Incidence of cerebrovascular accidents in patients undergoing minimally invasive valve surgery

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Objectives: Minimally invasive valve surgery has been associated with increased cerebrovascular complications. Our objective was to evaluate the incidence of cerebrovascular accidents in patients undergoing minimally invasive valve surgery.

Methods: We retrospectively reviewed all the minimally invasive valve surgery performed at our institution from January 2009 to June 2012. The operative times, lengths of stay, postoperative complications, and mortality were analyzed.

Results: A total of 1501 consecutive patients were identified. The mean age was 73 ± 13 years, and 808 patients (54%) were male. Of the 1501 patients, 206 (13.7%) had a history of a cerebrovascular accident, and 225 (15%) had undergone previous heart surgery. The procedures performed were 617 isolated aortic valve replacements (41.1%), 658 isolated mitral valve operations (43.8%), 6 tricuspid valve repairs (0.4%), 216 double valve surgery (14.4%), and 4 triple valve surgery (0.3%). Femoral cannulation was used in 1359 patients (90.5%) and central cannulation in 142 (9.5%). In 1392 patients (92.7%), the aorta was clamped, and in 109 (7.3%), the surgery was performed with the heart fibrillating. The median aortic crossclamp and cardiopulmonary bypass times were 86 minutes (interquartile range [IQR], 70-107) minutes and 116 minutes (IQR, 96-143), respectively. The median intensive care unit length of stay was 47 hours (IQR, 29-74), and the median postoperative hospital length of stay was 7 days (IQR, 5-10). A total of 23 cerebrovascular accidents (1.53%) and 38 deaths (2.53%) had occurred at 30 days postoperatively.

Conclusions: Minimally invasive valve surgery was associated with an acceptable stroke rate, regardless of the cannulation technique. (J Thorac Cardiovasc Surg 2014;148:156-60)

Minimally invasive valve surgery encompasses various surgical techniques that use smaller incisions and minimize surgical trauma compared with conventional median sternotomy. The advantages of a minimally invasive approach to valve surgery have been reported.[1-6] However, concerns remain regarding the adequacy of surgical field exposure, quality of valve repairs, increased operative times, and vascular complications.[7] In particular, reports have been published of a greater incidence of cerebrovascular accidents with minimally invasive surgery compared with median sternotomy.[1,8-11] We performed a retrospective review of the minimally invasive valve operations performed at our institution to evaluate the incidence of postoperative strokes.

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METHODS

After obtaining approval from the Mount Sinai Medical Center institutional review board, we retrospectively evaluated all consecutive minimally invasive valve surgery performed at our institution from January 2009 to June 2012 to identify patients who had experienced a cerebrovascular accident postoperatively. A cerebrovascular accident was defined as any confirmed neurologic deficit of abrupt onset that did not resolve within 24 hours. We excluded patients with active infective endocarditis or cardiogenic shock and those who required emergent surgery and/or concomitant coronary revascularization.

All patients had their valvular lesions documented by diagnostic catheterization and echocardiography, and all operative reports and echocardiograms were reviewed. The surgical technique time was compared on the basis of the aortic crossclamp and cardiopulmonary bypass times. The definitions and variables selected were from the Society of Thoracic Surgery database definitions.

Surgical Technique

At our institution, all valve cases are considered candidates for a minimally invasive approach, with the exception of an inability to cannulate the patient for cardiopulmonary bypass and/or any patient undergoing a valve-sparing procedure of the aortic valve. A femoral platform was the preferred method used to establish cardiopulmonary bypass. The femoral artery was cannulated with a 16F to 18F arterial cannula (Edwards LifeSciences, Irvine, Calif), and the femoral vein was cannulated with a 25F venous cannula (Biomedicus; Medtronic, Minneapolis, Minn). Transesophageal echocardiography was used to aid in the placement of the venous cannula in the superior vena cava. We did not routinely perform preoperative computed tomographic angiography to evaluate for the presence of peripheral vascular disease and/or aortic

> **Abbreviation and Acronym**
> IQR = interquartile range

pathologic features. If significant peripheral vascular disease was suspected from the history and/or physical examination findings or was present at femoral cannulation or severe aortic atherosclerosis was evident by transesophageal echocardiography, central (direct) aortic cannulation was performed for the aortic valves and axillary artery cannulation for the mitral valve procedures.

