Incidence of postoperative acute kidney injury in patients with chronic kidney disease undergoing minimally invasive valve surgery

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Background: We hypothesize that minimally invasive valve surgery in patients with chronic kidney disease (CKD) is superior to a conventional median sternotomy.

Methods: We retrospectively analyzed 1945 consecutive patients who underwent isolated valve surgery. Included were patients with CKD stages 2 to 5. In-hospital mortality, composite complication rates, and intensive care unit and total hospital lengths of stay of those who underwent a minimally invasive approach were compared with those who underwent a standard median sternotomy. Resource use was approximated based on intensive care unit and total hospital lengths of stay.

Results: There were 688 patients identified; 510 (74%) underwent minimally invasive surgery, and 178 (26%) underwent a median sternotomy. There was no significant difference in mortality. Minimally invasive surgery was associated with fewer composite complications (33.1% vs 49.4%; odds ratio, 0.5; $P \leq .001$), shorter intensive care unit (48 [interquartile range {IQR}, 33-74] hours vs 71 [IQR, 42-96] hours; $P < .01$), and hospital (8 [IQR, 6-9] days vs 10 [IQR, 8-15] days; $P < .001$) lengths of stay, and a lower incidence of acute kidney injury (8% vs 14.7%; odds ratio, 0.5; $P = .01$), compared with median sternotomy. In a multivariable analysis, minimally invasive surgery was associated with a 60% reduction in the risk of development of postoperative acute kidney injury.

Conclusions: In patients with CKD undergoing isolated valve surgery, minimally invasive valve surgery is associated with reduced postoperative complications and lower resource use. (J Thorac Cardiovasc Surg 2013;146:1488-93)

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According to data published by the National Institutes of Health, more than 10% of the US population is diagnosed with chronic kidney disease (CKD), and nearly 113,000 patients will progress to end-stage renal disease each year.[1] Cardiovascular disease is one of the leading causes of morbidity and mortality in this population, and the chronic inflammation, endothelial dysfunction, and metabolic disturbances seen in the progression of CKD have been strongly associated with the development of valvular heart disease.[2,3] Patients undergoing cardiac surgery have a 3.3-fold increased risk of developing acute kidney injury (AKI), with a 2.3-fold increased risk of requiring dialysis, and in the past decade, the associated mortality of AKI after cardiac surgery has increased from 30% to 47%.[4] In the setting of CKD, these effects are augmented, with an increased incidence of CKD progression and late-term mortality.[5]

When compared with a median sternotomy approach, the reported benefits of minimally invasive valve surgery include decreased blood loss, reduced incidence of postoperative atrial fibrillation, shorter intensive care unit and hospital length of stays, and faster patient recovery.[6-11] These findings have also been reported in such high-risk groups as elderly patients, obese patients, and those undergoing reoperative valve surgery, leading to an increased acceptance of minimally invasive surgery as a viable option to the standard median sternotomy approach.[12-15] The purpose of our study was to analyze the impact of minimally invasive valve surgery on the incidence of postoperative AKI and postoperative complications in patients with stage 2 to 5 CKD. We analyzed the outcomes of patients who underwent valve surgery via a minimally invasive approach, and compared them with a cohort who underwent median sternotomy valve surgery.

METHODS

After obtaining approval from the Mount Sinai Medical Center Institutional Review Board, we retrospectively evaluated 1945 valve operations performed at our institution between January 1, 2005, and December 7, 2011, to identify patients with stage 2 to 5 CKD who underwent isolated mitral or aortic valve surgery. Excluded were patients who had concomitant coronary artery bypass graft surgery, surgery on another valve and/or ascending aorta, a history of cardiac surgery, infective endocarditis, emergency surgery, and stage 1 CKD. The estimated glomerular filtration rate (eGFR) was calculated using the modification of diet in renal

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Abbreviations and Acronyms

AKI = acute kidney injury
CKD = chronic kidney disease
eGFR = estimated glomerular filtration rate
IQR = interquartile range
RIFLE = Risk, Injury, Failure, Loss, End-stage renal disease

disease equation: eGFR (mL/min per 1.73 m^2) = 186 × (serum creatinine)$^{-1.154}$ × (age)$^{-0.203}$ × (0.742 if female) × (1.21 if African American). Patients were grouped according to eGFR and the National Kidney Foundation stages for CKD, as follows: stage 1, 90 mL/min per m^2 or higher; stage 2, 60 to 89 mL/min per m^2; stage 3, 30 to 59 mL/min per m^2; stage 4, 15 to 29 mL/min per m^2; and stage 5, less than 15 mL/min per m^2 or patients undergoing dialysis.[16] The median sternotomy surgery was performed by 6 different surgeons, whereas the minimally invasive surgery was performed by a single surgeon.

