Understanding variability in hospital-specific costs of coronary artery bypass grafting represents an opportunity for standardizing care and improving resource use

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Background: This study was undertaken to examine interhospital variability in inpatient costs of coronary artery bypass grafting (CABG).

Methods: The Nationwide Inpatient Sample was used to identify isolated CABGs performed between 2005 and 2008 in the United States. Charges for inpatient care were supplied by the data set, and hospital charge-to-cost ratios were used to derive inpatient costs for each patient and aggregated at the hospital level. Mixed-effect linear regression models were created to evaluate variability in costs between hospitals adjusting for 34 patient, operative, complication, and hospital-related variables.

Results: A total of 633 hospitals performed isolated CABG in 183,973 patients. In unadjusted analysis, there was significant baseline variability in average inpatient costs of CABG between hospitals (SD, $12,130; $P < .001$). This variability represented 30% of the overall unadjusted average cost of performing CABG per hospital ($40,424). After risk adjustment, significant variability in average costs between hospitals persisted ($P < .001$). Of the 34 additional variables included in the model, only hospital region, postoperative sepsis, in-hospital mortality, and need for ventricular assist device, extracorporeal membrane oxygenation, permanent pacemaker, or implantable cardioverter-defibrillator were stronger predictors of increased costs compared with the hospital effect.

Conclusions: There is a wide variation in the cost of performing CABG in the United States. We determined that individual hospital centers, independent of multiple patient- and outcome-specific factors, are drivers of these differences. Comparison of hospital-specific behavior with identification of the causes of cost discrepancies represents an opportunity for standardization of care and improvement in resource use. (J Thorac Cardiovasc Surg 2014;147:109-16)

Health care spending in the United States continues to garner interest by multiple parties, including individual providers, hospitals, policy makers, and the public. Despite higher costs, the quality of care provided in the United States has not been demonstrated to be measurably superior to that in other countries.[1] This has underscored the importance of cost containment and specific strategies to reduce health care spending.

These themes apply specifically to coronary artery bypass grafting (CABG) as well. CABG represents one of the most commonly performed procedures in the United States. Although the heavy cost burden of coronary atherosclerosis on the health care system has been well studied, there is a paucity of literature identifying systematic factors that may contribute to variations in costs of coronary revascularization. In this study, we evaluated interhospital variability in inpatient costs of CABG in the United States.

PATIENTS AND METHODS

Data Source

The Nationwide Inpatient Sample was the data source used for this study. This registry was developed as part of the Agency for Healthcare Research and Quality Healthcare Cost and Utilization Project. It represents a 20% stratified sample of all hospitals within the United States, with patient-level data on approximately 8 million hospital stays per year from 1050 hospitals.[2] Because the data are publically available and deidentified, the Johns Hopkins University School of Medicine Institutional Review Board granted the study exempt status.

Inclusion and Exclusion Criteria

CABGs performed between January 1, 2005, and December 31, 2008, were identified in the Nationwide Inpatient Sample using the *International Classification of Diseases, Ninth Revision* procedure codes 36.10 to 36.19. Inclusion criteria included adults aged 18 years or older and isolated CABGs. Patients undergoing CABG concomitant with other major surgery

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Abbreviation and Acronym
CABG = coronary artery bypass grafting

were, therefore, excluded. Urgent or emergent procedures and reoperative CABGs were included in the study population.

Primary Outcome

The primary outcome of interest was inpatient cost of CABG. Charges for each individual patient undergoing CABG were supplied by the data set. Cost-to-charge ratios developed by the Agency for Healthcare Research and Quality, using Centers for Medicare and Medicaid Services data, were then used to derive costs from hospital charges. Unique ratios are calculated for each individual hospital. Hospital costs were used as the primary outcome as opposed to charges because the latter reflects pricing decisions related to payer policies and other factors unrelated to resource use.

