

## Mitral valve repair rates correlate with surgeon and institutional experience

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**Objectives:** Mitral valve (MV) repair rates have lagged despite reported superior outcomes in patients with mitral regurgitation. The purpose of the present study was to evaluate the relationship between procedure volume and the propensity for MV repair in a multi-institution, regional patient cohort.

**Methods:** Society of Thoracic Surgeons–certified patient records of those undergoing MV repair or MV replacement (MVR) for moderate or severe mitral regurgitation were evaluated from 17 different centers (2001–2011). The relationship between the annual hospital and surgeon volume and the propensity for MV repair over MVR was analyzed using multivariable, mortality risk-adjusted models with restricted cubic splines.

**Results:** A total of 4194 patients were evaluated (MV repair, 2516; MVR, 1662). The median annual mitral procedure volume was 54 operations for hospitals and 13 operations for surgeons. The overall MV repair rate was 60%, with significant variations among hospitals (range, 35%–70%) and surgeons (range, 0%–90%). The MVR patients presented with higher Society of Thoracic Surgeons Predicted Risk of Mortality scores (6% vs 2%,  $P < .001$ ). After adjustment for Predicted Risk of Mortality score, both annual hospital ( $P = .04$ ) and surgeon ( $P < .0001$ ) procedure volume were associated with the probability of MV repair. The likelihood for MV repair correlated with an operative volume of  $\geq 20$  procedures annually. Among surgeons and hospitals performing  $\geq 20$  mitral operations annually, MV repair rates were greater (73% vs 26% and 62% vs 37%, respectively,  $P < .001$  for both).

**Conclusions:** Significant variation in the performance of MV repair over MVR for mitral regurgitation persists in the modern surgical era. Average annual surgeon volume was more significantly associated with MV repair rate than institutional volume, with an increased likelihood for performance of MV repair among surgeons performing  $>20$  procedures annually. In the upcoming era of percutaneous MV repair, surgeon volume and expertise as a gatekeeper should dictate access to this technology and the decisions for the best approach to MV repair. (*J Thorac Cardiovasc Surg* 2014;148:995–1004)

Mitral valve (MV) surgery remains the standard of care for severe mitral regurgitation (MR) (grade 3–4+). The current joint American College of Cardiology/American Heart Association and European Society of Cardiology guidelines reflect the clear benefit of MV surgery over medical management for severe MR.<sup>1,2</sup> Despite these recommendations, only 50% of patients meeting the American College of Cardiology/American Heart Association guidelines for surgical treatment undergo surgery.<sup>3,4</sup> Moreover, significant variation in the performance of MV repair or

MV replacement (MVR) for moderate to severe MR has been demonstrated among hospitals and surgeons.<sup>5</sup> Although the accumulated data have favored reduced operative mortality and morbidity for MV repair over MVR, including the recently published Cardiothoracic Surgery Trials Network Severe Ischemic Mitral Regurgitation randomized controlled trial,<sup>6</sup> the overall performance of MV repair appears underused. Recent nationwide estimates have suggested usage of MV repair for functional MR of approximately 40%.<sup>7</sup> Although a few noteworthy reports have been published describing both patient-level and surgeon-related factors associated with the performance of MV repair,<sup>5,7,8</sup> additional multi-institution analyses using rigorous risk adjustment modeling methods are warranted to further characterize the individual influence of hospital and surgeon mitral procedure volume on the propensity for MV treatment allocation.

The purpose of the present study was to evaluate the relationship between annual surgeon and hospital procedure volume and the likelihood for MV repair in a multi-institution, regional cohort of patients with moderate

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**Abbreviations and Acronyms**

ACSD	= Adult Cardiac Surgery Database
MR	= mitral regurgitation
MV	= mitral valve
MVR	= mitral valve replacement
PROM	= Predicted Risk of Mortality
RCS	= restricted cubic spline
STS	= Society of Thoracic Surgeons
VCSQI	= Virginia Cardiac Surgery Quality Initiative

to severe MR. We hypothesized that significant variations in MV repair rates would be present among surgeons and hospitals in the modern surgical era; the probability for performance of MV repair over MVR would correlate with the average annual surgeon and/or hospital volume; and the effect of surgeon and hospital volume on the propensity for performance of MV repair over MVR would be independent of the effects of preoperative patient risk.

**METHODS**

The Virginia Cardiac Surgery Quality Initiative (VCSQI) consists of 17 cardiac surgical centers within the Commonwealth of Virginia that hold regular meetings to exchange and compare de-identified patient information to improve cardiac surgical care, quality, and costs. VCSQI centers perform approximately 99% of the Commonwealth's cardiac operations, contributing patient data to the Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database (ACSD).

