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ORIGINAL ARTICLE

ADULT CARDIAC

Outcomes of minimally invasive valve surgery in patients with chronic obstructive pulmonary disease

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Abstract

OBJECTIVES: We hypothesize that minimally invasive valve surgery in patients with chronic obstructive pulmonary disease (COPD) is superior to the conventional median sternotomy approach.

METHODS: We retrospectively reviewed 2846 consecutive surgery performed at our institution between January 2005 and September 2010, and identified 165 patients with COPD who underwent isolated valve surgery. In-hospital mortality, composite complication rates, intensive care unit and total hospital length of stay of those who had undergone a minimally invasive approach were compared with a cohort that underwent a standard median sternotomy approach.

RESULTS: Of the 165 patients, 100 underwent a minimally invasive approach and 65 had a median sternotomy. Baseline characteristics did not differ between the two groups. The mean age was 71 ± 11 years for the minimally invasive group and 68 ± 12 years for the median sternotomy group, ($P = 0.31$). In-hospital mortality was 1 (1%) in the minimally invasive group and 3 (5%) in the median sternotomy group, $P = 0.14$. Composite postoperative complications were significantly reduced in the minimally invasive group (30 versus 54%, $P = 0.002$). The median intensive care unit length of stay was 47 h (IQR 40–70) versus 73 h (IQR 51–112), $P < 0.001$, and the median postoperative length of stay was 6 days (IQR 5–9) versus 9 days (IQR 7–13), $P < 0.001$, for the minimally invasive and the median sternotomy groups, respectively.

CONCLUSIONS: Minimally invasive valve surgery in patients with COPD is associated with excellent short-term results, and thus should be considered an option in these patients.

Keywords: Minimally invasive • Valve surgery • Chronic obstructive pulmonary disease

INTRODUCTION

When compared with a standard median sternotomy approach, the reported benefits of minimally invasive valve surgery include reductions in surgical trauma, such as blood loss and the need for re-operation for bleeding and pain. In addition, practitioners report preserved lung function, a more rapid return to functional activity, shorter intensive care unit and hospital stay, less use of rehabilitation resources and reduced cost [1–4]. Alternatively, minimally invasive valve surgery is more technically demanding, tends to have longer aortic cross clamp and cardiopulmonary bypass times [4], which could potentially negatively impact the outcomes. However, because of less chest wall trauma with minimally invasive valve surgery, we hypothesized that patients with chronic obstructive pulmonary disease (COPD) might have improved outcomes when compared with COPD patients undergoing a median sternotomy.

METHODS

After obtaining approval from the Institutional Review Board, we retrospectively reviewed a computerized database of 2846 consecutive heart surgery done at the Mount Sinai Heart Institute, Miami Beach, FL, USA, between January 2005 and September 2010, to identify those patients with COPD who underwent isolated valve surgery. The outcomes of those who underwent a minimally invasive approach were compared with a cohort of matched patients who underwent a median sternotomy approach. The median sternotomy surgery was performed by a group of five surgeons, while the minimally invasive surgery was performed by a single surgeon.

The definitions and variables selected were based on the Society of Thoracic Surgeons (STSs) Database definitions. COPD was defined as mild when the forced expiratory volume in 1 min (FEV1) was ≥80% of predicted, and/or the patient was on chronic inhaled or oral bronchodilator therapy. Moderately severe COPD was defined as a FEV1 of ≥50% to <80% of predicted, and/or the patient was on chronic steroid therapy aimed at the lung disease, and severe COPD was defined as having an FEV1 of <50% of predicted, and/or a room air $pO_2 < 60$ mmHg or a room air $pCO_2 > 50$ mmHg.

In all patients, the valvular lesions were documented by diagnostic catheterization and echocardiography. All operative reports and echocardiograms were reviewed. The primary outcome was operative mortality, defined as in-hospital mortality, surgical complications, intensive care unit length of stay and postoperative length of stay. Surgical complications were defined as the presence of postoperative renal failure, prolonged ventilation (>24 h), re-intubation, deep wound infection, sepsis, pneumonia, bleeding requiring re-exploration, stroke, development of atrial fibrillation and death. The surgical technique time was compared with the aortic cross clamp time and total cardiopulmonary bypass time. The predicted surgical mortality was calculated based on the STS risk algorithm. Excluded were patients with previous coronary artery bypass graft or valve surgery, those needing emergency surgery, those with endocarditis and those who had concomitant coronary artery bypass graft surgery or needed surgery on a second valve. The same extubation protocol was used in all patients. The blood transfusion protocol utilized is the one recommended by the American Society of Anesthesiology [5].

