The challenge of achieving 1% operative mortality for coronary artery bypass grafting: A multi-institution Society of Thoracic Surgeons Database analysis

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Objectives: Cardiothoracic surgical leadership recently challenged the surgical community to achieve an operative mortality rate of 1.0% for the performance of isolated coronary artery bypass grafting (CABG). The possibility of achieving this goal remains unknown due to the increasing number of high-risk patients being referred for CABG. The purpose of our study was to identify a patient population in which this operative mortality goal is achievable relative to the estimated operative risk.

Methods: Patient records from a multi-institution (17 centers) Society of Thoracic Surgeons (STS) database for primary, isolated CABG operations (2001-2012) were analyzed. Multiple logistic regression modeling with spline functions for calculated STS predicted risk of mortality (PROM) was used to rigorously assess the relationship between estimated patient risk and operative mortality, adjusted for operative year and surgeon volume.

Results: A total of 34,416 patients (average patient age, 63.9 ± 10.7 years; 27% [n = 9190] women) incurred an operative mortality rate of 1.87%. Median STS predicted risk of mortality was 1.06% (interquartile range, 0.60%-2.13%) and median surgeon CABG volume was 544 (interquartile range, 303-930) operations over the study period. After risk adjustment for the confounding influence of surgeon volume and operative year, the association between STS PROM and operative mortality was highly significant ($P < .0001$). More importantly, the adjusted spline function revealed that an STS PROM threshold value of 1.27% correlated with a 1.0% probability of death, accounting for 57.3% (n = 19,720) of the total study population. Further, the STS PROM demonstrated a limited predictive capacity for operative mortality for STS PROM > 25% as observed to expected mortality began to diverge.

Conclusions: Achieving the goal of 1.0% operative mortality for primary, isolated CABG is feasible in appropriately selected patients in the modern surgical era. However, this goal may be achieved in only 60% of CABG patients without other improvements in processes of care. Calculated STS PROM can be used to strongly identify patients with estimated mortality risk <1.27% to achieve this goal, but it appears limited in its predictive capacity for those patients with estimated risk >25.0%. These data provide a foundation for further study to determine if 1.0% mortality for CABG is achievable nationwide. (J Thorac Cardiovasc Surg 2014;148:2686-96)

Surgical myocardial revascularization with coronary artery bypass grafting (CABG) remains 1 of the most common operations performed in the United States.[1] Over the past few decades, the use of CABG for first-line treatment of coronary artery disease has declined as percutaneous coronary intervention (PCI) technology has advanced.[2] Reduced mortality rates following performance of PCI over CABG as demonstrated in the SYNTAX trial and other series has become central to the argument by many proponents for PCI for coronary disease amenable to both percutaneous and surgical revascularization despite improved long-term outcomes favoring CABG.[3] Current estimates of mortality following PCI have been reported at 1%, whereas those for the performance of isolated CABG are approximately 2%.[1,3] As a result, the surgical community was recently challenged by leadership in the field of cardiothoracic surgery to achieve a 1% mortality rate or less for the performance of isolated CABG operations within the next 3 to 5 years.[4] Although ambitious, achieving this goal would not only significantly influence the debate regarding choice for PCI versus CABG but would also provide for higher-quality care for hundreds of thousands of US patients annually.

> **Abbreviations and Acronyms**
> CABG = coronary artery bypass grafting
> PCI = percutaneous coronary intervention
> PROM = predictive risk of mortality
> RCS = restricted cubic spline
> STS = Society of Thoracic Surgeons
> VCSQI = Virginia Cardiac Surgery Quality
> Initiative

The Society for Thoracic Surgeons (STS) maintains a nationwide database of adult cardiac surgeries performed in the United States. Representing the largest clinical database of its kind, the STS National Cardiac Database provides clinicians and researchers the ability to assess risk-adjusted outcomes for several different cardiac operations, including isolated CABG. Furthermore, the STS has developed various risk models for cardiac operations that allow for the prediction of an expected outcome for a patient based on a given set of risk factors.[5,6] Perhaps the most commonly used STS risk model is that which estimates the predicted risk of mortality (PROM) for individual patients. Adjusting for the prevalence of 30 different demographic, clinical, and operative present-on-admission factors, the STS PROM can be calculated for an individual patient to determine that patient's expected mortality risk.[7] The use of the STS PROM has been validated and widely accepted by the US cardiothoracic surgery community as a reliable preoperative metric to evaluate patient risk.[5,8,9] Thus, STS PROM scores should be able to identify patients with expected mortality rates ≤1%.

