

Cost of individual complications following coronary artery bypass grafting

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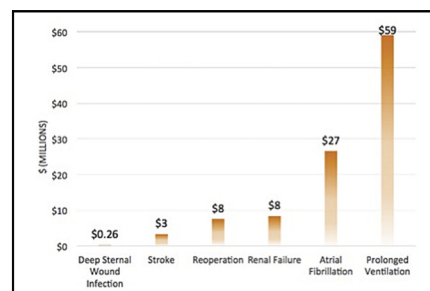
ABSTRACT

Objective: The financial implications of postoperative complications in cardiac surgery remain poorly understood. The purpose of this study was to define the cost of surgery without complications and demonstrate the incremental cost of each complication.

Methods: All patients undergoing isolated coronary artery bypass grafting (CABG) were evaluated (2006-2015) from a statewide Society of Thoracic Surgeons database collaborative (N = 36,588). Patients were stratified by presence of postoperative complications, including major morbidities as defined by the Society of Thoracic Surgeons (ie, prolonged ventilation, renal failure, reoperation, stroke, and deep sternal wound infection). Hierarchical modeling was used to identify the independent inflation-adjusted cost of each complication while controlling for hospital variation and time.

Results: The median age was 64 years, 74.3% were men, and average predicted risk of mortality was 1.9%. A total of 24,738 (67.7%) patients experienced no complications at an average cost of \$36,580. Each complication independently increases the cost of care and resulted in an exponential increase in cost. After accounting for incidence and incremental costs, institutions in our collaborative have spent an estimated \$59.1 million on prolonged ventilation, \$8.3 million on renal failure, \$7.6 million on reoperation, \$3.3 million on stroke, and \$256,000 on deep sternal wound infections over the past 10 years.

Conclusions: The average cost of CABG without complication was \$36,580. Each additional major complication resulted in an exponential increase in cost. Over the past 10 years, the total cost of complications after isolated CABG was \$78.6 million, emphasizing the importance of quality improvement projects to contain costs. (J Thorac Cardiovasc Surg 2017; ■:1-8)



Complication-related expenditures over 10 years in the Virginia Cardiac Services Quality Initiative.

Central Message

Coronary artery bypass grafting without complications costs \$36,580 on average. Each additional major morbidity results in exponential cost increases with a 10-year total cost of \$78.6 million.

Perspective

Given the fiscal challenges expected with the bundled payment program for coronary artery bypass grafting, it is critical to understand the financial implications of postoperative complications in cardiac surgery. Understanding the costs of adverse events will help guide quality improvement projects, adapt to alternative payment models, and ultimately contain cost increases.

See Editorial Commentary page XXX.

Given the growing emphasis on value-driven health care, research should evaluate both sides of this equation; that is, health care-related cost and clinical outcomes. Therefore, it is critical to understand the financial implications of postoperative complications after cardiac

surgery. Complications are the major driver of cost variability and are a key target for cost reduction.¹ Furthermore, it is critical to understand the cost of adverse events to estimate true costs and guide quality improvement projects. Knowing this information also allows for critical

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Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
CMS	= Centers for Medicare and Medicaid Services
IPPS	= Inpatient Prospective Payment System
LOS	= length of stay
STS	= Society of Thoracic Surgeons
VCSQI	= Virginia Cardiac Services Quality Initiative



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review of projects with accurate cost-effectiveness analyses.^{2,3} As we transition away from a fee-for-service model to a quality-based system, understanding these costs will be critical in building risk-adjusted payment models.⁴

