Does the Society of Thoracic Surgeons risk score accurately predict operative mortality for patients with pulmonary hypertension?

Jamie L. W. Kennedy, MD,[a] Damien J. LaPar, MD, MSc,[b] John A. Kern, MD,[b] Irving L. Kron, MD,[b] James D. Bergin, MD,[a] Sandeep Kamath, MD,[a] and Gorav Ailawadi, MD[b]

Objective: This study assessed the impact of pulmonary hypertension (PH) on morbidity and mortality after the most common cardiac operations and evaluated the accuracy of the Society of Thoracic Surgeons (STS) risk model for patients with PH.

Methods: At a single center between 1994 and 2010, all adult cardiac operations performed with recorded preoperative mean pulmonary arterial pressure (MPAP) and STS predicted mortality were reviewed. MPAP was defined as normal (<25 mm Hg) or as mild (25-34 mm Hg), moderate (35-44 mm Hg), or severe (≥45 mm Hg) PH. Multivariate analysis was performed to elucidate the contribution of PH to morbidity and mortality.

Results: In all, 3343 patient records were reviewed. Coronary artery bypass grafting (CABG) was the most common procedure (67.5%), followed by aortic valve replacement (24.9%) and mitral valve procedures (6.3%). Postoperative complications and mortality increased with increasing MPAP. Multivariable analysis found that both moderate (odds ratio, 7.17; $P < .001$) and severe (odds ratio, 13.73; $P < .001$) PH were significantly associated with increased mortality, even after accounting for STS risk. A subset analysis of isolated CABG cases revealed markedly increased mortality for all categories of PH (mild odds ratio, 1.99; moderate odds ratio, 11.5; severe odds ratio, 38.9; $P < .001$).

Conclusions: Morbidity and mortality were independently associated with PH. Observed mortality was significantly higher than predicted by the STS model for patients with moderate and severe PH, particularly in isolated CABG. Addition of PH to the STS risk model should be considered, or alternative tools should be used to assess risk in these patients. (J Thorac Cardiovasc Surg 2013;146:631-7)

Pulmonary hypertension (PH) is defined as the presence of elevated pulmonary arterial pressure, specifically mean pulmonary arterial pressure (MPAP) greater than 25 mm Hg.[1] In patients with acquired cardiac disease, PH is most often due to elevated left atrial pressure.[2] Long-standing high left atrial pressure can lead to pulmonary vascular remodeling, as evidenced by elevated pulmonary vascular resistance (PVR) or transpulmonary gradient.[2] The most effective therapy for PH related to left-sided heart disease is correction of the underlying cardiac pathology, such as aortic valve replacement (AVR) for aortic stenosis; however, PH has long been recognized as a risk factor for morbidity and mortality for patients undergoing cardiac surgery. A host of perioperative factors, such as protamine, hypoxia, hypercapnia, positive pressure ventilation, and systemic inflammatory response to cardiopulmonary bypass and blood products can exacerbate underlying PH and result in right ventricular failure, with additional morbidity and mortality.[3]

The Society of Thoracic Surgeons (STS) risk model evolved to guide surgeons and cardiologists by estimating risk of operative mortality on the basis of multiple risk factors, including patient demographic characteristics, comorbidities, procedure, and clinical status. Importantly, pulmonary arterial pressure is not one of these preoperative variables, because it is infrequently measured and is dependent on the ''clinical state and volume-loading status of the patient when the measurement is obtained.''[4] By comparison, the EuroSCORE risk model does include PH, defined as pulmonary arterial systolic pressure (PASP) greater than 60 mm Hg.[5] Moreover, the recently released EuroSCORE II model further stratifies PH into moderate (PASP 31-55 mm Hg) and severe (PASP >55 mm Hg).[6] Although the use of PASP is attractive because it can be estimated noninvasively by echocardiography, there can be significant differences between

From the Divisions of Cardiology[a] and Thoracic and Cardiovascular Surgery,[b] University of Virginia Health System, Charlottesville, Va.

Disclosures: Authors have nothing to disclose with regard to commercial support.
Received for publication May 2, 2012; revisions received June 24, 2012; accepted for publication July 26, 2012; available ahead of print Sept 17, 2012.

Address for reprints: Gorav Ailawadi, MD, Division of Thoracic and Cardiovascular Surgery, University of Virginia Health System, PO Box 800679, Charlottesville, VA 22908 (E-mail: gorav@virginia.edu).

