19,976	8653	
Congestive heart failure					<0.001
This admission	1373	11.4	25,256	9906	
Before this admission	412	3.4	21,315	8953	
None	10,231	85.1	19,228	8222	
Emergency dx[†] cath					0.29
Yes	198	1.7	20,724	9815	
No	11,818	98.4	19,976	8653	
Emergency PCI					0.19
Yes	21	0.2	22,916	9890	
No	11,995	99.8	19,983	8671	
PCI this admission					0.039
Yes	80	0.7	22,025	8722	
No	11,936	99.3	19,974	8672	

(*Continued*)

TABLE 1. (*Continued*)

Characteristics	Prevalence	%	Average Cost	Standard Deviation	*P*
PCI before this admission					0.009
Yes	2190	18.2	19,565	8276	
No	9826	81.8	20,082	8757	
Malignant ventricular arrhythmia					<0.001
Yes	91	0.8	25,782	10,249	
No	11,925	99.2	19,944	8646	
COPD					<0.001
Yes	2152	17.9	21,259	9132	
No	9864	82.1	19,711	8545	
Diabetes					<0.001
Yes	4173	34.7	20,617	8940	
No	7843	65.3	19,653	8510	
Renal failure					<0.001
Dialysis	182	1.5	25,822	9683	
Creatinine >2.5	219	1.8	26,994	10,747	
None	11,615	96.7	19,764	8525	
Hepatic failure					0.24
Yes	2	0.0	27,709	4395	
No	12,014	99.9	19,987	8673	
Hemodynamic state					
Unstable					<0.001
Yes	142	1.2	22,864	9592	
No	11,874	98.8	19,954	8535	
Shock					0.44
Yes	20	0.2	21,647	9474	
No	11,996	99.8	19,985	8572	
Left main disease					<0.001
Yes	3633	30.2	20,877	8878	
No	8383	69.8	19,603	8555	
Vessels diseased					<0.001
1	2031	16.9	18,880	8623	
2	3729	31.0	19,394	8413	
3	6256	52.1	20,702	8778	
Health behavior					
Smoking, 2 wk					0.012
Yes	1997	16.6	20,446	8983	
No	10,019	83.4	19,897	8508	
Smoke, 1 yr					0.018
Yes	885	7.4	20,681	9053	
No	11,131	92.6	19,933	8540	
Hospital characteristics					
Ownership					<0.001
Not-for-profit	28	84.8	19,894	8750	
Public	5	15.2	20,876	7858	
Teaching status					<0.001
Nonteaching	10	30.3	18,889	6834	
Teaching	23	69.7	20,660	9565	
Bedsize					<0.001
<440	10	30.3	17,759	6662	
440–749	11	33.3	20,441	7664	
750+	12	36.4	22,026	11,067	
Operating margin					<0.001
<−5%	4	12.1	20,600	12,493	
−5%–−0.01%	5	15.2	21,362	9233	
0%–4.99%	19	57.6	20,357	8197	
5%+	5	15.2	18,370	6500	

(*Continued*)

TABLE 1. (*Continued*)

Characteristics	Prevalence	%	Average Cost	Standard Deviation	P
No. CABG procedures					<0.001
<100	2	6.1	26,987	10,423	
1–249	6	18.2	20,771	8136	
250–499	15	45.5	20,711	9072	
500+	10	30.3	19,129	8256	
Use of clinical pathways					<0.001
Yes	17	51.5	18,881	8386	
No	16	48.5	22,048	8882	

*MI indicate myocardial infarction.
†Dx indicates diagnostic; Cath, catheterization; PCI, percutaneous coronary intervention; COPD, chronic obstructive pulmonary disease; CABG, coronary artery bypass graft surgery.

