Society of Thoracic Surgeons Risk Score predicts hospital charges and resource use after aortic valve replacement

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Objective: The impact of Society of Thoracic Surgeons predicted mortality risk score on resource use has not been previously studied. We hypothesize that increasing Society of Thoracic Surgeons risk scores in patients undergoing aortic valve replacement are associated with greater hospital charges.

Methods: Clinical and financial data for patients undergoing aortic valve replacement at The Johns Hopkins Hospital over a 10-year period (January 2000 to December 2009) were reviewed. The current Society of Thoracic Surgeons formula (v2.61) for in-hospital mortality was used for all patients. After stratification into risk quartiles, index admission hospital charges were compared across risk strata with rank-sum and Kruskal–Wallis tests. Linear regression and Spearman's coefficient assessed correlation and goodness of fit. Multivariable analysis assessed relative contributions of individual variables on overall charges.

Results: A total of 553 patients underwent aortic valve replacement during the study period. Average predicted mortality was 2.9% (±3.4) and actual mortality was 3.4% for aortic valve replacement. Median charges were greater in the upper quartile of patients undergoing aortic valve replacement (quartiles 1–3, $39,949 [interquartile range, 32,708–51,323] vs quartile 4, $62,301 [interquartile range, 45,952–97,103], $P < .01$]. On univariate linear regression, there was a positive correlation between Society of Thoracic Surgeons risk score and log-transformed charges (coefficient, 0.06; 95% confidence interval, 0.05–0.07; $P < .01$). Spearman's correlation R-value was 0.51. This positive correlation persisted in risk-adjusted multivariable linear regression. Each 1% increase in Society of Thoracic Surgeons risk score was associated with an added $3000 in hospital charges.

Conclusions: This is the first study to show that increasing Society of Thoracic Surgeons risk score predicts greater charges after aortic valve replacement. As competing therapies, such as percutaneous valve replacement, emerge to treat high-risk patients, these results serve as a benchmark to compare resource use. (J Thorac Cardiovasc Surg 2011;142:650-5)

The grim natural course of untreated symptomatic severe aortic stenosis (AS) was first shown by Ross and Braunwald in 1968[1] and reaffirmed by the medically managed cohort of patients in the recent publication of the PARTNER trial.[2] In the PARTNER study, patients receiving optimal medical treatment experienced 50% 1-year mortality.[2] In light of these sobering statistics, the effectiveness of aortic valve replacement (AVR) for severe AS cannot be overstated. Patients across all age ranges not only derive a dramatic survival advantage but also enjoy greater quality of life, whether undergoing standard sternotomy or a less invasive partial sternotomy approach.[3-6]

In 2002, the first successful percutaneous AVR was performed, avoiding the need for median sternotomy.[7] Retrospective results with this transcatheter aortic-valve implantation (TAVI) approach have subsequently been widely reported.[8-12] The first randomized, prospective trial in the United States was recently published, which revealed a significant survival advantage for TAVI over best medical management in inoperable patients with severe AS.[2] As this new technology gains widespread application, it will be incumbent on the cardiovascular community to give consideration to cost-effectiveness with regard to this new therapy. The Society of Thoracic Surgeons (STS) risk prediction models enable clinicians to compare groups of patients on the basis of similar preoperative risk profiles.[13] In the PARTNER study, STS risk scores were used to define the eligible patient population. To serve as a benchmark for cost-effectiveness comparisons, the hypothesis that increasing STS risk scores in patients undergoing AVR are associated with greater hospital charges and resource consumption was tested.

MATERIALS AND METHODS

Patient Data

This was a retrospective review of the cardiac surgery database, which is managed by a dedicated data center team within the Division of Cardiac

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Dr Arnaoutakis is the Irene Piccinini Investigator in Cardiac Surgery and Dr George is the Hugh R. Sharp Cardiac Surgery Research Fellow.

Disclosures: Authors have nothing to disclose with regard to commercial support.

Received for publication Dec 4, 2010; revisions received Feb 3, 2011; accepted for publication Feb 22, 2011; available ahead of print April 19, 2011.

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0022-5223/$36.00

doi:10.1016/j.jtcvs.2011.02.038

Abbreviations and Acronyms

AS = aortic stenosis
AVR = aortic valve replacement
CI = confidence interval
CVA = cerebrovascular accident
HSCRC = Health Services Cost Review Commission
IQR = interquartile range
RRT = renal replacement therapy
STS = Society of Thoracic Surgeons
TAVI = transcatheter aortic-valve implantation

Surgery at The Johns Hopkins Hospital. All patients undergoing AVR with a tissue or mechanical prosthesis at The Johns Hopkins Hospital from January 2000 to December 2009 were included. Patients with prior sternotomy were included. Those patients who underwent other concomitant cardiac surgical procedures (coronary artery bypass, ascending aortic aneurysm repair, atrial septal defect repair, radiofrequency ablation) and pediatric patients (<18 years) were excluded. There were 553 patients with isolated AVR who comprised the cohort for this analysis.