0022-5223/$36.00

http://dx.doi.org/10.1016/j.jtcvs.2012.07.055

Abbreviations and Acronyms

AVR = aortic valve replacement
CABG = coronary artery bypass grafting
CI = confidence interval
MPAP = mean pulmonary arterial pressure
OR = odds ratio
PASP = pulmonary arterial systolic pressure
PH = pulmonary hypertension
PROM = predicted risk of mortality
PVR = pulmonary vascular resistance
STS = Society of Thoracic Surgeons

noninvasive estimates and the criterion standard of invasive measurement.[7]

This study sought to assess the impact of PH in cardiac surgery. We hypothesized that PH is associated with greater morbidity and mortality for patients undergoing cardiac operations and that the STS risk model is not valid for patients with significant PH. We included a subset analysis of patients undergoing isolated coronary artery bypass grafting (CABG), because the literature on PH in this most common cardiac operation is limited. We hypothesized that PH would be an independent risk factor for mortality for patients undergoing CABG as well.

MATERIALS AND METHODS

Patients

The University of Virginia institutional review board approved this study, including a waiver for individual patient consent.

A total of 11,983 adult cardiac operations were performed at the University of Virginia during the study period of January 1, 1994, to December 3, 2010, and were evaluated for inclusion in this study. Patient records from our institutional STS Adult Cardiac Surgery Database were queried. A total of 5241 case records reported MPAP, and 5241 cases had a calculated STS predicted risk of mortality (PROM). A total of 3343 cases included both MPAP and PROM, and these comprise the study population. All included procedures represent standard surgical approaches, and standard STS variable definitions were used. Patient preoperative risk was assessed by the calculated STS PROM for each patient at the time of the operation. MPAP was the first recorded value after placement of the pulmonary artery catheter before incision.

Outcomes

The primary outcomes of interest included differences between observed and expected mortalities for patients with varying severity of PH, as well as risk-adjusted associations between mortality and morbidity and degree of PH. Secondary outcomes included observed differences in patient morbidity, mortality, and resource use. Operative mortality was defined as all patient deaths occurring during hospitalization as well those within 30 days of the date of surgery regardless of discharge status. A composite outcome of major complications was used as a proxy for major morbidity and included the cumulative incidence of postoperative stroke, perioperative myocardial infarction, renal failure, prolonged mechanical ventilation, and pneumonia. Standard STS definitions for postoperative events and complications were used, including prolonged mechanical ventilation (>24 hours), new-onset atrial fibrillation, and renal failure (increase in serum creatinine level >2.0 or double the most recent preoperative creatinine level).

Statistical Analysis

All study outcomes and data comparisons were established a priori before data collection. Descriptive, univariate statistics included either Pearson χ^2 test or Fisher's exact test for categoric variables and either independent sample single-factor analysis of variance for parametric data comparisons or the Mann-Whitney *U* test for nonparametric data comparisons. Continuous variables are expressed as either mean ± SD or median with interquartile range, depending on overall variable distribution.

Multiple logistic regression analysis was used to estimate confounder-adjusted associations between PH category and patient morbidity (major complications) and operative mortality. Models were adjusted for patient risk by inclusion of the STS PROM score as well as operating surgeon and operative year. Confounder-adjusted measures of association are reported as odds ratios (ORs) with 95% confidence interval (CI). Model performance and the ability of the model to discriminate between dependent outcomes (major complications and mortality) were assessed with the area under the receiver operating characteristic curve. Predictive Analytics SoftWare (PASW version 18.0.0; IBM Corporation, Armonk, NY) was used for all data manipulation and statistical analyses.

RESULTS

Baseline and Operative Characteristics Stratified by MPAP

Although ages were similar across groups, the proportion of female patients increased with increasing MPAP (Table 1). Risk factors, including renal failure, lung disease, cerebrovascular disease, and New York Heart Association class IV heart failure, were all more common with increasing severity of PH ($P < .001$ for all). Left ventricular ejection fraction decreased with increasing MPAP ($P < .001$). Interestingly, the incidence of acute myocardial infarction did not vary with MPAP, and the incidences of angina, left main disease, and multivessel disease decreased with increasing MPAP.

Operative characteristics also varied considerably with increasing MPAP. Patients with normal or mildly elevated MPAP were more likely to undergo CABG, whereas patients with moderate or severe PH were more likely to undergo valve operations. Reoperations were more common with increasing MPAP. Accounting for these variations in risk factors and operations, the STS PROM increased with increasing MPAP (normal, 1.8%; mild, 2.3%; moderate, 4.6%; severe, 5.2%; $P < .001$). Finally, crossclamp and CPB times were significantly longer in patients with increasing MPAP.

Adjusted and Unadjusted Risks Rise With Increasing MPAP

Complications occurred more frequently with increasing MPAP (Table 2). Pneumonia, prolonged mechanical ventilation, and renal failure were all significantly associated with PH, as were rare but catastrophic complications such as cardiac arrest. The composite incidence of major complications increased significantly with higher MPAP (normal,