Outcomes of Reoperative Aortic Valve Replacement via Right Mini-Thoracotomy versus Median Sternotomy

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Background and aim of the study: **The study aim was to determine the safety and efficacy of a minimally invasive right mini-thoracotomy for aortic valve replacement (AVR) in patients who had undergone previous median sternotomy.**
Methods: **Between January 2005 and December 2011, a total of 3,603 consecutive cases was retrospectively reviewed to identify patients with previous median sternotomy who subsequently underwent AVR. The outcomes of patients having minimally invasive surgery were compared with those in whom a median sternotomy approach had been employed.**
Results: **Among 77 patients identified, 36 (47%) underwent a minimally invasive approach, and 41 (53%) had a median sternotomy. The mean age of the minimally invasive group (33 males, three females) was 75.3 ± 9.0 years, and that of the median sternotomy group (33 males, eight females) was 68.2 ± 13.6 years (p = 0.009). The minimally invasive group had more prior sternotomy for coronary artery bypass graft surgery (86% versus 59%, p = 0.007), and fewer for prior valve surgery (33% versus 59%, p = 0.02). In-hospital mortality was zero for the minimally invasive cohort versus four (10%) in the median sternotomy group (p = 0.08); composite postoperative complications occurred in six (17%) versus 19 (46%) (p = 0.005) of these two groups, respectively. The median intensive care unit and total hospital length of stay were 48 h [interquartile range (IQR) 41-97] versus 69 h [IQR 45-174] (p = 0.03), and seven days [IQR 5-10] versus 9 days [IQR 7-15] (p = 0.03) for the minimally invasive and median sternotomy group, respectively.**
Conclusion: **Minimally invasive AVR via a right mini-thoracotomy in patients with previous cardiac surgery can be performed safely, and is associated with shorter intensive care unit and total hospital stays, a lower morbidity, and a trend towards lower mortality.**

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According to the Society of Thoracic Surgeons (STS) National database, the number of patients undergoing isolated aortic valve surgery has increased significantly over time. In 1997, a total of 9,407 patients underwent single aortic valve surgery, but by 2006 this had increased to 15,397 (1). The proportion of patients with a history of prior coronary bypass graft or valve surgery who underwent subsequent isolated aortic valve surgery was also increased, from 13.6% in 1997 to 15.9% in 2006. Compared with primary valve surgery, patients requiring reoperation are at increased risk for sternal wound infection, and bleeding (2). They also require more transfusions, have prolonged cardiopulmonary bypass (CPB) times, and a higher mortality (1,3-5). The mortality rate reported in the STS database for aortic valve surgery in patients with a previous sternotomy was 6.17%, compared to 2.35% for first-time procedures (1). Other studies have reported mortality rates in the range of 2% to 11.3%, but this can increase up to 32% for elderly patients (3,6,7).

These increased mortality rates are most likely due to mediastinal adhesions; reoperated patients also require longer CPB times and are at increased risk for injuries to cardiac structures, including coronary artery bypass grafts (5,8). In theory, minimally

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invasive surgery could limit local complications and therefore modify the postoperative outcomes.

In the present study, a retrospective comparison was made between the outcomes of patients with a history of prior median sternotomy for coronary bypass or valve surgery who underwent a right mini-thoracotomy for aortic valve replacement (AVR), and those who had undergone a standard median sternotomy.

Clinical material and methods

Patients

A total of 3,603 consecutive cardiac operations performed at the present authors' institution between January 2005 and December 2011 was retrospectively evaluated to identify patients with a history of prior median sternotomy for coronary artery bypass or valve surgery who underwent AVR. The outcomes of patients who had undergone minimally invasive surgery via a right mini-thoracotomy were compared to those who had a repeat median sternotomy. Patients who had undergone concomitant ascending aorta procedures, those that required surgery on another valve, and/or had emergent surgery were excluded.

The minimally invasive surgery was performed by a single surgeon, while median sternotomies were carried out by a group of five surgeons, none of whom performed minimally invasive surgery.

Approval to conduct the study was granted by the Mount Sinai Medical Center Institutional Review Board.

Data acquisition

The variables analyzed included a composite of in-hospital death, stroke, re-exploration for bleeding, prolonged ventilation, reintubation, renal failure, and deep wound infection. Standard STS definitions of end-points were used (9). The need to transfuse red blood cells, the number of units transfused, aortic cross-clamp time and total CPB time, intensive care unit length of stay and postoperative hospital length of stay were analyzed, as were the individual components of the primary end-point. The STS risk score of mortality was calculated for all patients. Patients undergoing minimally invasive surgery were evaluated 30 days postoperatively, at the surgeon's office.