For the mitral valve procedures, a 4- to 5-cm transverse incision was made over the right fourth intercostal space at the anterior axillary line. The pericardium was opened anterior to the phrenic nerve, and cannulation of the coronary sinus was performed by way of the right atrium. A transthoracic aortic crossclamp was then placed. Antegrade cardioplegia was given by way of a 14-gauge angiographic catheter inserted into the aortic root. Usually, a single dose of antegrade cardioplegia was given to arrest the heart, and retrograde cardioplegia was then continued throughout the remainder of the procedure. In patients with a previous coronary artery bypass graft, cardioplegia was avoided, and the procedure was done with the heart fibrillating; thus, crossclamping of the aorta was avoided. The left atrium was then accessed by way of an incision through Sondergaard's groove. The mitral procedure was performed, and the atrium was then closed. Removal of air was performed similar to our sternotomy procedures, with the patient placed in a steep Trendelenburg position, as the heart began to eject with a vent placed in the aortic root. The venting needle was placed laterally on the greater curvature of the aorta in the mitral cases and more anteriorly in the aortic cases.

For the aortic valve procedures, a 4- to 5-cm transverse incision was made at the mid-clavicular line over the right third intercostal space. Usually, the inferior rib was transected at the cartilage. A retrograde cardioplegia cannula was inserted directly through the right atrial appendage. A left ventricular vent was placed by way of the right superior pulmonary vein. The aorta was crossclamped, and cardioplegia was given both antegrade and retrograde. A transverse aortotomy was made above the sinotubular junction and closed at the conclusion of the valve replacement procedure. In patients undergoing aortic valve replacement with a previous coronary artery bypass graft and a patent left internal mammary graft, we used moderate hypothermia (28°C) with 1 induction dose of antegrade cardioplegia. Thereafter, retrograde cardioplegia was delivered at 20-minute intervals.

Isolated tricuspid valve surgery was performed similar to mitral valve surgery. However, the femoral venous cannula was placed only up to the inferior vena cava, and pump suction was placed in the superior vena cava after the right atrium was opened, and both cavae were snared to allow for bicaval venous drainage. Double- and triple-valve surgery was performed similar to the above procedures with slight variations in the size and location of the incisions. For the aortic with mitral valve procedures, a 6- to 7-cm incision was performed over the fourth intercostal space starting at the midclavicular line; the cartilage was also transected. For mitral and tricuspid valve surgery, a 5- to 6-cm incision was made in the right fourth to fifth intercostal space at the anterior axillary line.

In patients with a history of atrial arrhythmias, a concomitant, modified, left atrial ablation procedure was often performed after exposure of the left atrium and mitral valve. The intra-atrial ablation lines were created with a saline-irrigated, unipolar radiofrequency probe (Cardioblate, Medtronic, Minneapolis, Minn). The ablation lines included isolation of the pulmonary veins, followed by a box lesion communicating with the pulmonary veins. Additional lines were created around the left atrial appendage and from the appendage to the left pulmonary veins. The last lesion set was from the left pulmonary veins to the mitral annulus (P2-P3 region). The left atrial appendage was ligated from within the left atrium with a double-row, continuous suture line. We did not perform right atrial ablation in any of the patients.

Statistical Analysis

The patient demographics and operative data are presented as the mean ± standard deviation or median and interquartile range (IQR or 25%-75%), as appropriate. All statistical analyses were performed using Statistical Package for Social Sciences, version 19 (SPSS, Chicago, Ill).