All patients underwent left heart catheterization and echocardiography to evaluate their valvular lesions, and all operative reports and echocardiograms were reviewed. *Postoperative composite complications* were defined as the development of AKI, prolonged ventilation (>24 hours), reintubation, atrial fibrillation, deep wound infection, pneumonia, sepsis, bleeding requiring reexploration, stroke, or death. *In-hospital mortality* was defined as death at any time after the operation if the patient was not discharged from the hospital alive. The surgical technique time was evaluated by comparing the aortic crossclamp with the total cardiopulmonary bypass times. The definitions and variables selected were based on the Society of Thoracic Surgeons Database definitions. Postoperative AKI was further analyzed by the Risk, Injury, Failure, Loss, End-stage renal disease (RIFLE) classification system, proposed by the Acute Dialysis Quality Initiative group.[16] This classification divides the patients with AKI into 5 categories: (1) risk, GFR decrease of less than 25%, serum creatinine increase of 1.5 times, or urine production of less than 0.5 mL/kg per hour for 6 hours; (2) injury, GFR decrease of greater than 50% and doubling of creatinine or urine production by less than 0.5 mL/kg per hour for 12 hours; (3) failure, GFR decrease of greater than 75%, tripling of creatinine or creatinine increase greater than 355 μmol/L (with an increase of >44 μmol/L [>4 mg/dL]), or urine output lower than 0.3 mL/kg per hour for 24 hours; (4) loss, persistent AKI or complete loss of kidney function for more than 4 weeks; and (5) end-stage renal disease, need for renal replacement therapy for more than 3 months.

Technique for Minimally Invasive Valve Surgery

A femoral or axillary platform was used to establish cardiopulmonary bypass. The femoral/axillary artery was cannulated with a 15-19 Fr arterial cannula (Biomedicus; Medtronic, Minneapolis, Minn), and the femoral vein was cannulated with a 25 Fr venous cannula (Biomedicus). Transesophageal echocardiography was used to aid in the placement of the venous cannula in the superior vena cava.

For the mitral valve procedures, a 5- to 6-cm skin incision was made in the fourth to fifth intercostal space lateral to the anterior axillary line. The mitral valve was accessed through the Waterston groove, then through the atrial septum into the left atrium. Mitral valve repair or replacements were performed in the standard manner. For aortic valve procedures, a 5- to 6-cm right transverse skin incision was made 1 cm lateral to the sternum over the second to third intercostal space. In all aortic valve procedures, the second or third costochondral cartilage was transected to allow adequate exposure of the aorta and avoid fracturing the rib. At the completion of the operation, the rib was reattached to the sternum with a 1-cm metal plate (Synthes, West Chester, Pa), and a fiber wire was placed in a figure-of-eight manner. A left ventricular vent was inserted into the left ventricle via a purse string suture in the right superior pulmonary vein, and a retrograde cardioplegia cannula was inserted via the right atrial appendage using transesophageal echocardiographic guidance. A transverse aortotomy was performed to expose the aortic valve, and valve replacement was performed under direct vision using standard techniques.

For all procedures, cardiopulmonary bypass was initiated at 32°C to 36°C using a closed-membrane oxygenator and roller pump. Venous drainage was augmented with vacuum assistance, applying negative pressures of 30 to 70 mm Hg as needed to decompress the right side of the heart. Transincisional direct aortic crossclamping was performed using a flexible and retractable shaft crossclamp (Novare Surgical Systems, Cupertino, Calif). One dose of antegrade cold blood cardioplegia was given to establish electromechanical arrest of the heart. Thereafter, retrograde cold blood cardioplegia was given throughout the procedure at 20- to 25-minute intervals. If retrograde cardioplegia was not possible, a cardioplegia cannula was left in the ascending aorta, or direct cannulation of the coronary ostia was performed to deliver antegrade cardioplegia. Carbon dioxide was infused into the operative field during the entire procedure. Removal of air from the heart was performed with a venting needle in the root of the aorta and under transesophageal echocardiographic guidance. After discontinuing cardiopulmonary bypass and administering protamine, decannulation was performed. A single chest tube was left in the pleural space. For pain relief, all patients had an On-Q pain relief system inserted (I-Flow Corporation, Lake Forest, Calif). Two catheters were placed in the interspace to deliver 0.25% bupivacaine for 72 hours. The thoracotomy incision was closed in the routine manner.

Statistical Analyses

Patient demographics and operative data were expressed as the mean ± 1 SD, or median and interquartile range (IQR, or 25%-75%), as appropriate. Continuous variables with a normal distribution were compared using an independent Student *t* test and correlation coefficient, when appropriate, whereas variables that did not exhibit a normal distribution were compared using a Mann-Whitney *U* test. A χ^2, Pearson χ^2, or Fisher exact test was used to compare dichotomous variables, when appropriate. A univariable analysis was performed for baseline characteristics, surgical procedural variables, postoperative outcomes, and other known risk factors that could influence the clinical outcomes. The variables with $P \leq .2$ were included in a binary logistic regression analysis to determine their independent effects. The model was assessed by the Hosmer-Lemeshow goodness-of-fit test. All statistical analyses were performed with the assistance of a statistician using SPSS, version 17 (SPSS Inc, Chicago, Ill).

RESULTS

A total of 688 patients were identified. Of these patients, 510 had valve surgery via a minimally invasive approach, and 178 underwent a median sternotomy. The patients in the minimally invasive group were older (71.3 ± 11.6 vs 67.8 ± 12 years; $P = .001$), whereas those in the median sternotomy group had a higher body mass index (27.3 ± 4.8 vs 28.5 ± 5.8 kg/m^2; $P = .03$) and greater incidence of stage 5 CKD (4% vs 1%; $P = .008$). There were no other differences between the 2 groups regarding baseline characteristics (Table 1).

In the entire cohort of patients (excluding those with stage 5 CKD at baseline), 66 developed AKI and 608 did not. Those who developed AKI were significantly older, obese, had a greater incidence of median sternotomy, and had a higher baseline mean pulmonary artery

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