The Virginia Cardiac Surgery Quality Initiative (VCSQI) is a voluntary group of 17 different cardiac surgery centers, both academic and private, within the Commonwealth of Virginia. This group holds quarterly meetings to exchange and compare de-identified patient information in an effort to improve cardiac surgical care, quality, and costs. The primary objective of the organization is to identify quality improvement opportunities in cases where high cost, resource intensive, or frequently occurring preventable outcomes might occur. Collectively, the VCSQI centers perform approximately 99% of the cardiac surgeries performed in the Commonwealth, and each center individually contributes patient data to the STS National Cardiac Database.

The purpose of our study was to determine if the challenge to achieve a ≤1% operative mortality rate for primary, isolated CABG operations is feasible in the modern surgical area, to identify in which patient populations this mortality goal is achievable relative to estimated operative risk, and to identify patient- and operation-related risk factors that contribute most to mortality among patients where goal mortality was deemed not achievable to discern if certain patients should not be receiving surgical myocardial revascularization.

METHODS

This investigation was exempt from formal institutional review board review at each participating center because it represents a secondary analysis of the VCSQI data registry with the absence of Health Insurance Portability and Accountability Act patient identifiers and because the data is collected for quality analysis and purposes other than research.

Patients and Data Acquisition

De-identified patient-level data were obtained from the VCSQI database for the study period January 1, 2001, through June 30, 2012. All records included patients undergoing primary, isolated CABG operations (STS procedure type "CAB Only" and incidence type "First Cardiovascular Surgery"). All CABG procedures represent standard surgical approaches to surgical myocardial revascularization with and without the use of cardiopulmonary bypass support. Patient preoperative risk was assessed by prevalence of patient comorbid disease, extent of coronary artery disease, operative status, and individually calculated STS PROM score.

Measured Outcomes

The primary outcomes of interest was the risk-adjusted association between the probability of death (operative mortality) and STS PROM score to identify in which patients a predicted probability of death <1% could be achieved. Secondary outcomes included estimated risk-adjusted associations between CABG mortality and established patient risk factors used to calculate the STS PROM score as well as several process of care measures endorsed by the STS and National Quality Forum. Operative mortality was defined as all patient deaths occurring during hospitalization as well those within 30 days of the date of surgery despite discharge status. Standard STS clinical definitions for all analyzed variables were used.[10]

Statistical Analysis

Descriptive statistics. All statistical analyses were designed to test the null hypothesis that operative mortality following primary, isolated CABG would not be significantly associated with calculated STS PROM score. Study outcomes and data comparisons were established a priori before data collection. Categorical variables are expressed as standard group percentages, whereas continuous variables are expressed as either mean ± standard deviation or median (25th, 75th percentile) depending on overall variable distribution. Descriptive, univariate statistics included either Pearson χ^2 or Fisher exact test for categorical variables and either independent sample single factor analysis of variance for comparisons of normally distributed data or the Wilcoxon rank sum test for nonnormally distributed data comparisons. Calculated test statistics were used to derive all 2-tailed P values with standard statistical significance set to $\alpha < 0.05$.

Estimated mortality risk and surgeon volume measurement. STS PROM was analyzed as a continuous function, using restricted cubic spline (RCS) smoothing transformations to account for both linear and nonlinear associations with operative mortality. RCS functions are beneficial because they use all data points to estimate the shape of the relationship between an exposure (STS PROM) and an outcome (operative mortality). The use of RCS transformations, therefore, provides a more robust method to determine if nonlinear relationships exist between a continuous variable and a dependent outcome. Use of RCS forces the tails of a function to be linear, which simplifies the representation. In these analyses, an RCS function was developed for both STS PROM and individual surgeon volume using a total of three knots placed at the 5th, 50th, and 95th percentiles of the distribution of both STS PROM and surgeon volume to define the tails of each function.

Hierarchical regression models. Hierarchical multiple regression models were used to estimate confounder-adjusted associations between calculated STS PROM score and the probability of operative mortality for patients undergoing primary, isolated CABG operations. In