RESULTS

A total of 1501 consecutive patients were identified, with a mean age of 73 ± 13 years. Of the 1501 patients, 808 (54%) were men and 693 (46%) were women. Essential hypertension was noted in 1320 patients (87.9%). A total of 206 patients (13.7%) had a history of a cerebrovascular accident. In patients with a history of previous cardiac surgery, 125 (8.3%) had undergone previous coronary artery bypass grafting, and 100 (6.6%) had undergone previous valve surgery (Table 1).

The surgery consisted of 1281 single valve procedures (85.5%), 216 double valve procedures (14.1%), and 4 triple valve procedures (0.3%). The single valve surgery included 617 aortic valve replacements (41%), 658 mitral valve procedures (43.8%), and 6 tricuspid valve repairs (0.4%). The mitral valve procedures included 372 mitral valve repairs and 286 mitral valve replacements. The double valve procedures included 125 cases of aortic and mitral valve surgery, 90 mitral and tricuspid valve surgery, and 1 case of aortic and tricuspid valve surgery. Four patients underwent triple valve surgery. Femoral cannulation for cardiopulmonary bypass was used in 1359 patients (90.5%), axillary arterial cannulation was used in 72 (4.8%), and direct central aortic cannulation was performed in 70 (4.7%). Direct aortic crossclamping was performed in all cases that involved surgery of the aortic valve. Of the mitral valve surgery cases, 549 (83.4%) were performed with direct aortic crossclamping (62% repairs, 38% replacements) and 109 (16.5%) with the heart fibrillating (34% repairs, 66% replacements). A modified left atrial ablation procedure was performed in 282 patients (18.8%). The median aortic crossclamp and cardiopulmonary bypass time was 86 minutes (IQR, 70-107) and 116 minutes (IQR, 96-143), respectively (Table 2).

Overall, 23 strokes (1.53%) were diagnosed clinically during hospitalization. Of the 23 strokes, 3 patients (3 of 206, 1.45%) had a history of previous stroke. The stroke rate for the isolated aortic valve surgery was 1.1% (7 of 617) and 1.5% for the isolated mitral valve procedures (10 of 658). When evaluating the mitral procedures in which an aortic crossclamp was used, 6 strokes occurred, for a rate of 1.09% (6 of 549). For the isolated mitral valve surgery performed with the heart fibrillating, the stroke rate was 2.75% (3 of 109). None of the patients undergoing isolated tricuspid valve repair experienced a stroke. For the double valve procedures, the stroke rate was 2.7%

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TABLE 1. Patient demographics (n = 1501)

Variable	Value
Age (y)	73 ± 13
Male gender	808 (54)
Body mass index (kg/m^2)	27 ± 5.2
Preoperative creatinine (mg/dL)	0.98 ± 0.8
Ejection fraction (%)	58 ± 12
Diabetes mellitus	401 (26.7)
Hypertension	1320 (87.9)
History of atrial fibrillation	440 (29.3)
Peripheral vascular disease	145 (9.6)
History of cerebrovascular disease	206 (13.7)
Previous coronary artery bypass grafting	125 (8.3)
Previous valve surgery	100 (6.6)
History of heart failure	172 (11.5)

Data presented as mean ± standard deviation or n (%).

(6 of 216). When evaluating the cannulation techniques, 19 of the 23 with a stroke had undergone femoral arterial cannulation, and 3 had undergone axillary cannulation. Therefore, the stroke rate for femoral arterial cannulation and axillary and/or direct cannulation was 1.4% (19 of 1359) and 2.9% (4 of 136), respectively (Table 3).