Technique for minimally invasive valve surgery

All patients were placed in the supine position and underwent anaesthetic induction and intubation with a single-lumen endotracheal tube and a bronchial blocker. A roll was placed underneath the right scapula in patients undergoing a minimally invasive mitral valve procedure. Every patient had a Swan-Ganz catheter and a radial arterial line placed. A transoesophageal echocardiogram Doppler probe was placed intra-operatively to evaluate the diseased valves as well as to assess the postoperative results.

In all the cases, a left femoral platform was utilized to establish cardiopulmonary bypass. We choose the left side for cannulation because the right side is usually used to perform the cardiac catheterization, and by utilizing the left side we avoid further trauma to the right side. A 2- to 3-cm incision was made in the left inguinal crease. Limited dissection was performed to decrease the risk of groin complications. A 5–0 Prolene (Ethicon, Somerville, NJ, USA) purse string suture was placed on the femoral artery and vein. After heparinization, a Seldinger technique was utilized to cannulate the femoral vessels. The left femoral artery was cannulated with a 16–18 French arterial cannula (Edwards Lifescience, Irvine, CA, USA), and the left femoral vein was cannulated with a 25 French venous cannula (Bio-medicus, Medtronic, Minneapolis, MN, USA). Transoesophageal echocardiography was utilized to aid in placement of the venous cannula in the superior vena cava. We do not routinely perform preoperative CT angiography to check for the presence of peripheral vascular disease and/or aortic pathology. If a significant peripheral vascular disease is suspected by history and/or physical examination, present at the time of femoral cannulation, or severe aortic atherosclerosis is evident by transoesophageal echocardiography, then central aortic cannulation would have been performed for the aortic valves, and axillary artery cannulation would have been done for the mitral valve procedures.

For the mitral valve procedures, a 5-cm skin incision was made in the 4–5th intercostal space at the site of the anterior axillary line. For the aortic valve procedures, a 5-cm transverse parasternal incision was made over the 2nd–3rd intercostal space, and the 2nd or 3rd costochondral cartilage was transected to allow for an adequate exposure of the aorta. At the completion of the operation, the rib was reattached to the sternum with a 1-cm metal plate (Synthes, West Chester, PA, USA) and a fiberwire placed in a figure-of-eight fashion. In all cases, the pericardium was opened above the phrenic nerve and over the aorta to facilitate the exposure. Utilizing transoesophageal echocardiography guidance, a retrograde coronary sinus catheter was inserted through a purse string suture placed in the right atrium directly through the incision. In aortic valve procedures, a left ventricular vent was inserted into the left ventricle via a purse string suture in the right superior pulmonary vein.

Cardiopulmonary bypass was initiated at 32–36°C using a closed membrane oxygenator and a roller pump. Venous drainage was augmented with vacuum assistance applying negative pressures of 30–70 mmHg, as needed to decompress the right heart. Trans-incisional direct aortic cross clamping was performed utilizing a flexible and retractable shaft cross clamp (Novare Surgical Systems, Cupertino, CA, USA). 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 20–25 min intervals. If retrograde cardioplegia cannulation was not possible, a cannula was left in the ascending aorta to deliver antegrade cardioplegia. Cold fibrillatory arrest was utilized only in patients undergoing mitral valve surgery who had a history of previous cardiac surgery.

For the mitral valve repair and replacements, the mitral valve was accessed through Waterson's groove, and a left lateral atriotomy is performed to enter the left atrium. A specially designed atrial lift retractor and atrial exposure device was utilized for visualization of the mitral valve. Mitral valve repair or replacement was carried out in the standard fashion under direct transincisional visualization. A 4–0 Prolene suture was used to close the left atrium. For the aortic valve procedures, a transverse aortotomy was performed for exposure of the aortic valve. Valve replacement was carried out under direct vision as well as utilizing standard techniques. All procedures were performed with specially designed long-shafted minimally invasive instruments (Geister, Tuttlingen, Germany). Carbon dioxide was infused into the operative field during the entire procedure.

