Outcomes of Minimally Invasive Valve Surgery Versus Median Sternotomy in Patients Age 75 Years or Greater

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Background. **Advanced age is a major predictor of poor outcome in patients undergoing valve surgery. We hypothesized that elderly patients who underwent minimally invasive valve surgery for aortic or mitral valve disease would do better when compared with those undergoing the standard median sternotomy.**

Methods. **We retrospectively reviewed 2,107 consecutive heart operations at our institution and identified 203 patients, age 75 years or greater, who underwent isolated mitral or aortic valve surgery. Outcomes of those who had minimally invasive valve surgery through a right minithoracotomy were compared with those who had a median sternotomy.**

Results. **Of the 203 patients, 119 (59%) underwent a minimally invasive approach, while 84 (41%) had a median sternotomy. The median postoperative length of stay was 7 days (interquartile range [IQR] 6 to 10) versus 12 days (IQR 9 to 20), p less than 0.001, and intensive care unit length of stay was 52 hours (IQR 44 to 93) versus 119 hours (IQR 57 to 193), p less than 0.001 for minimally invasive and median sternotomy, respectively. In-hospital mortality was 2 (1.7%) versus 8 (9.5%, p = 0.01 and composite postoperative morbidity and mortality occurred in 25 (21%) versus 38 (45.2%), p less than 0.001, in minimally invasive versus median sternotomy, respectively. The difference was driven by the following: a lower incidence of acute renal failure, 1 (0.8%) versus 14 (16.7%), p less than 0.001; prolonged intubation 23 (19.3%) versus 32 (38.1%), p = 0.003; wound infections 1 (0.8%) versus 5 (6%), p = 0.034; and death.**

Conclusions. **Minimally invasive surgery for isolated valve lesions in elderly patients yields a lower morbidity and mortality when compared with median sternotomy and should be considered when such individuals require valve surgery.**

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Individuals of age 80 and greater account for the fastest growing sector of the population, and valvular heart disease disproportionately affects these patients [1]. Nkomo and colleagues [2], published data from Olmstead County and from several National Institutes of Health registries showing an increase in valvular heart disease from less than 2% in those age 65 and less years to 11% to 13% in those age 75 and greater. Severity data reported from the Framingham Heart Study [3] calculated that the incidence of at least moderate mitral regurgitation increased from 2.4% in patients ages 60 to 69 to 11.2% in those ages 70 to 83. Similarly, more than 4% of the US population age 75 years and greater have aortic stenosis, and half of those affected will progress to hemodynamically severe aortic stenosis [4]. This is a potential population of 4.2 to 5.6 million at present, expected to double by 2030. Unfortunately, elderly patients undergoing cardiac surgery are more likely to have comorbid conditions, a prolonged postoperative course, and a higher mortality [5].

Historically, valve surgery through a median sternotomy has been the standard of care, but in the past decade minimally invasive approaches have demonstrated improved outcomes [6–15]. Most of these favorable data, however, come from studies in which the elderly were excluded or had a small representation in the sample. Therefore, robust data addressing surgical techniques in elderly patients are lacking. In the present study, we retrospectively analyzed the outcomes of patients 75 years of age or greater with isolated valve lesions who underwent exclusively a right minithoracotomy as the minimally invasive approach for valve repair or replacement, and compared them with those who were candidates for this approach but instead had a standard median sternotomy.

Material and Methods

After obtaining approval from the Institutional Review Board, we retrospectively reviewed a computerized database of 2,107 consecutive heart surgery done at our

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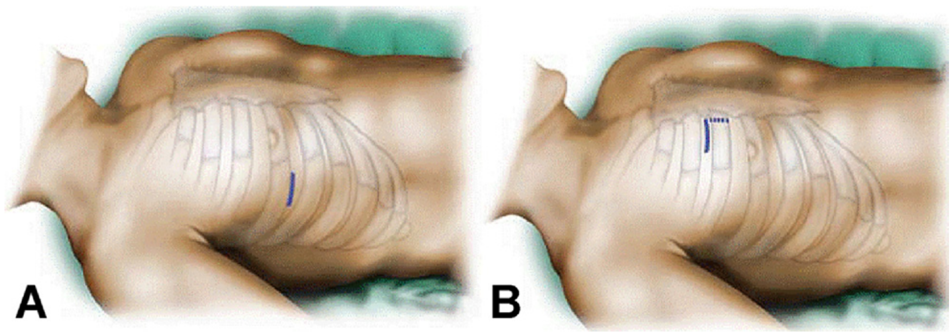

