Quantifying the incremental cost of complications associated with mitral valve surgery in the United States

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Objective: The goal of this study was to quantify the net increase in resource use associated with complications after isolated mitral valve surgery.

Methods: Deidentified patient-level claims data on a random sample of mitral valve operations performed in the United States from January 1, 2006, to December 31, 2007, were obtained from the National Inpatient Sample (n = 16,788). Patients with major concomitant cardiac procedures were excluded from the analysis for a net sample size of 6297 patients. Risk-adjusted median total hospital costs and length of stay were analyzed by major complications, including pneumonia, sepsis, stroke, renal failure requiring hemodialysis, cardiac tamponade, myocardial infarction, gastrointestinal bleed, and venous thromboembolism.

Results: There were a total of 1323 complication events that occurred in 1089 patients. The most common complication was pneumonia (n = 346, 5.5%), which was associated with a $29,692 increase in hospital costs and a 10.2-day increase in median length of stay (*P* < .001). The most costly complication was cardiac tamponade, which resulted in an increase in hospital cost of $56,547 and an increase in length of stay of 19.3 days (*P* < .001). There was a stepwise association between the hospital costs and length of stay and the number of complications per patient (*P* < .001). There was also a significant association between the discharge location and the occurrence of a complication, with 25% more patients who underwent routine home discharge when there were no complications (*P* < .001).

Conclusions: In patients undergoing isolated mitral valve surgery, postoperative complications were associated with significant increases in mortality, hospital costs, and length of stay, as well as with discharge location. With growing national attention to improving quality and containing costs, it is important to understand the nature and impact of complications on outcomes and costs. (J Thorac Cardiovasc Surg 2012;143:864-72)

Among patients undergoing mitral valve surgery (MVS), significant improvements in outcomes have been observed nationally over the past decade.[1,2] Data from large national registries have demonstrated that length of stay and perioperative morbidity and mortality have achieved acceptably low levels.[3,4] These improvements in outcomes have occurred in the face of an increased frequency of comorbidities among patients presenting for MVS, including an increased prevalence of diabetes, hypertension, and hyperlipidemia.[5] Despite advances in care, with an aging US population, patients will continue to face significant perioperative risk after MVS.

It is well recognized that postoperative complications are associated with increased mortality, prolonged hospital stay, and greater resource use.[6] However, detailed data regarding the clinical and economic impact of postoperative complications, particularly after valvular surgery, remain scarce.[7] Availability of this information could be used to target further quality improvement efforts, which may significantly improve outcomes for patients and cost-containment efforts in an era when cost-effectiveness is at the forefront of healthcare policy initiatives.[8]

The purpose of this study was to characterize the impact of postoperative complications on clinical outcomes, such as mortality and discharge disposition, and the net increase in resource use, including in-hospital cost and length of stay, in a national cohort of patients undergoing isolated MVS.

METHODS AND MATERIALS
Data Source and Study Population

The Nationwide Inpatient Sample (NIS), which is sponsored by the Agency for Healthcare Research and Quality, Healthcare Cost and Utilization Project, was used to identify patient discharges related to MVS that

Abbreviations and Acronyms

AVR = aortic valve replacement
CABG = coronary artery bypass grafting
CI = confidence interval
CMS = Centers for Medicaid and Medicare Services
ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification
MVR = mitral valve replacement
MVS = mitral valve surgery
NIS = Nationwide Inpatient Sample
OR = odds ratio
STS = Society of Thoracic Surgeons

occurred between January 1, 2006, and December 31, 2007 (n = 16,788). The NIS provides only deidentified patient claims data, and thus this analysis qualified for institutional review board exception. The NIS is a 20% sampling of abstracted discharge data from a national survey of all nonfederal acute care hospitals in the United States and contains discharge records from more than 1000 hospitals in 37 states.[9]

The NIS contains up to 15 procedure codes per patient using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure code index. MVS was abstracted using ICD-9-CM codes 35.23, 35.24, and 35.12 in the first, second, or third procedure code position. For the primary analysis, major concomitant cardiac procedures (coronary artery bypass grafting [CABG], aortic valve surgery, tricuspid valve surgery, and arrhythmia surgery) were excluded using appropriate ICD-9-CM codes to study only patients with isolated MVS (n = 6297) and avoid the potential confounding effect of multiple procedures on resource use. In addition, patients aged less than 18 years were excluded from the analysis. The NIS does not provide data on repeat procedures.