Variation in Hospital-Specific Costs

Inpatient costs of CABG were aggregated at the hospital level. To measure interhospital variability in costs, a mixed-effect linear regression model was created using variables associated with cost of CABG in univariate linear regression analysis (exploratory $P < .20$). All variables tested for potential inclusion in the model were associated with CABG cost in univariate analysis ($P < .20$) and were, therefore, included in the final model. Patient-level variables included in the model were age, sex, primary payer status, and Charlson comorbidity index. The Charlson comorbidity index is a highly validated cumulative score based on patient comorbidities that is predictive of mortality, with higher scores representing higher comorbidity burdens. Operative variables in the model included elective versus urgent or emergent procedure, number of coronary vessels bypassed, use of cardiopulmonary bypass, use of the internal mammary artery, cardiac catheterization during the same admission, intra-aortic balloon pump, permanent pacemaker or implantable cardioverter-defibrillator, ventricular assist device as postcardiotomy support, extracorporeal membrane oxygenation, coronary angioplasty during same admission, non–drug-eluting or drug-eluting coronary stent during same admission, and redo CABG. Complications that were included in the multivariable model were as follows: respiratory failure, pneumonia, acute renal failure, sepsis, stroke, pulmonary embolism, gastrointestinal tract bleed, wound complication, hemorrhage, and cardiac shock or arrest. Hospital-related variables included hospital region, teaching status, urban versus rural location, and annual hospital CABG volume. Although the analysis was limited to isolated CABGs, annual volume was inclusive of all CABGs, including those performed concomitant to another procedure, because this would be expected to add to the "overall experience" of the center in performing CABG. Length of hospitalization, in-hospital mortality, and the year the operation was performed were also included in the model.

These 34 covariates comprised the fixed-effect parameters in the mixed-effect linear regression model. The random-effect parameters were the individual hospitals. The SD of the hospital effect was calculated in the model to determine if there was significant between-center variability in costs of CABG after adjusting for the fixed-effect parameters. All statistical analyses were performed using STATA, version 11, software (StataCorp LP, College Station, Tex).

RESULTS

Patient and Operative Characteristics

A total of 183,973 isolated CABG patients were included in the analysis. The mean age was 65.2 ± 10.8 years (Table 1). Most patients were males (73%), with a primary payer status of Medicare (52%) or private insurance (40%). Half of the patients had a Charlson comorbidity score of 2 or greater (47%). The most common comorbidities included myocardial infarction (39%), diabetes mellitus (31%), atrial fibrillation (25%), congestive heart failure (21%), and chronic obstructive pulmonary disease (21%). A total of 9% of the study population had chronic renal insufficiency.

Regarding operative characteristics, most CABGs were done on an urgent or emergent basis (55%) (Table 1). A total of 55% of patients had a cardiac catheterization during the same admission. Approximately half of the cases involved a 3- or more vessel bypass. The internal mammary artery was used as a conduit in 89%, with 73% being performed on cardiopulmonary bypass. A total of 9% of patients required an intra-aortic balloon pump. The use of a permanent pacemaker or implantable cardioverter-defibrillator (2%), ventricular assist device (0.1%), or extracorporeal membrane oxygenation (0.02%) was uncommon in the study population. Coronary angioplasty (3%) or non–drug-eluting (0.7%) or drug-eluting (0.9%) coronary stent placement during the same admission was also uncommon.

Hospital Characteristics

There were 633 hospitals included in the analysis. Most patients were treated at teaching hospitals (57%) in an urban setting (97%) (Table 1). Hospital region included South (44%), Midwest (25%), West (16%), and Northeast (15%). The mean annual overall CABG volume was 441 ± 340 per year.

Mortality and Morbidity

The overall unadjusted in-hospital mortality rate was 2.2% (n = 3967) (Table 2). As expected, this rate was lower in elective cases (1.5% vs 2.7%; $P < .001$). The mean length of hospitalization was 9.4 ± 7.2 days, with a median hospitalization of 7 days (interquartile range, 6-11 days). A major postoperative complication was observed in 36% (n = 65,538) of the study population. Individual complication rates were as follows: respiratory failure (17%; n = 31,081), pneumonia (5%; n = 9308), acute renal failure (9%; n = 17,136), sepsis (1%; n = 2351), stroke (2%; n = 3096), pulmonary embolism (0.4%; n = 683), gastrointestinal tract bleed (0.5%; n = 853), wound complication (2%; n = 3094), hemorrhage (5%; n = 9299), and cardiac shock or arrest (11%; n = 20,257).

Costs

The overall average inpatient cost of CABG was $37,924 ± $25,374 per patient (Figure 1, *A*). The average cost of a CABG at the hospital level was $40,424, with the SD of average CABG cost between hospitals being