Fig 1. (A) For mitral valve procedures, a 4 to 5 cm skin incision is made in the right fourth to fifth intercostal space medial to the anterior axillary line. (B) For aortic valve procedures, a 4 to 5 cm transverse parasternal incision is made over the right second to third intercostal space and the second or third costochondral cartilage is transected.

institution between January 2005 and September 2009. Of these, 854 were coronary artery bypass surgery, 683 involved single valve aortic or mitral surgery, 411 were concomitant valve and bypass surgery, and 144 were multivalve surgery. Of the 683 single valve procedures, 227 were in subjects 75 years of age and greater. Of those that had been performed by a median sternotomy, 108 cases were reviewed to identify those that would have been candidates for a minimally invasive approach. A total of 24 median sternotomy cases were excluded, 19 due to a history of prior sternotomy requiring aortic valve surgery (11 for coronary artery bypass grafting and 8 for a prior valve surgery), the remaining 5 were excluded due to a concomitant aortic aneurysm requiring repair. Of note, no mitral valve cases were excluded, because a prior sternotomy or redo mitral valve did not preclude from performing a right minithoracotomy. The median sternotomy cases that we included in the analysis were compared with those that underwent the minimally invasive approach. Subjects who started as minimally invasive and were converted to median sternotomy were included in the minimally invasive group in order to conform to the "intention-to-treat" principle.

All minimally invasive cases were performed by a single surgeon (J.L.) who operates by this approach exclusively. During this period of time only 6 cases were performed by him through a median sternotomy, in patients not candidates for a right minithoracotomy. These cases were individually reviewed to identify the technical contraindications to the right minithoracotomy approach. All median sternotomy cases were carried out by a different group of four operating surgeons, none of whom perform minimally invasive surgery.

The primary endpoint for analysis was a composite of in-hospital death, stroke, reexploration for bleeding, prolonged ventilation, renal failure, and deep wound infection. The definitions for the individual complications can be found in the Society of Thoracic Surgeons database, which has been previously published [16]. Intensive care unit length of stay, postoperative hospital stay, cross-clamp time, and total bypass time were also analyzed, as were the individual components of the primary endpoint.

Technique for Minimally Invasive Surgery Using a Right Minithoracotomy

A femoral platform was utilized to establish cardiopulmonary bypass. The left femoral artery was cannulated with a 16 to 18 French arterial cannula, and the left femoral vein was cannulated with a 25 French venous cannula (Bio-medicus; Medtronic, Minneapolis, MN). With the aid of transesophageal echocardiography the venous cannula was placed in the superior vena cava. If significant peripheral vascular disease was present, central ascending aortic cannulation was utilized for the aortic valve replacements and axillary artery cannulation was performed for the mitral valve procedures.

For the mitral valve procedures a 4 to 5 cm skin incision was made in the right fourth to fifth intercostal space medial to the anterior axillary line. For the aortic valve procedures a 4 to 5 cm transverse parasternal incision was made over the right second or third intercostal space, and the second or third costochondral cartilage was transected in order to allow adequate exposure of the aorta (Fig 1). At the completion of the operation the rib was reattached to the sternum with a 1-cm metal plate (Synthes, West Chester, PA). Utilizing transesophageal echocardiography guidance, a retrograde coronary sinus catheter was directly inserted through the incision. The rest of the surgical technique was performed as previously described by Cohn and colleagues [6].