All charts of these patients were available for review, and after institutional review board approval all relevant clinical information was extracted from the institutional cardiac surgery database and the electronic medical record as necessary. Demographic and clinical variables included age, gender, race, cardiovascular comorbidities, smoking history, and ejection fraction. STS risk score for operative mortality was calculated according to version 6.21, which was introduced in 2008. For patients before 2008, all necessary data were used to extrapolate a risk score according to version 6.21.

Outcomes

Postoperative data included operative mortality, length of stay, in-hospital drug-treated infections, postoperative cerebrovascular accidents (CVAs), renal replacement therapy (RRT), and deep sternal infections. These complications were reviewed from both data submitted to the STS database and independent review of the electronic medical record. Survival status was supplemented using the Social Security Death Index.

Charges Data

Hospital charges are obtained through the hospital billing department as reported to the Maryland State authorities and represent total hospital charges for the index admission only. These charges include those incurred during the operation and for all aspects of postoperative care. The state of Maryland Health Services Cost Review Commission (HSCRC) is the only system of its kind in the United States, and this commission minimizes cost-shifting by establishing payment rates for all insurers within the state of Maryland.

Charges data are divided into the following categories: routine charges, operating room facility use, operating room supply use, pharmacy charges, laboratory charges, radiology charges, physical therapy charges, and other charges. For any patient hospitalized before AVR, index admission charges begin with the date of the operation. All financial information was inflation-adjusted according to the US Department of Labor Consumer Price Index in US dollars for the year 2009.

Statistical Analysis

Patients were stratified into quartiles according to STS risk scores. Differences between patients in STS Q1–3 and STS Q4 were compared using the 2-tailed Student *t* test for normally distributed continuous variables. Chi-square analysis was used for categoric variables. For nonparametric continuous data, Wilcoxon rank-sum test was used. To confirm nonparametric distributions, the data were visually inspected in graphic form and checked for skewness. The Wilcoxon rank-sum test compared index admission charges data between Q1–3 and Q4. To determine differences among the 4 individual quartiles, the Kruskal–Wallis nonparametric analysis of variance was used. Post hoc multiple pairwise testing analyzed individual differences among the 4 quartiles, with Bonferroni-adjusted *P* values.

To test for an STS risk score that would predict increased charges, receiver operating characteristic curves were used. The outcome measure for high charges was defined as the upper 5% of median index admission charges. An area under the curve greater than 0.7 was deemed significant.

A histogram of absolute charges revealed a non-normal distribution. After logarithmic transformation of charges data, visual inspection revealed a more normal distribution. To further confirm that no assumptions of linear regression had been violated, residual values of the regression model were plotted against fitted values and demonstrated equal variance across the spectrum of STS risk scores. Univariate linear regression assessed the correlation between continuous STS risk score and log index hospitalization charges. A separate univariate linear regression was performed with STS risk score greater than or less than 10% as a binary independent variable. Multivariable linear regression determined the relative contributions of individual variables toward index admission charges. In addition to variables associated with charges on exploratory univariate analysis ($P < .1$), those with biological plausibility were incorporated in a forward and backward stepwise fashion into the multivariable linear regression model. The likelihood ratio test and Akaike's information criterion in a nested model approach were used to identify which covariates increased the explanatory power of the model. The final model incorporated the following covariates: STS risk score, age, ejection fraction, preoperative CVA, chronic kidney dysfunction, chronic obstructive pulmonary disease, diabetes mellitus, postoperative major complication (composite of CVA, RRT, or pneumonia), and operative mortality.

Continuous variables are presented with the mean ± standard deviation. Categoric variables are shown in whole numbers and percentages. All actual charges data are presented in median and interquartile range (IQR). Regression coefficients are presented with 95% confidence intervals (CIs). Actual *P* values are reported except when less than .001. Analysis was performed using Stata statistical software, version 9.2 (StataCorp, College Station, Tex).

RESULTS

Cohort Statistics

From January 2000 to December 2009, 553 patients underwent isolated AVR at our institution and comprise the cohort for this analysis. The mean age was 67.0 ±14.1 years, and 40% were female (n = 222). The race distribution of the cohort was Caucasian (81%; n = 447), African American (14%; n = 76), Hispanic (0.5%; n = 2), and other (4.5%; n = 26). Forty-three patients (8%) reported a history of smoking. Throughout the study period, the number of yearly adult isolated AVR procedures remained relatively constant, ranging from 42 to 86 procedures annually.

Society of Thoracic Surgeons Risk Score Results

Mean STS risk score for the entire isolated AVR cohort was 2.95 (±3.4). Isolated AVR patients were grouped into the following STS quartiles: Q1, 0.37 to 1.02, n = 139; Q2, 1.03 to 1.90, n = 138; Q3, 1.91 to 3.44, n = 138; Q4,

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