TABLE 2. Procedural characteristics and operative results (n = 1501)

Variable	Value
Femoral cannulation	1359 (90.5)
Axillary artery cannulation	72 (4.8)
Direct central aortic cannulation	70 (4.7)
Isolated aortic valve replacement	617
Isolated mitral valve surgery	658
Mitral valve repair	372
Crossclamped	336
Fibrillating	36
Mitral replacement	286
Crossclamped	213
Fibrillating	73
Isolated tricuspid valve repair	6
Double valves	216
Aortic and mitral	125
Mitral and tricuspid	90
Aortic and tricuspid	1
Triple valves	4
Modified left atrial ablation	282 (18.8)
Aortic crossclamp time (min)	
Median	86
IQR	70-107
Cardiopulmonary bypass time (min)	
Median	116
IQR	96-143
Ventilation time (h)	34 ± 4.5
Intensive care unit length of stay (h)	
Median	47
IQR	29-74

Data presented as n (%), n, or mean ± standard deviation, unless otherwise noted. *IQR*, Interquartile range.

TABLE 3. Association of postoperative cerebrovascular accident and procedural characteristics

Cerebrovascular accidents	n (%)
Total	23 (1.53)
Stratified by procedural characteristic	
Previous stroke	3/206 (1.45)
Isolated aortic valve surgery	7/617 (1.1)
Isolated mitral valve procedures	10/658 (1.5)
Isolated mitral valve surgery with aortic crossclamp	6/549 (1.09)
Isolated mitral valve with heart fibrillating	3/109 (2.75)
Isolated tricuspid valve repair	0
Double valve surgery	6/216 (2.7)
Femoral arterial cannulation	19/1359 (1.4)
Axillary and/or direct cannulation	3/142 (2.1)

The median intensive care unit and hospital length of stay was 47 hours (IQR, 29-74) and 7 days (IQR, 5-10), respectively. Postoperatively, 49 patients (3.3%) developed acute kidney injury, 75 (5%) developed pneumonia, and 266 (17.7%) developed atrial fibrillation. At 30 days, 38 patients (2.53%) had died (Table 4).

DISCUSSION

The number of valve operations performed using a minimally, or less invasive, approach has been increasing.[11] Compared with standard median sternotomy, the benefits of minimally invasive surgery include decreased blood loss, shorter hospital length of stay, less morbidity, and a reduction in mortality in the elderly and obese.[3,4,12-16] However, despite the benefits, discussions have ensued regarding the best operative techniques to minimize vascular complications, most notably strokes.[8,9]

Grossi and colleagues[8] reviewed 3180 isolated primary valve procedures, of which 28% were performed by sternotomy and 72% by a minimally invasive technique. Of the minimally invasive procedures, antegrade perfusion was used in 83.2% of the procedures, retrograde femoral cannulation in 16.8%, and without a crossclamp in 0.2%.

TABLE 4. Postoperative outcomes (n = 1501)

Variable	Value
Acute kidney injury	49 (3.3)
Reintubation	87 (5.8)
Deep wound infection	0
Bleeding requiring reoperation	40 (2.7)
Sepsis	15 (1)
Pneumonia	75 (5)
Postoperative atrial fibrillation	266 (17.7)
Intensive care unit readmission	47 (3.1)
Hospital length of stay (d)	
Median	7
IQR	5-10
30-d Mortality	38 (2.53)

Data presented as n (%) or median (IQR). *IQR*, Interquartile range.

The overall stroke rate was 2.2% and was similar between the median sternotomy and minimally invasive groups. They noted an increased stroke risk associated with an atherosclerotic aorta, previous cerebrovascular disease, an emergent operation, an ejection fraction < 30%, no aortic crossclamping, and retrograde perfusion, but not with incision location. They also noted that retrograde perfusion had no significant effect on the incidence of stroke in patients ≤50 years old and proposed that retrograde perfusion should be limited to young patients with no evidence of aortic or peripheral vascular disease. These results were similar to their earlier observation of patients undergoing reoperative mitral valve procedures, revealing that retrograde perfusion was the only independent risk factor for stroke (odds ratio, 4.4; $P = .001$).[17,18] Recently, Murzi and colleagues[9] reported their series of 1280 consecutive patients who had undergone first time minimally invasive mitral valve surgery. Their cohort consisted of 167 patients with retrograde arterial perfusion and 1113 patients with antegrade perfusion. They concluded that the use of retrograde arterial perfusion contributed to a greater incidence of neurologic complications and aortic dissections. However, a limitation of their study was that the patient population spanned from 2003 to 2012, and early in their series, 33% of the patients who had undergone retrograde perfusion had received a balloon endoclamp, which is known to be associated with a greater incidence of cerebrovascular accidents.[1,10] Although their data suggest a worse outcome with retrograde perfusion, most (90.5%) of the patients in our study had received femoral cannulation with retrograde perfusion and had an acceptable stroke rate of 1.39%. Data from large series involving robotic techniques have also demonstrated a low incidence of stroke with peripheral cannulation. A study by Nifong and colleagues,[19] involving 540 consecutive robotic mitral valve repairs, reported a stroke rate of 0.6%.