In patients with a previous coronary artery bypass graft surgery and a patent LIMA (left internal mammary graft) undergoing aortic valve replacement, we use moderate hypothermia (28°C) with one induction dose of antegrade cardioplegia. Thereafter, retrograde cardioplegia is delivered at 20-minute intervals. We do not dissect the LIMA pedicle. In the setting of a patent LIMA, we prefer the native left anterior descending artery to be totally occluded. This diminishes a constant stream of blood return from the left main obscuring the operative field. If the left anterior descending artery is patent, we place a no. 10 French red rubber catheter connected to a pump suction into the left main to aspirate the blood. In patients undergoing a mitral valve surgery, with a history of coronary artery bypass graft surgery, we use moder-

Table 1. In-Hospital Mortality Univariable Analysis

Variable	Yes = 10	No = 193	p Value
Age (mean)	83.6	80.4	0.08
Body mass index (mean)	25.1	26.7	0.15
Preoperative creatinine (mean)	1.85	1.08	0.03
Ejection fraction (mean)	0.546	0.539	0.51
Diabetes mellitus	2 (20%)	50 (26%)	0.68
Hypertension	10 (100%)	179 (93%)	0.38
Peripheral artery disease	2 (20%)	13 (6.7%)	0.12
Cerebrovascular disease	2 (20%)	26 (13.5%)	0.56
Prior coronary artery bypass surgery	5 (50%)	17 (8.9%)	<0.001
Prior valve surgery	3 (30%)	13 (6.7%)	0.001
Congestive heart failure	8 (80%)	82 (42.5%)	0.02
Minithoracotomy	2 (20%)	117 (60.9%)	0.01

ate-to-deep hypothermia (24 to 26°C) and fibrillatory arrest. Cardioplegia is not delivered at all. Very little dissection is performed and removal of air from the heart is performed through a vent placed through the atriotomy, mitral valve, and into the left ventricle.

Statistical Methods

All continuous variables were expressed as the median and interquartile range (IQR). Continuous variables with normal distribution were analyzed using the Student *t* test. The Mann-Whitney *U* test was utilized to compare those variables with nonparametric distributions. All dichotomous variables were compared using χ^2 analysis. Comorbidities and other risk factors that could have a significant influence on clinical outcomes, including surgical procedural variables, were also evaluated by univariable analyses. Those with a p value 0.2 or less were included in logistic regression analysis to determine independent effects (Table 1). A p value of less than 0.05 was considered statistically significant. The statistical analyses were done using SPSS version 17 (SPSS Inc, Chicago, IL).

Results

There were 203 patients at least 75 years of age who underwent isolated valve surgery during the analysis period. Of these, 119 (59%) underwent minimally invasive surgery and 84 (41%) underwent a median sternotomy. The operations were evenly distributed between aortic and mitral valve surgery (Table 2). There were three cases (2.5%) that were initiated minimally invasively but were converted to a median sternotomy; two of them because of heavily calcified aortic roots and the third because of severe scarring and fibrosis of the right pleural space. The two groups were well matched for age, gender, ejection fraction, preoperative serum creatinine, and most other comorbidities (Table 2). Of note, the incidence of preoperative congestive heart failure was higher in the median sternotomy group (p = 0.005).

The aortic cross-clamp and bypass times were significantly longer in the minimally invasive group ($p < 0.001$ for both). The in-hospital mortality was 2 (1.7%) for the

Table 2. Patient Clinical Characteristics

Characteristics	Median Sternotomy (n = 84)	Right Minithoracotomy (n = 119)	p Value
Patient characteristics:			
Age, years (median, IQR)	80 (78–84)	79 (77–83)	0.12
Males (%)	37 (44)	47 (39)	0.18
Body mass index (IQR)	26.2 (23.9–29.2)	26.5 (23.1–29.7)	0.95
Preoperative creatinine (IQR)	1.02 (0.87–1.3)	1.02 (0.86–1.25)	0.65
Ejection fraction (median, IQR)	0.55 (0.46–0.60)	0.58 (0.50–0.63)	0.29
Diabetes mellitus (%)	20 (23.8)	32 (26.9)	0.31
Hypertension (%)	80 (95.2)	109 (91.6)	0.62
Peripheral vascular disease (%)	8 (9.5)	7 (5.9)	0.33
Cerebrovascular disease (%)	9 (10.7)	19 (16)	0.29
Prior coronary bypass graft surgery (%)	10 (11.9)	12 (10.1)	0.68
Prior valve surgery (%)	8 (9.5)	8 (6.7)	0.47
Prior heart failure (%)	47 (56)	43 (36.1)	0.005
Procedural characteristics:			
Mitral valve surgery	49%	51%	0.75
Aortic valve surgery	51%	49%	0.75
Cardiopulmonary bypass time minutes (IQR)	86 (39–268)	118 (67–186)	<0.001
Cross-clamp time minutes (IQR)	61 (25–156)	84 (40–154)	<0.001

IQR = interquartile range.