TABLE 2. Hierarchical Regression Analysis of CABG Costs

Characteristics	Multiplier* (95% CI)	P
Patient characteristics		
Intercept	16,718 (13.915–20.085)	<0.001
No. yr of age >65+	1.005 (1.004–1.006)	<0.001
Female gender	1.05 (1.04–1.07)	<0.001
Black	1.04 (1.01–1.07)	0.018
Ejection fraction		
<20	1.21 (1.13–1.31)	<0.001
20–29	1.09 (1.06–1.13)	<0.001
30–39	1.07 (1.04–1.09)	<0.001
40–49	1.03 (1.02–1.05)	<0.001
Previous MI		
< 6 h	1.25 (1.11–1.41)	<0.001
6–23 h or 1–7 d	1.13 (1.10–1.15)	<0.001
Carotid/cerebrovascular disease	1.05 (1.03–1.08)	<0.001
Femoral/popliteal disease	1.06 (1.05–1.08)	<0.001
CHF, this admission	1.17 (1.14–1.21)	<0.001
Malignant ventricular arrhythmia	1.16 (1.09–1.22)	<0.001
COPD	1.08 (1.05–1.10)	<0.001
Renal failure		
Dialysis	1.25 (1.16–1.34)	<0.001
Creatinine >2.5	1.27 (1.21–1.33)	<0.001
Left main disease	1.05 (1.04–1.07)	<0.001
Three vessels diseased	1.05 (1.04–1.07)	<0.001
Previous open heart operations	1.10 (1.07–1.13)	<0.001
Hospital characteristics		
Teaching	0.88 (0.78–1.00)	0.056
Use of clinical pathways	0.93 (0.82–1.05)	0.23
Public ownership	0.96 (0.85–1.07)	0.47
Bedsize (reference <440)		
440–749	1.29 (1.15–1.45)	<0.001
750+	1.41 (1.23–1.61)	<0.001
CABG volume (reference <100)		
100–249	0.92 (0.78–1.08)	0.30
250–499	0.85 (0.74–0.98)	0.031
500+	0.81 (0.70–0.95)	0.013

*Exponentiated parameter estimates from log model.
MI indicate myocardial infarction.

Findings revealed that selected demographic characteristics, including older age, female gender and being black, were associated with higher costs. Furthermore, several clinical characteristics were found to affect CABG discharge costs such as lower ejection fraction, the duration between CABG admission and the occurrence of myocardial infarction, number of diseased vessels, previous open heart operations, and a number of comorbidities. The findings of the effect of demographic and clinical characteristics on CABG discharge costs are consistent with that of other investigations that examined preoperative determinants of CABG costs.[6,44–47] Understanding the differential impact of these risk factors, specifically clinical, can aid in cost containment efforts, eg, possibility of intervention among patients with certain preoperative characteristics for cost reduction techniques.[41,48,49] In addition, given the expected exclusion of complications as basis for DRG assignment/upgrading[50] and the CMS decision to use costs to determine DRG weights in 2008, it will be important to properly code comorbid patient risk factors, especially those associated with higher costs.

Another set of factors examined included hospital characteristics. The findings revealed that larger hospitals had higher CABG discharge costs. On the other hand, costs significantly decreased with increased CABG volume. Perhaps the former finding is more challenging to interpret given the different factors that may cause such a relationship, eg, inefficiencies of larger hospitals or the fact that larger hospitals are more likely to be teaching hospitals and these usually have higher costs than nonteaching hospitals. A more relevant finding is the association between high procedure volume and lower costs; such an association has been widely documented for a number of procedures.[51–53] Very few studies explored the association between volume and discharge costs for coronary revascularization procedures and these reported similar results.[54] As such, it can be argued that to enhance efficiency, providers should aim to attract more CABG procedures to their facility-specifically 250 or more procedures per year based on study findings. Furthermore, payers may reward, eg, selectively contract, with high-volume–and consequently lower costs–hospitals as part of implementing a value-based purchasing system.[55]

There are several limitations in the study that merit consideration. First, generalization may be limited by the fact that the study used data derived from one state. Second, the study was based on data derived from procedures that occurred in 2003. Changes in surgical practices in the past 5 years may have a potential effect on cost structures and determinants. Third, it is possible that hospital characteristics, other than those examined in the study, eg, staffing, operating room scheduling, also affect CABG discharge costs. However, given the nature of the datasets used, it was not possible to extract such information. Finally, the study used clinical risk factors which are not collected in most states or in national dataset (eg, MedPAR). Hence, the replicability of the results may be limited-especially since most current administrative data do not differentiate between comorbidities and complications. Fortunately, CMS will revise the severity adjustments of DRGs to reflect differences that would help make that differentiation by 2008.[56]

In conclusion, several patient and hospital characteristics affect CABG discharge costs. Hospitals should explore ways to reduce the impact of such characteristics, when possible, in an attempt to reduce costs.

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