Cost, quality, and value in coronary artery bypass grafting

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Objective: Pay-for-performance measures, part of the Affordable Care Act, aim to reduce health care costs by linking value with Medicare payments, but until now the concept of value has not been applied to specific procedures. We sought to define value in coronary artery bypass grafting (CABG) and provide a framework to identify high-value centers.

Methods: In a multiinstitutional statewide database, clinical patient-level data from 42,839 patients undergoing CABG were matched with cost data. Hierarchical models adjusting for relevant preoperative patient characteristics and comorbidities were used to estimate center-specific risk-adjusted costs and risk-adjusted postoperative length of stay. Variation in value across centers was assessed by the correlation between risk-adjusted measures of quality (mortality, morbidity/mortality) and resource use (costs and length of stay).

Results: There were no significant correlations between risk-adjusted costs and risk-adjusted mortality ($r = 0.20$, $P = .45$) or morbidity/mortality ($r = 0.15$, $P = .57$) across centers. Risk-adjusted costs and length of stay were not significantly associated ($r = 0.23$, $P = .37$) because of cost accounting differences across centers. This may explain the lack of correlation between risk-adjusted quality and risk-adjusted cost measures. When risk-adjusted length of stay and morbidity/mortality were used for the framework, there was a strong positive correlation ($r = 0.67$, $P = .003$), indicating that higher risk-adjusted quality is associated with shorter risk-adjusted length of stay.

Conclusions: Risk-adjusted length of stay and risk-adjusted combined morbidity/mortality are important outcome measures for assessing value in cardiac surgery. The proposed framework can be used to define value in CABG and identify high-value centers, thereby providing information for quality improvement and pay-for-performance initiatives. (J Thorac Cardiovasc Surg 2014;148:2729-35)

Supplemental material is available online.

The soaring costs of the US health care system are an increasing burden on society and threaten the financial stability of the government. Currently, health care expenditures represent 10% to 12% of the gross domestic product in many western European countries and Canada; this proportion is nearly 18% (almost US$3 trillion) in the United States.[1,2] There is wide consensus that we must contain health care expenditure while improving quality, and numerous approaches focusing on value have been proposed.[3,4] Pay-for-performance measures and value-based payment modifiers, to be implemented in 2015 as part of the Affordable Care Act, aim to reduce health care costs by linking quality and resource use performance measures with Medicare payments to physicians and hospitals. Physicians will be held accountable for resource utilization and costs for their hospitalized patients.

With more than 200,000 costly procedures performed in the United States annually, coronary artery bypass grafting (CABG) is an important procedure for improving health care value.[5] Value can be defined by a combination of clinical quality and resource use and should use risk-adjusted measures.[4,6] Although comparisons in efficiency exist[7] and quality assessment measures have been proposed,[8-10] the concept of value (combining risk-adjusted measures of resource use and quality) has not been applied to specific procedures like CABG.

We conducted a study to define value in CABG and to provide a framework to identify high-value centers. By adjusting for relevant preoperative patient characteristics and comorbidities, we derived measures of risk-adjusted

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Disclosures: A. Speir has served as consultant/advisory board member for Medtronic, Inc; C.E. Fonner is a former employee of the database manager, ARMUS Corporation; G. Ailawadi has served as consultant/advisory board member for Edwards Lifesciences, Mitralign, Abbott, and has received speaker's honoraria from Atricure. J. Rich has received an education grant from Medtronic. All other authors have nothing to disclose with regard to commercial support.

Received for publication March 12, 2014; revisions received July 2, 2014; accepted for publication July 13, 2014; available ahead of print Sept 16, 2014.

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0022-5223/$36.00

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http://dx.doi.org/10.1016/j.jtcvs.2014.07.089

Abbreviations and Acronyms

CABG = coronary artery bypass grafting
CMS = Centers for Medicare and Medicaid Services
STS = Society of Thoracic Surgeons
STS-PROM = Society of Thoracic Surgeons-predicted risk of mortality
STS-PROMM = Society of Thoracic Surgeons-predicted risk of morbidity or mortality
UB = Uniform billing
VCSQI = Virginia Cardiac Surgery Quality Initiative

resource use and risk-adjusted quality after CABG. Subsequently, we tested whether higher risk-adjusted quality was correlated with shorter risk-adjusted length of stay and lower risk-adjusted costs.

METHODS

The Virginia Cardiac Surgery Quality Initiative (VCSQI) database was used for this analysis. Clinical records of patients undergoing cardiac surgery were collected prospectively and all primary isolated CABGs between January 2003 and April 2013 were selected for the current study.