Table 3. Results

Outcomes	Median Sternotomy	Right Minithoracotomy	p Value
Postoperative complications (%)	38 (45)	25 (21)	<0.001
In-hospital death (%)	8 (9.5)	2 (1.7)	0.01
Stroke (%)	4 (4.8)	4 (3.4)	0.61
Reoperation for bleeding (%)	5 (6)	8 (6.7)	0.83
Prolonged ventilation (%)	32 (38)	23 (19)	0.003
Renal failure (%)	14 (16.7%)	1 (0.8%)	<0.001
Wound infection (%)	5 (6%)	1 (0.8%)	0.03
Intensive care unit length of stay hours (IQR)	119 (57–193)	52 (44–93)	<0.001
Total hospital length of stay days (IQR)	12 (9–20)	7 (6–10)	<0.001

IQR = interquartile range.

minimally invasive group and 8 (9.5%) for the median sternotomy group ($p = 0.01$). The complication rates were significantly lower in the minimally invasive group (25 [21%] vs 38 [45%], $p < 0.001$). The difference in postoperative complication rate was mainly driven by a significantly lower incidence of renal failure, prolonged ventilation, and wound infection in the minimally invasive group ($p < 0.001$, $p = 0.003$, and $p = 0.03$, respectively). There was no difference in stroke rate or need for reexploration for bleeding.

The intensive care unit length of stay was significantly lower in the minimally invasive group; 52 hours (IQR 44 to 93) versus the median sternotomy group of 119 hours (IQR 57 to 193) ($p < 0.001$). The postoperative hospital length of stay was also significantly lower in the minimally invasive group; 7 days (IQR 6 to 10) versus 12 days (IQR 9 to 20) in the median sternotomy group ($p < 0.001$) (Table 3).

Multivariable analyses controlled for known predictors of postoperative survival and for imbalances between groups. These analyses identified that prior coronary artery bypass graft surgery, and an elevated preoperative serum creatinine increased the risk of in-hospital mortality (OR [odds ratio] 7.5, 95% CI [confidence interval] 1.5 to 36, $p = 0.01$ and OR 5.5, 95% CI 1.03 to 29, $p = 0.05$, respectively). A higher body mass index and a right minithoracotomy approach, however, independently decreased the risk of in-hospital mortality in these elderly patients (OR 0.8, 95% CI 0.75 to 0.9, $p = < 0.001$ and OR 0.1, 95% CI 0.02 to 0.7, $p = 0.02$, respectively) (Table 4).

Data-derived post hoc analyses showed that, although women had fewer comorbidities than men (Table 5), 7 of the 10 patients who died were women. Thus, the overall reduction in mortality was driven by a significant reduction of mortality in women undergoing a right minithoracotomy approach (1 [1.6%] vs 6 [12.8%], $p = 0.027$).

Comment

When compared with a standard median sternotomy, minimally invasive valve surgery has been shown to reduce morbidity. However, individual studies and meta-analyses of the major trials evaluating minimally invasive valve surgery have failed to demonstrate a reduction in mortality for either mitral or aortic minimally invasive valve surgery [12–15]. The failure to demonstrate a reduction in mortality may have been due to subject selection, with lower-risk populations such as younger individuals, and those with normal renal function. Elderly patients tended to be excluded from these studies, with some surgical centers excluding patients older than 75 years of age [17]. Current preoperative care and surgical technique, which have greatly improved over the last two decades, have reached the point where it may be very difficult to find a mortality benefit in low-risk groups without analyzing prohibitively large samples.

Previous studies have identified advanced age as a predictor of poor outcome after mitral or aortic valve surgery [18–20]. This group of patients develops more postoperative complications that lead to prolonged intensive care unit and total hospital stay that, in turn, translates into higher short-term and long-term mortality [21].