The removal of air from the heart was performed with a needle in the root of the aorta with transoesophageal echocardiographic guidance. The heart was not directly manipulated during de-airing manoeuvres. If needed, external compression of the chest wall is performed to aid in de-airing. With the heart empty, a ventricular pacing wire was placed. After discontinuing cardiopulmonary bypass, once half of the protamine is given, we remove the femoral venous cannula and tie the purse string suture. When the entire protamine dose is given and the patient is haemodynamically stable, the arterial cannula is removed and the arterial purse string suture is also tied. We do not obtain proximal or distal control of the vessel nor perform a direct open repair, unless there is a suspicion of diminished distal flow. A single chest tube was left in the pleural space. The thoracotomy incision was closed in the routine fashion. The median sternotomy cases were performed using standard techniques, with central cannulation.

For the median sternotomy cases, a median sternotomy incision was performed. A sternal saw was utilized to perform a median sternotomy. After placement of a sternal retractor, the pericardium was opened in the midline and tacked to the skin. Aortic, venous and cardioplegia cannulation were performed in the routine fashion. Cardiopulmonary bypass was initiated and the aorta was cross clamped. Cardioplegia was given in an antegrade and retrograde fashion and repeated at 15 min intervals. After electromechanical arrest of the heart, the valve repair/replacement was performed in the routine fashion.

Statistical methods

All continuous variables were expressed as the mean ± 1 standard deviation, or median and interquartile range (IQR, 25–75). To compare continuous variables between groups that had a normal distribution an independent *t*-test was used. Continuous variables that did not exhibit a normal distribution were compared with a Mann–Whitney test. All dichotomous variables were compared using chi-square analysis. Multivariable logistic regression analysis was performed to analyse the variables that were predictors of composite complications. A *P*-value of <0.05 was considered statistically significant. The statistical analyses were done using SPSS, version 19 (Chicago, IL, USA).

RESULTS

We identified 165 patients with COPD who underwent isolated valve surgery. Of these, 100 had minimally invasive surgery, while 65 underwent valve surgery via a median sternotomy. The minimally invasive group had a mean age of 71 ± 11 years, and consisted of 49 males (49%) and 51 females (51%), while the median sternotomy group had a mean age of 68 ± 12 years and consisted of 35 (54%) males and 30 females (46%), *P* = 0.31 and 0.54, respectively. In addition, STSs predicted surgical mortality, preoperative creatinine, hypertension, diabetes mellitus, history of coronary artery disease, and ejection fraction, or history of cerebrovascular accident did not differ significantly between the minimally invasive and median sternotomy groups. The severity of the COPD was mild, moderate or severe in 15, 82 and 3% of the patients in the minimally invasive group, while in the median sternotomy group, 19% were mild, 75% were moderate and 6% were severe, *P* = 0.49. The minimally invasive group had 47% aortic valve replacements and 53% had mitral valve surgery, while the median sternotomy group had 43% aortic valve replacement and 57% had mitral valve surgery, *P* = 0.62 and 0.57, respectively (Table 1).

The aortic cross clamp and cardiopulmonary bypass times were 84 (IQR 71–102) and 118 (IQR 102–140) min, respectively, for the minimally invasive group, and 53 (IQR 41–74) (*P* < 0.001) and 80 (IQR 60–106) min (*P* < 0.001) for the median sternotomy group. However, the number of units of packed red blood cells transfused were lower in the minimally invasive group with a median of 2 units (IQR 0–4), compared with 4 units (IQR 3–7) in the median sternotomy group, *P* ≤ 0.001. The intensive care unit length of stay was significantly shorter for the minimally invasive group compared with the median sternotomy group, 47 h (IQR 40–70) versus 71 h (IQR 49–96), *P* ≤ 0.001 (Table 2).