Surgical technique

The technique for minimally invasive valve surgery used in this series has been described previously (10,11). In brief, a femoral platform is utilized to establish CPB, after which a 4-5 cm transverse parasternal skin incision is made over the right second or third intercostal space, and the second or third costochondral cartilage is transected in order to allow adequate exposure of the aorta. Replacement of the aortic valve was conducted in routine fashion. On completion of surgery the rib was reattached to the sternum, using a 1 cm metal plate (Synthes, West Chester, PA, USA).

In patients who had previously undergone coronary artery bypass graft (CABG) surgery with a patent left internal mammary graft (LIMA), moderate hypothermia (28º C) was used with one induction dose of antegrade cardioplegia. Thereafter, retrograde cardioplegia was delivered at 20-min intervals. The LIMA pedicle was not dissected. In the setting of a LIMA placed to a left anterior descending (LAD) artery that is totally occluded, there is less blood return from the left main into the aortic root. If the native LAD artery is patent, a 10 Fr red rubber catheter connected to pump suction was placed in the left main artery to aspirate the constant blood return that would otherwise obscure the operative field. If a continuous cardioplegia strategy was used, then a red rubber catheter was placed into the left main artery.

Statistical analysis

Continuous variables were expressed as mean ± SD, or median and interquartile range (IQR, 25-75). Continuous variables with normal distribution were analyzed using Student's *t*-test. The Mann-Whitney *U*-test was used to compare those variables with non-parametric distributions. All dichotomous variables were compared using a chi-squared analysis.

Comorbidities and other risk factors that may have a significant influence on clinical outcomes, including surgical procedural variables, were also evaluated by univariable analyses. Those with $p \leq 0.2$ were included in a logistic regression analysis to determine independent effects. A p-value <0.05 was considered to be statistically significant. All statistical analyses were performed using SPSS software (v. 17; SPSS, Chicago, IL, USA).

Results

A total of 77 patients was identified with a history of prior median sternotomy for coronary bypass graft surgery and/or valve surgery who subsequently underwent AVR. Of these patients, 36 (33 males, three females) underwent a right mini-thoracotomy, and 41 (33 males, eight females) a median sternotomy.

Patients in the right mini-thoracotomy group were significantly older compared to those in the median sternotomy group (mean 75.3 years ± 9.0 versus 68.2 ± 13.6 years; $p = 0.009$). There were no statistically

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Table I: Patient clinical and operative characteristics.

Variable	Right mini-thoracotomy (n = 36)	Median sternotomy (n = 41)	p-value
Clinical characteristics			
Age (years)*	75.3 ± 9.0	68.2 ± 13.6	0.009
Male gender	33 (92)	33 (81)	0.14
Preop. serum creatinine level (mg/dl)+	1.1 (0.9-1.3)	1.2 (1.0-1.5)	0.11
LV ejection fraction (%)+	55 (41-60)	53 (47-58)	0.74
Diabetes mellitus	23 (64)	31 (76)	0.19
Hypertension	33 (92)	35 (85)	0.31
Peripheral vascular disease	6 (17)	9 (22)	0.39
Cerebrovascular disease	5 (14)	7 (17)	0.47
Coronary artery disease	32 (89)	24 (59)	0.003
Prior CABG surgery	31 (86)	24 (59)	0.007
Prior valve surgery	12 (33)	24 (59)	0.02
STS risk score of mortality+	3.0 (2.2-4.3)	3.0 (2.3-5.5)	0.73
Operative characteristics			
CPB time (min)+	134 (119-146)	93 (82-122)	<0.001
Aortic cross clamp-time (min)+	90 (76-99)	66 (49-92)	<0.001

*Values are mean ± SD.
+Values are median (IQR).
Values in parentheses are percentages.
CABG: Coronary artery bypass graft; CPB: Cardiopulmonary bypass; IQR: Interquartile range; LV: Left ventricular.

significant differences between the two groups with regards to left ventricular ejection fraction, preoperative serum creatinine level, diabetes mellitus, and most other comorbidities (Table I). However, patients in the minimally invasive group were more likely to have coronary artery disease (89% versus 59%, p = 0.003), and prior sternotomy for CABG surgery (86% versus 59%, p = 0.007). Hence, a greater proportion of patients in the median sternotomy group had a prior sternotomy for valve surgery (59% versus 33%, p = 0.02). The median STS mortality risk score for the right mini-thoracotomy and median sternotomy groups were 3.0 (IQR 2.2-4.3) and 3.0 (IQR 2.3-5.5), respectively (p = 0.73). All patients were hemodynamically stable, and none had endocarditis as the cause of the valve lesion.