Clinical Outcomes and Complications

Major clinical outcomes of interest included length of hospitalization, in-hospital morbidity, and in-hospital mortality. Given that the NIS includes data on up to 15 diagnoses per discharge, a focus on specific major postoperative complications (eg, pneumonia) rather than complication systems-based categories (eg, respiratory complications) was used to maximize specificity of results. Specific major postoperative complications extracted from the NIS using appropriate ICD-9 codes included pneumonia (ICD-9-CM codes 480–487); acute renal failure (ICD-9-CM code 584); septicemia (ICD-9-CM code 038); acute myocardial infarction (ICD-9-CM code 410); stroke (ICD-9-CM code 436.* and 437.*); cardiac tamponade (ICD-9-CM code 423.3); gastrointestinal bleed (ICD-9-CM codes 530.82, 535.61 and 578.9); and venous thromboembolism (ICD-9-CM codes 451.* and 453.*). The number of complications per patient was also analyzed to study the multiplicative effect of complications on resource use. Last, discharge location was assessed for all patients.

Cost Outcomes

Total billed charges for each hospitalization are present in the NIS dataset. These data reflect the amount hospitals billed for services rendered rather than the costs for the specific hospitalization or the amount hospitals received in payments. Estimated institutional cost data were obtained by multiplying Healthcare Cost and Utilization Project supplied cost-to-charge ratios by total charges. Grouped average cost-to-charge ratios are a weighted average for the hospitals in the group (defined by state, urban/rural, investor owned/other, and number of beds) and use the proportion of group beds as the weight for each hospital. Total costs related to the complication were calculated on the basis of incremental cost multiplied by the annual incidence multiplied by a factor of 5 to account for the 20% sample. All costs were rounded to the nearest $100.

Statistical Analysis of Cost and Clinical End Points

Because medical costs are traditionally right skewed, as costs cannot be negative, we report median cost in the analysis unless otherwise specified. For univariate analysis of median cost, results of the Wilcoxon rank-sum test are reported. To assess the independent effect of complications on total median hospital costs, multivariable quantile regression using 1000 bootstrapped iterations was used where the outcome of interest was median cost. Demographic variables used in multivariable regression included age and all comorbidities presented in Appendix 1 that had a P value less than .20 in univariate analysis.

For clinical data, continuous variables were reported as mean ± standard error and compared using the Student t test or Wilcoxon rank-sum test when noted. Categoric variables were reported as percentages and compared using the chi-square or Fisher exact test when appropriate. Median length of stay was reported rather than mean given the potential for outliers, and risk-adjusted length of stay was analyzed in a similar fashion as cost using multivariable quantile regression with 1000 bootstrapped iterations. Long-term survival data are not present in the current dataset; however, in-hospital mortality is coded and reported. Logistic regression was used to assess the independent effect of the number of complications on in-hospital mortality. All reported P values are 2-sided. All statistical analyses were performed using Stata 11 (StataCorp, College Station, Tex).

RESULTS
Study Population

From January 1, 2006, to December 31, 2007, there were 16,788 patients in the NIS registry who underwent MVS. Appendix 2 shows the distribution of repairs, replacements, and concomitant procedures in the series. There were 6297 (37.5%) isolated mitral valve operations that formed the study cohort for the primary end points. Among isolated mitral valve operations, cases were distributed as follows: mechanical mitral valve replacement (27.5%, n = 1732), tissue mitral valve replacement (20.4%, n = 1282), and mitral valve repair (52.1%, n = 3283). The distribution of baseline characteristics of the study cohort is summarized in Table 1. The mean age of patients was 64.6 ± 13.4 years, the majority of procedures were elective (65.2%, n = 4103), and the 2 most common comorbidities included peripheral vascular disease (38.2%, n = 2406) and heart failure (38%, n = 2396).

Clinical Outcomes

The mean and median lengths of stay were 11.6 ± 12.1 and 8 days, respectively, for all isolated mitral valve operations. The distribution of postoperative complications for the series is summarized in Table 2. There were a total of 1323 complication events that occurred in 1089 patients. The 3 most common complications were pneumonia (5.5%, n = 346), sepsis (4.1%, n = 261), and renal failure requiring dialysis (3.5%, n = 223). When analyzed by the

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