In-hospital mortality was 1 (1%) for the minimally invasive group and 3 (5%) for the median sternotomy group (*P* = 0.14). The cause of death of the patient in the minimally invasive group was worsening heart failure, and in the median sternotomy group, the causes of death were: pneumonia, ventricular tachycardia and multisystem organ failure. Composite postoperative complications were significantly reduced in the minimally invasive group (30 versus 54%), *P* = 0.002. The incidence of acute renal failure was 0 versus 1 (1.5%), *P* = 0.21. The incidence of prolonged intubation was 13 versus 28%, *P* = 0.02, and re-intubation was 6 versus 9%, *P* = 0.44; while deep wound infections were 0 versus 2%, *P* = 0.21, in the minimally invasive and median sternotomy groups, respectively. There were no statistically significant differences in the incidence of bleeding requiring re-operation, strokes or incidence of postoperative atrial fibrillation between the two groups, *P* = 0.98, 0.66 and 0.1, respectively. The median postoperative length of stay was 6 days (IQR 5–9) versus 9 days (IQR 7–13), *P* < 0.01, for the minimally invasive and

Table 1: Patient baseline characteristics

Variables	Minimally invasive, *n* = 100	Median sternotomy, *n* = 65	*P*-value
Age (mean ± SD)	71 ± 11	68 ± 12	0.31
Male gender (%)	49 (49)	35 (54)	0.54
STS score predicted mortality (%)	3.64 ± 2.9	4.98 ± 4.4	0.08
Preoperative creatinine (mg/dl)	1.22 ± 0.8	1.13 ± 10.6	0.72
Hypertension (%)	89 (89)	58 (89)	0.96
Diabetes mellitus (%)	38 (38)	32 (49)	0.15
History of coronary artery disease (%)	56 (56)	42 (65)	0.28
Ejection fraction (%)	53 ± 14	51 ± 15	0.76
History of cerebrovascular accident (%)	8 (8)	5 (8)	0.94
Pulmonary artery systolic pressure (mean ± SD)	28.5 ± 11	28.6 ± 8	0.89
History of atrial fibrillation (%)	25 (25)	20 (31)	0.34
Severity of lung disease (mild/moderate/severe), *n* (%)	15/82/3 (15/82/3)	12/49/4 (19/75/6)	0.49
Aortic valve replacement (%)	47 (47)	28 (43)	0.62
Mitral valve replacement/repair (%)	20/33 (20/33)	11/26 (17/40)	0.57

SD: standard deviation.

Table 2: Operative results

Variables	Minimally invasive	Median sternotomy	*P*-value
Aortic cross-clamp time (min, IQR)	84 (71–102)	53 (41–74)	<0.001
Cardiopulmonary bypass time (min, IQR)	118 (102–140)	80 (60–106)	<0.001
Transfusion of PRBC's (units, median, IQR)	2 (0–4)	4 (3–7)	<0.001
Intensive care unit length of stay (h, median, IQR)	47 (40–70)	71 (49–96)	<0.001

PRBC's: packed red blood cells; IQR: interquartile range.

Table 3: Postoperative results

Variables	Minimally invasive, *n* = 100	Median sternotomy, *n* = 65	*P*-value
In-hospital mortality (%)	1 (1)	3 (5)	0.14
Composite complications (%)	30 (30)	35 (54)	0.002
Postoperative renal failure	0	1 (1.5%)	0.21
Prolonged ventilation (%)	13 (13)	18 (28)	0.02
Re-intubation (%)	6 (6)	6 (9)	0.44
Sternal deep wound infection (%)	0 (0)	1 (2)	0.21
Sepsis (%)	1 (1)	3 (5)	0.14
Pneumonia (%)	1 (1)	2 (3)	0.33
Bleeding requiring re-operation (%)	3 (3)	2 (3)	0.98
Stroke (%)	2 (2)	2 (3)	0.66
Atrial fibrillation (%)	17 (17)	18 (28)	0.1
Any infection (%)	3 (3)	7 (11)	0.04
Need for dialysis	0 (0)	1 (1.5%)	0.21
Hospital length of stay (days, median, IQR)	6 (5–9)	9 (7–13)	<0.001

Table 4: Binary logistic regression analysis of composite complications

Variables	Odds ratio	95% confidence interval		*P*-value
		Lower	Upper	
Minimally invasive surgery	0.367	0.192	0.703	0.002

The variables entered in the logistic regression were minimally invasive surgery, surgeon and coronary artery disease.

the median sternotomy groups, respectively (Table 3). All patients who were scheduled to undergo minimally invasive surgery did so, and did not need to undergo conversion to a median sternotomy.