The present study was exempt from formal institutional review board review at each participating hospital owing to the secondary analysis of the VCSQI de-identified (absence of Health Insurance Portability and Accountability Act patient identifiers) data registry and because the data were collected for quality analysis and purposes other than research.

**Patients and Data Acquisition**

De-identified patient data were extracted from the VCSQI data registry for the study period (January 1, 2001 to December 31, 2011). All records included patients undergoing isolated MV repair or MVR for moderate or severe MR (STS procedure type "MV repair" and "MV replacement"). Patients undergoing concomitant coronary artery bypass grafting, other valve procedures, or arrhythmia ablation procedures were excluded. All mitral procedures used standard open surgical approaches to MV surgery with the use of cardiopulmonary bypass support. Patient preoperative risk was assessed by the prevalence of patient comorbid disease, the degree of MR, operative status, and individually calculated STS Predicted Risk of Mortality (PROM) scores.

**Measured Outcomes**

The primary outcomes of interest included the risk-adjusted association between the probability of MV repair and average annual surgeon and hospital procedure volume. The secondary outcomes of interest included variations in MV repair rates and mitral procedure volume among surgeons and hospitals and the identification of a threshold volume at which MV repair was more commonly performed over MVR, independent of the baseline patient risk. The average annual procedure volume was calculated for each surgeon and hospital according to the performance of operations

throughout the entire study period. Standard STS clinical definitions for all analyzed variables were used.<sup>9</sup>

**Statistical Analysis**

**Descriptive statistics.** All statistical analyses were designed to test the null hypotheses that the average annual procedure volume would not be significantly associated with the likelihood for MV repair (vs MVR). All study outcomes and data comparisons were established a priori before data collection. Categorical variables are expressed as group percentages and continuous variables as either the mean  $\pm$  standard deviation or median and 25th, 75th percentile, depending on the overall variable distribution. Univariate comparisons included either Pearson's chi-square or Fisher's exact test for categorical variables and either independent-sample, single-factor, analysis of variance for normally distributed data or the Wilcoxon rank sum test for non-normally distributed data. Two-sided *P* values were used to define variable associations.

**Risk-adjusted regression models.** Two separate multiple regression models were first used to estimate the confounder-adjusted associations between the probability of MV repair (vs MVR) and average annual hospital (model 1) and surgeon (model 2) procedure volume for patients undergoing isolated MV operations for moderate to severe MR. The average annual procedure volumes for both individual surgeons and hospitals were analyzed as continuous functions, using restricted cubic spline (RCS) smoothing transformations to account for both linear and nonlinear associations with the performance of MV repair. 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 whether nonlinear relationships exist between a continuous variable and a dependent outcome. The use of RCS forces the tails of a function to be linear, which simplifies the representation. For RCS functions, procedure volumes were analyzed using a total of 3 knots placed at the 5th, 50th, and 95th percentiles to define the tails of each function. The predicted association between procedure volume and MV repair were adjusted for the confounding effects of the preoperative patient risk profile (STS PROM) and the effects of operations performed by different surgeons (model 1) and at different hospitals (model 2) through the inclusion of these variables as model covariates. The relative strength of the association between the average annual procedure volume and probability for MV repair (vs MVR) compared with other modeled factors was determined by each factors' likelihood ratio (Wald chi-square statistic) within the model. In addition, the risk-adjusted RCS function for both average annual surgeon and hospital procedure versus the probability of MV repair was graphically represented to identify an apparent threshold value (or inflection point) for procedure volume that correlated with an increase in the likelihood for MV repair.

**Risk-adjusted propensity matched analyses.** To further verify the multivariable model results for the estimated effects of the average annual surgeon and hospital mitral procedure volume on the probability of MV repair, additional risk-adjusted propensity score-matched analyses were performed to compare the study cohorts of matched MV repair and MVR. Propensity scores were estimated using logistic regression modeling with performance of MV repair (vs MVR) as the response variable and patient age, sex, operative year, surgeon, hospital, operative status (elective, urgent, or emergency), operative incidence (first operation or reoperation), and a history of endocarditis or heart failure as possible confounding predictor variables. Propensity scores were then used to match MV repair and MVR patients in a 1:1 ratio using the nearest neighbor greedy method, resulting in equal-size study cohorts. The MV repair and MVR rates were then compared as a function of the estimated volume thresholds and adjusted relationship between the procedure volume, and likelihood for MV repair was modeled within this cohort.

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