Cardiac surgery has a unique set of complications that are major drivers in the cost of surgery.⁵ Brown and colleagues⁶ found the mean cost of coronary artery bypass grafting (CABG) amongst Medicare beneficiaries to be \$32,201 ± \$23,059 in 2008. In this same study, 13.64% of the study population experienced a postoperative complication resulting in increased costs and length of stay (LOS) of \$15,468 and 5.3 days, respectively. These costs continue to increase and are outpacing estimates of medical inflation by the Centers for Medicare and Medicaid Services (CMS) Inpatient Prospective Payment System (IPPS). Another study by Speir and colleagues⁵ specifically demonstrated isolated postoperative atrial fibrillation to increase the cost of CABG on average \$2574, whereas prolonged ventilation, renal failure, and deep sternal wound infection had the greatest increases in total cost. Other studies have shown isolated postoperative atrial fibrillation to be associated with an additional \$7000 to \$14,000 cost increase.⁷⁻¹⁰ The large cost of complications and variation in estimates has resulted in poorly defined costs that are unable to be accurately predicted with current cost models.¹¹⁻¹⁴

The purpose of this study is to analyze data from a statewide collaborative to define the cost of surgery without complications and demonstrate the incremental cost of each complication. These data may be used to identify and prioritize quality improvement initiatives that will improve patient care while providing cost-effective interventions.

MATERIALS AND METHODS**Patient Data**

The Virginia Cardiac Services Quality Initiative (VCSQI) is composed of 18 hospitals and cardiac surgical practices in Virginia capturing 99% of adult cardiac surgery cases in the state. Data are collected using the Society of Thoracic Surgeons (STS) clinical data entry form to capture administrative, demographic, baseline clinical, operative, and 30-day outcome data. VCSQI clinical and cost data acquisition and matching has been described previously.^{15,16} Charges are captured by the International Classification of Diseases, ninth revision, based revenue codes and Uniform Billing-04/92 files are matched to the STS data, with a successful matching rate of 99%. These final hospital charges are then converted to estimate costs using cost-to-charge ratios submitted to CMS by each institution. Inflation estimates of the CMS IPPS were used to adjust cost to 2015 dollars to account for medical-specific inflation.

All patients undergoing isolated CABG (N = 36,588) in the VCSQI database from January 2006 through December 2015 were evaluated. Patients were excluded for missing cost data. STS definitions were used, including postoperative atrial fibrillation and major morbidity (renal failure, reoperation, stroke, deep sternal wound infection, and prolonged ventilation).¹⁷ The data were de-identified with removal of all Health Insurance Portability and Accountability Act patient identifiers. The study was granted exemption by the University of Virginia Institutional Review Board.

Statistical Analysis

Distributions of continuous variables were not normal so they were presented as median and interquartile range except cost, which was presented as mean ± standard deviation to more fully account for costs incurred. Categorical data were summarized as number and corresponding proportion. Nonparametric tests were used to compare categorical and continuous data for each of the preoperative variables stratified by incidence of an STS major morbidity. Additionally, mean costs were calculated with an incremental additive cost from surgery without complications. To ascertain the cost of each individual complication, hierarchical multivariate linear regression was used to estimate the contribution of each event to the total hospital cost. This was also performed for total hospital LOS and intensive care unit LOS. Each in-hospital postoperative event occurring with a frequency of at least 5% was included in the model as well as all STS major morbidities. Models included all complications of interest, and were adjusted for surgery without complications, hospital and year. Variation of inflation factors was used to assess collinearity of variables within the model. All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc, Cary, NC). Statistical significance was set at $\alpha < 0.05$. Incremental cost of major morbidities and change in cost over time were modeled in Prism 7 (GraphPad Software Inc, La Jolla, Calif) with calculation of goodness of fit.

RESULTS**Baseline Characteristics and Outcomes**

Over the past decade, 36,588 patients underwent isolated CABG at the 18 centers in the Commonwealth of Virginia. The average age was 64 years, 74.3% were men, and mean STS predicted risk of mortality was 1.9% at 30 days. Patients experiencing STS major morbidities postoperatively were older, with significantly higher rates of medical comorbidities and underwent longer operations (Table 1). Additionally, over the past 10 years patients undergoing isolated CABG have had increasing risk profiles for both STS Predicted Risk of Mortality (slope [m] = 0.103; $P = .003$) and STS Predicted Risk of Morbidity and Mortality (slope [m] = 0.330; $P < .0001$) as demonstrated in Figure E1. Despite this

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