Multivariable analyses

Binary logistic regression analysis showed that the minimally invasive technique was an independent factor for a lower composite complication rate (OR 0.367, 95% CI 0.192–0.703, $P = 0.002$), while the specific surgeon performing the procedure was not statistically significant as an independent predictor factor of this outcome (Table 4).

DISCUSSION

A clinical history of COPD is present in 4–27% of patients undergoing cardiac surgery [6–8], and is associated with an increase in postoperative pulmonary, infectious complications and death [9–13]. Traditionally, cardiac surgery has been performed via a median sternotomy. However, in the past decade, minimally invasive approaches have demonstrated improved outcomes, especially in high-risk patients, such as the elderly, obese and patients undergoing re-operation [14–16]. Because of the benefits noted in high-risk patients with minimally invasive surgery, we hypothesized that there would be a similar benefit in patients with COPD when compared with those with a median sternotomy approach.

The data on the pulmonary effects of minimally invasive valve surgery are limited. There are five small randomized controlled trials, in patients without COPD, which reported on the pulmonary status when comparing minimally invasive valve surgery with median sternotomy [17–21]. None of the trials recruited more than 120 patients. The total number of patients evaluated was 340, with 170 patients being in the minimally invasive group and 170 in the median sternotomy group. Three of the trials, involving only aortic valve replacement surgery, demonstrated that minimally invasive surgery was associated with a shorter ventilation time, a higher total lung capacity, improved maximum inspiratory and expiratory pressures [17–19]. The other two trials, one involving aortic valve replacement and another involving mitral valve surgery, reported no significant differences in extubation times, or pulmonary function tests performed postoperatively, when comparing the minimally invasive group with the median sternotomy group [20, 21]. To our knowledge, there are no studies directly comparing the outcomes of minimally invasive valve surgery against median sternotomy in patients with COPD. Our study demonstrated that in patients with COPD a significant reduction in composite complications is noted with a minimally invasive approach when compared with a median sternotomy, with the difference in prolonged intubation being statistically significant.

After a median sternotomy, there are decreases in forced vital capacity, expiratory volume in the first second of forced expiration, peak expiratory flow rate, and maximum voluntary ventilation [22]. The cause of this is multi-factorial, with the effects of cardiopulmonary bypass playing a role, probably due to the effects of a systemic inflammatory response [23]. In our study, the patients who underwent minimally invasive surgery had significantly longer aortic cross clamp, and cardiopulmonary bypass times, yet had improved outcomes. Our study suggests that the benefits of a minimally invasive approach, which include less pain, less structural alterations of chest wall mechanics and less respiratory muscle weakness, may outweigh the deleterious effects of increased cardiopulmonary bypass times.

The better stability of the thorax noted with minimally invasive surgery leads to earlier mobilization and return to daily activities [2]. This enhanced recovery was confirmed in our study, with the minimally invasive group having a significant decrease in the incidence of prolonged ventilation, leading to reductions in both intensive care unit and hospital lengths of stay, when compared with the median sternotomy group. There was also a reduction in the use of packed red blood cells transfusions, all of which contribute to a lowering of cost by reducing resource utilization [24, 25].

Study limitations

This was a single-centre retrospective study. A single surgeon performed all minimally invasive surgery (Joseph Lamelas), while the median sternotomy surgery was performed by a five-surgeon group, without overlap. Thus, there are significant uncontrollable confounders. In addition, the follow-up period was short, and the main comparison of the two groups was limited to in-hospital outcomes. The vast majority (96%) of patients also had COPD that was mild or moderate in severity, so our results are more applicable to these types of patients.

In conclusion, minimally invasive valve surgery in patients with COPD is associated with a significant reduction in morbidity, and resource utilization, when compared with a median sternotomy approach. It should be considered a surgical option in these patients.

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Conflict of interest: none declared.

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