VCSQI is a voluntary group of 17 cooperating cardiac surgery centers in the Commonwealth of Virginia.[11] The aim of the consortium is to improve the quality of cardiac surgical care, while reducing costs. The database covers ~100% of all cardiac surgical procedures in the state. VCSQI members contribute their data to the Society of Thoracic Surgeons (STS) Adult Cardiac Database. Each of VCSQI's centers agreed to share deidentified patient data for secondary research and quality improvement. Institutional review boards at each participating center exempted this study because it represents a secondary analysis of the VCSQI data registry in the absence of Health Insurance Portability and Accountability Act patient identifiers. Business Associates Agreements are in place between VCSQI, its 17 members, and the database vendor (ARMUS Corporation, San Mateo, Calif).

Clinical Data

Postoperative outcomes were routinely collected in the STS database and included death, stroke, renal failure, atrial fibrillation, deep sternal wound infection, permanent stroke, prolonged ventilation, and reoperations for bleeding, graft occlusion, and other reasons, all defined according to the STS database definitions.[12] Operative death was defined as death within 30 days after discharge or within the hospital stay. Preoperative risk was assessed using the STS-predicted risk of mortality (STS-PROM) and the STS-predicted risk of morbidity or mortality (STS-PROMM). Each center was responsible for coding and submitting its data to VCSQI and agreed on the definitions, data collection, and timely submission.

Cost Data

Patient-level clinical and financial data in the VCSQI database were combined as previously described.[13,14] Briefly, STS patient records were matched with uniform billing (UB) discharge records. The UB-04 form is used throughout the United States and represents the patient's final hospital bill. Charges for all of the ICD-9 (International Classification of Diseases, ninth revision) revenue codes were grouped into 20 logical cost categories (Table E1). Because charges reflect institutional pricing decisions and other factors unrelated to resource use, we applied cost-to-charge ratios.[15] These ratios were updated annually and were specific for each participating institution and category within that institution. The total costs estimate was the sum of all 20 categories. The variation in total costs and postoperative length of stay as a result of postoperative complications was reflected in the total estimate for the individual patient.[14] The medical care service component of the US consumer price index was used to convert all costs to US dollars for the year 2013.[13,16]

Statistical Analysis

We calculated risk-adjusted costs and postoperative length of stay for each of the 17 centers by adjusting for differences in the patient case mix. Risk-adjusted estimates were derived from hierarchical models, which account for clustering of outcomes within hospitals, provide more stable estimates for hospitals with low volumes, and adjust for multiplicity of comparisons. This approach to risk standardization has been gaining increasing traction in recent years and has been adopted by Centers for Medicare and Medicaid Services (CMS).[17] We modeled cost and postoperative length of stay as dependent variables, applying hierarchical generalized linear models, with a gamma distribution for costs and a negative binomial distribution for length of stay.[18] These models included a random effect for hospital and adjustment for preoperative patient characteristics and comorbidities (Table E2). Given the iterative modeling and large number of variables included, only variables that were significant at a level of $P \leq .01$ were preserved in the models.[19] The variables age, gender, and race were forced into the models. The models were recently validated for prediction of postoperative length of stay and costs.[19] Regressions were estimated in log and linear form, and reported in linear form, because there were no substantial differences in the results and linear regression coefficients are more easily interpreted.

Hospital mean risk-adjusted costs were derived by calculating the ratio of average model-predicted costs for a given hospital to the expected costs based only on patient characteristics, and then multiplying this ratio by the average cost of the overall population. Hospital mean risk-adjusted lengths of stay were calculated in a similar way.[20-22] Risk-adjusted measures of mortality and morbidity/mortality were also calculated per center, based on validated STS risk calculators.

Morbidity/mortality was defined as postoperative deep sternal wound infection, reoperation, permanent stroke, prolonged ventilation, renal failure or operative mortality.[8,9,12] Correlation between risk-adjusted quality and resource use measures were assessed with the Spearman correlation coefficient. Analyses were performed using Excel 2010 (Microsoft, Redmond, Wash) and SPSS version 20.0.0 (SPSS, Chicago, Ill), and the hierarchical models were fitted using the GLIMMIX macro in SAS 9.3 (SAS Institute, Inc, Cary, NC).

RESULTS

The patient characteristics and comorbidities of the 42,839 patients who underwent CABG are presented in Table 1. The STS-PROM averaged 2.2% and the STS-PROMM was 13.8%. Postoperative clinical outcomes and resource use are presented in Table 2. Atrial fibrillation was the most common postoperative complication (17.2%), followed by prolonged ventilation (9.3%) and renal failure (3.5%). Mean total length of stay was 9.3 days, most of which consisted of postoperative stay (6.9 days). The mean total costs for CABG were US$38,848.

There was significant variation in risk-adjusted costs (US$27,380-55,296), risk-adjusted postoperative length of stay (6.26-8.77 days), risk-adjusted mortality (0.95%-2.13%), and risk-adjusted morbidity/mortality

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