Gammie and colleagues[11] examined the outcomes of less invasive mitral operations from the Society of Thoracic Surgeons database. They observed that, although less invasive mitral operations resulted in a shorter length of hospital stay, fewer blood transfusions, and a greater rate of mitral valve repair than did conventional sternotomy, the perfusion times were longer and, more importantly, the incidence of stroke was greater. The greater stroke rate was noted in a propensity analysis they performed on 4322 patients who had undergone less invasive surgery and were compared with a matched cohort of patients who had undergone conventional sternotomy. The stroke rate in the less invasive group was 1.87% versus 0.93% in the median sternotomy group ($P = .0002$). Femoral cannulation was not independently related to the increased incidence of stroke (odds ratio, 1.39; 95% confidence interval, 0.9-2.15; $P = .14$). However, the use of beating or fibrillating heart techniques compared with aortic crossclamping with cardioplegic cardiac arrest was associated with an adjusted threefold greater risk of stroke (odds ratio, 3.03; 95% confidence interval, 1.66-5.51; $P = .0003$). Our study also showed a slightly greater incidence of stroke (2.75%) with procedures that were performed without an aortic crossclamp on a fibrillating heart. All these cases involved patients undergoing mitral valve surgery who had a history of previous cardiac surgery. We hypothesized that the increased stroke rate in that subgroup of patients might have resulted from cerebral air embolism, most likely because of an inadequate removal of air. Because of the limited exposure of the aorta on our reoperative procedures, our removal of air procedure was slightly different than that for our sternotomy procedures. Because a crossclamp was not needed, we did not mobilize the scar tissue around the aorta; thus, a needle to remove air was not inserted into the root of the aorta. Instead, our removal of air site was solely through the atriotomy incision. The remainder of the removal of air technique was similar to that for our sternotomy procedures, with the patient placed in the Trendelenburg position, the heart beating, and the venting site connected to our pump, while verifying the successful removal of air using transesophageal echocardiography. Using this technique, our stroke rate in this subgroup of patients was 3.2% (3 of 94). We recently altered our removal of air technique during the minimally invasive reoperative fibrillating procedures and now include placing a venting needle in the root of the aorta. The new approach has been implemented in 15 patients; thus far, we have observed no strokes. We postulate that this technique of air removal might reduce the stroke rate in this subgroup of patients.

The limitations of our study are that it was a single-center, retrospective study of a heterogeneous group of patients. All operations were performed by a single surgeon (J.L.). Our results are applicable to minimally invasive surgery using a right anterior minithoracotomy, as described in the ‘‘Methods’’ section, and should not be extrapolated to other techniques. Also, neither a full neurologic examination by a trained neurologist nor radiographic cerebral imaging was routinely performed on patients pre- and postoperatively; thus, the detected strokes were clinically evident, and more subtle or silent deficits were missed. Nonetheless, these were clinically relevant results.

In conclusion, we have shown that minimally invasive valve surgery has an acceptable stroke rate, regardless of the cannulation technique used. For procedures performed without an aortic crossclamp, the techniques for removal of air should not be compromised and should mimic the technique used during standard median sternotomy to possibly reduce the incidence of stroke.

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