One patient (2.8%) in the minimally invasive group who had a prior CABG surgery was converted to median sternotomy. In this case, the surgery was initially carried out as a right mini-thoracotomy but, due to multiple mediastinal adhesions, the exposure of the old grafts was incomplete such that a conversion to median sternotomy was required.

Among patients, the median aortic cross-clamp and CPB times were 90 min (IQR 76-99) versus 66 min (IQR 49-92) (p <0.001) and 134 min (IQR 119-146) versus 93 min (IQR 82-122) (p <0.001) and for the minimally invasive and median sternotomy group, respectively. The in-hospital mortality was zero for the mini-thoracotomy group and four (10%) for the median sternotomy group (p = 0.08). The mortality rate in the minimally invasive group was less than the predicted STS risk score of mortality, although it did not achieve statistical significance (p = 0.56). The composite complication rate was significantly lower in the mini-thoracotomy group [six (17%) versus 19 (46%); p = 0.005]. The difference in postoperative complication rate was driven by a significantly lower incidence of prolonged ventilation (11% versus 42%, p = 0.003). The individual incidences of bleeding requiring reoperation, renal failure, and deep wound infections were lower in the mini-thoracotomy group, but did not achieve statistical significance. There was no inter-group difference in the incidence of stroke or reintubation (Table II).

The need to transfuse packed red blood cells (72% versus 93%, p = 0.02), and the median number of units transfused (1 versus 5, p <0.001) were also significantly lower in the mini-thoracotomy group. The mean intensive care unit and total hospital length of stay were significantly lower in the mini-thoracotomy group than in the median sternotomy group [48 h (IQR 41-97) versus 69 h (IQR 45-174), p = 0.03, and seven days (IQR 5-10) versus nine days (IQR 7-15), p = 0.03] (Table II).

Multivariable analysis controlled for known predictors of postoperative complications and for imbalances between groups. The analysis identified

Table II: Results of the study.

Variable	Right mini-thoracotomy (n = 36)	Median sternotomy (n = 41)	p-value
Postoperative complications	6 (17)	19 (46)	0.005
In-hospital death	0 (0)	4 (10)	0.08
Stroke	3 (8)	1 (2)	0.26
Reoperation for bleeding	0 (0)	4 (10)	0.08
Prolonged ventilation	4 (11)	17 (42)	0.003
Renal failure	1 (3)	4 (10)	0.22
Deep wound infection	0 (0)	2 (5)	0.28
Re-intubation	3 (8)	4 (10)	0.57
Transfusion of packed RBCs	26 (72)	38 (93)	0.02
Units of packed RBCs transfused+	1 (0-2)	5 (3-7)	<0.001
ICU stay (h)+	48 (41-97)	69 (45-174)	0.03
Hospital length of stay (days)+	7 (5-10)	9 (7-15)	0.03

+Values are median (IQR).
Values in parentheses are percentages.
ICU: Intensive care unit; IQR: Interquartile range; RBCs red blood cells.

that a preoperative serum creatinine level >1.6 mg/dl increased the risk of postoperative complications (OR 10.81, 95% CI 2.26-51.73, p = 0.003), while the mini-thoracotomy approach was associated with fewer postoperative complications (OR 0.25, 95% CI 0.08-0.83, p = 0.023) (Table III). Notably, all patients in the minimally invasive group were alive at the 30-day follow up examination.

Discussion

It has been hypothesized that patients with a prior sternotomy who required a second heart operation for AVR would benefit from a minimally invasive surgical approach. Indeed, at the present authors' institution, high-risk patients - including the elderly, obese, and those with previous sternotomy undergoing mitral valve surgery - derive the greatest benefit from minimally invasive surgery (10-12). The present information on reoperative AVR extends these findings to patients with a prior sternotomy and demonstrates that, in this setting, a right mini-thoracotomy is associated with fewer postoperative complications, less need for transfusions, a decreased number of packed red blood cell units transfused, shorter intensive care unit and total hospital lengths of stay, and a trend towards lower mortality, when compared to a standard median sternotomy. It is felt that the less traumatic nature of this surgery, coupled with a lower use of blood products, overcomes the deleterious effects of the longer operative times, leading to an enhanced recovery in these patients.

The information currently available on patients undergoing minimally invasive AVR and with a history of previous sternotomy is limited, and consists mainly of using an upper hemi-sternotomy approach (13-17). Grossi et al. (18) reported the first case series of 42 patients with prior cardiac surgery who underwent reoperative AVR via a right mini-thoracotomy, and reported a mortality of 9.5%. In only one retrospective study was a minimally invasive approach compared to median sternotomy for reoperative isolated valve surgery (6), and the outcomes of 161 patients (100 undergoing mitral and 61 undergoing aortic surgery) who had a right mini-thoracotomy were compared to those of 339 patients who had a median sternotomy. These authors reported results similar to those of the present study, with decreases in the median hospital

Table III: Multivariable analysis of independent predictors of complications.

Variable	Odds ratio	95% CI		p-value
		Lower	Upper	
Preop. creatinine >1.6 mg/dl	10.81	2.26	51.73	0.003
Minimally invasive surgery	0.25	0.08	0.83	0.023

Age, coronary artery disease, left ventricular ejection fraction, prior coronary bypass surgery, and prior valve surgery were also entered into the multivariable analysis, but were not significant.

stay, in the need for fresh frozen plasma, in deep wound infections, and in postoperative mortality.

The reported postoperative complications rate associated with a right mini-thoracotomy in patients with previous sternotomy undergoing AVR was 23.6% (6). In the present study, a right mini-thoracotomy was shown to be associated with a significant decrease in composite postoperative complications when compared to median sternotomy. Furthermore, the minimally invasive approach was the only independent predictor of lower composite complications in the multivariable analysis. The morbidity benefit was mainly driven by a decreased incidence of prolonged ventilation, most likely associated with the superior chest stability achieved when sternotomy is avoided (8). Other individual components of the primary end-point were numerically less in the right mini-thoracotomy group, but not significantly so.

Bleeding is a common complication of cardiac reoperations (1-5). In a large case series of minimally invasive procedures that included 130 reoperations, it was shown that 83% of patients who had reoperative AVR required blood transfusions, compared to only 49% for primary AVR (13). In another study, the minimally invasive approach via a right mini-thoracotomy for reoperative aortic valve surgery was associated with a decreased number of fresh frozen plasma units transfused when compared to median sternotomy (6). The results of the present study demonstrated that a right mini-thoracotomy for reoperative AVR would significantly reduce the need for the transfusion of packed red blood cells, as well as the number of units transfused.

Although the present study did not include any analysis of cost data, the length of stay may be considered a surrogate for resource uses. A prolonged length of stay will increase hospital costs at all levels (19). Hence, a reduction in both total hospital and intensive care unit lengths of stay, as well as in transfusion requirements, reflects a desirable impact on resource utilization.

Although the present study evaluated the outcomes of minimally invasive valve surgery, an option that may be considered in a select group of patients is the use of transcatheter aortic valve implantation (TAVI). In one treatment arm of the PARTNER (Placement of Aortic Transcatheter Valves) trial, the outcomes of TAVI were compared with surgical AVR in 699 patients with severe aortic stenosis who were considered at high surgical risk (20). The mean STS predicted risk of death at 30 days in the patients studied was 11.8 ± 3.4%. In this prospective randomized trial, 43% of the patients had a history of CABG surgery. The two-year follow up demonstrated similar results between the two treatment options with respect to mortality, reduction in symptoms, and improved valve hemodynamics, but paravalvular regurgitation was more frequent after TAVI and was associated with an increased late mortality. With improvements in patient selection, procedural techniques and device technologies, however, it is likely that TAVI will begin to play a greater role in the treatment of these patients.

Study limitations

The main limitations of the present study were its single-center, retrospective nature, and the heterogeneity of the patients, who underwent surgery over a multi-year span. In addition, the small total number of minimally invasive surgery patients (n = 36) limited the ability to draw any firm conclusions. Furthermore, the surgical teams for each approach were different, which introduced a potential uncontrollable confounder. Other points were that the follow up period was short and the cohorts comprised mainly male patients. Finally, it must be noted that the results obtained were exclusive to minimally invasive surgery via a right mini-thoracotomy, and cannot be extrapolated to other minimally invasive techniques. Nonetheless, the results obtained suggested that minimally invasive AVR by means of a right mini-thoracotomy in patients with a previous median sternotomy is feasible, and may have a low rate of morbidity and mortality. Although suggestive, the present study results cannot firmly conclude whether a minimally invasive approach in these patients is superior to median sternotomy, and further studies are required to confirm the available data. From a purely clinical perspective, however, such a less-invasive approach could well be considered in these patients.

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References

1. Brown JM, O'Brien SM, Wu C, Sikora JA, Griffith BP, Gammie JS. Isolated aortic valve replacement in North America comprising 108,687 patients in 10 years: Changes in risks, valve types, and outcomes in the Society of Thoracic Surgeons National Database. J Thorac Cardiovasc Surg 2009;137:82-90
2. Gulbins H, Pritisanac A, Hannekum A. Minimally invasive heart valve surgery: Already established in clinical routine? Expert Rev Cardiovasc Ther 2004;2:837-843

3. Maganti M, Rao V, Armstrong S, Feindel CM, Scully HE, David TE. Redo valvular surgery in elderly patients. Ann Thorac Surg 2009;87:521-526
4. Langanay T, Verhoye JP, Ocampo G, et al. Current hospital mortality of aortic valve replacement in octogenarians. J Heart Valve Dis 2006;15:630-637
5. Follis FM, Pett SB, Jr., Miller KB, Wong RS, Temes RT, Wernly JA. Catastrophic hemorrhage on sternal reentry: Still a dreaded complication? Ann Thorac Surg 1999;68:2215-2219
6. Sharony R, Grossi EA, Saunders PC, et al. Minimally invasive reoperative isolated valve surgery: Early and mid-term results. J Card Surg 2006;21:240-244
7. LaPar DJ, Yang Z, Stukenborg GJ, et al. Outcomes or reoperative aortic valve replacement after previous sternotomy. J Thorac Cardiovasc Surg 2010;139:263-272
8. Phillips BJ. Minimally-invasive surgery: Reoperative AVR. Internet J Thorac Cardiovasc Surg 2005;7(1).
9. Edmunds LH, Clark RE, Cohn LH, Grunkemeier GL, Miller C, Weisel RD. Guidelines for reporting morbidity and mortality after cardiac valvular operations. Ann Thorac Surg 1996;62:932-935
10. Lamelas J, Sarria A, Santana O, Pineda AM, Lamas GA. Outcomes of minimally invasive valve surgery versus median sternotomy in patients 75 years of age with isolated valve lesions. Ann Thorac Surg 2011;91:75-80
11. Santana O, Reyna J, Grana R, Buendia M, Lamas GA, Lamelas J. Outcomes of minimally invasive valve surgery versus standard sternotomy in obese patients undergoing isolated valve surgery. Ann Thorac Surg 2011;91:406-410
12. Mihos CG, Santana O, Lamas GA, Lamelas J. Outcomes of right mini-thoracotomy mitral valve surgery in patients with previous sternotomy. Ann Thorac Surg 2011:91:1824-1828
13. Tabata M, Umakanthan R, Cohn LH, et al. Early and late outcomes of 1000 minimally invasive aortic valve operations. Eur J Cardiothorac Surg 2008;33:537-541
14. Bakir I, Casselman FP, De Geest R, et al. Should minimally invasive aortic valve replacement be restricted to primary interventions? Thorac Cardiovasc Surg 2007;55:304-309
15. Tabata M, Khalpey Z, Shekar PS, Cohn LH. Reoperative minimal access aortic valve surgery: Minimal mediastinal dissection and minimal injury risk. J Thorac Cardiovasc Surg 2008;136:1564-1568
16. Totaro P, Carlini S, Pozzi M, et al. Minimally invasive approach for complex cardiac surgery procedures. Ann Thorac Surg 2009;88:462-467
17. Byrne JG, Karavas AN, Adams DH, et al. Partial upper re-sternotomy for aortic valve replacement or re-replacement after previous cardiac surgery. Eur J Cardiothorac Surg 2000;18:282-286
18. Grossi EA, LaPietra A, Bizekis C, Ribakove G, Galloway AC, Colvin SB. Minimal access reoperative mitral and aortic valve surgery. Curr Cardiol Rep 2000;2:572-574
19. Black D, Pearson M. Average length of stay, delayed discharge, and hospital congestion. Br Med J 2002;325:610-611
20. Kodali SK, Williams MR, Smith CR, et al. Two-year outcomes after transcatheter or surgical aortic-valve replacement. N Engl J Med 2012;366: 1686-1695