Published comparisons evaluating minimally invasive surgery versus standard median sternotomy in the elderly are limited. A reduction in morbidity with minimally invasive surgery, however, has been reported. In a study by Grossi and colleagues [22], 111 patients undergoing minimally invasive mitral valve surgery who were at least 70 years old were compared with 259 patients who had a median sternotomy. The minimally invasive group had a significantly lower incidence of sepsis and wound complications, required less frozen plasma transfusions, and had a shorter length of hospital stay; however, there was no difference in mortality. Another report [23] showed excellent results in a group of 123 patients 70 or greater years of age who had minimally invasive mitral valve surgery. They had a 1.6% operative mortality as well as 5-year actuarial survival of 87%, and a 5-year

Table 4. Multivariable Analysis of Mortality

Variable	Odds Ratio	Lower CI	Upper CI	p Value
Prior coronary bypass	7.5	1.5	36.4	0.01
Preoperative creatinine	5.5	1.03	29	0.05
Minimally invasive surgery	0.1	0.02	0.7	0.02
Body mass index	0.8	0.75	0.9	<0.001

Prior heart failure, prior valve surgery, age, and peripheral arterial disease were entered into the multivariable analysis and were not significant.

CI = 95% confidence interval.

Table 5. Baseline Characteristics by Gender

Variable	Men (n = 100)	Women (n = 103)	*p* Value
Age (median, IQR)	80 (77–82)	80 (78–84)	0.56
Ejection fraction (IQR)	0.55 (0.43–0.60)	0.60 (0.55–0.65)	0.01
Preoperative creatinine level (median, IQR)	1.1 (0.95–1.4)	0.9 (0.8–1.2)	0.01
Body mass index (IQR)	26.6 (24.7–29.9)	25.5 (22.7–28.8)	0.02
Diabetes mellitus (%)	31	20.4	0.08
Hypertension (%)	94	92.2	0.6
Peripheral vascular disease (%)	5	9.7	0.2
Cerebrovascular disease (%)	11	16.5	0.3
Prior coronary artery bypass graft surgery (%)	16	5.8	0.02
Prior valve surgery (%)	8	7.8	0.9
Congestive heart failure (%)	41	47.6	0.3

IQR = interquartile range.

freedom of reoperation of 93%. Unfortunately, there was no comparison group in this report.

In the largest case series of elderly patients undergoing minimally invasive aortic valve replacement, Sharony and colleagues [24] reported the results of 189 patients with a mean age of 75.3 ± 6.4 undergoing minimally invasive valve surgery. These investigators showed that there was a significantly shorter hospital length of stay, higher frequency of home discharge, but similar in-hospital mortality. Also, Tabata and colleagues [25], reported a 1.9% mortality in a subgroup analysis of 160 patients undergoing isolated aortic valve replacement who were 80 or greater years of age. Using the Society of Thoracic Surgeons algorithm, the predicted mortality of their patients was 7.5%, indicating that the reported mortality was lower than expected.

Taking into account the demographic growth, rising life expectancy, and the increase of valvular disease in the elderly, we are poised for a twofold increase in the cases of severe valvular heart disease, much of which will be in patients older than 75 years. Nkomo and colleagues [2], estimate that 1 out of every 8 individuals over the age of 75 will have moderate to severe valvular disease. Many of these same patients, by current standards, are denied intervention despite definite guideline-based indications, mostly because of old age [26]. Likewise, treating this growing population with standard surgical approaches will strain healthcare resources even further. For this reason, we evaluated minimally invasive valve surgery, using a right minithoracotomy, in a population older than that of any other prior study we found.

Our hypothesis was that this higher risk population would have the greatest benefits and proportionally have fewer postoperative complications than a healthier population. At the same time we expected higher mortality in this age group with both approaches, which would potentially allow us to document improved survival on a small sample. Our data in patients 75 or greater years, with a median age of 80, demonstrated a significant reduction in postoperative complication rates and reduction in both intensive care unit and total hospital stay by about half. The mortality we encountered with median sternotomy was higher than expected for this population and could be a product of a small cluster of deaths in this small sample size. In comparison there was an exceptionally good survival for this age group in the minimally invasive group, which proved to be significantly better than that of median sternotomy group. These results are encouraging and suggest that the benefits of minimally invasive valve surgery are particularly important in an elderly population.

Women undergoing heart surgery have also been noted to be a higher risk group when compared with matched males [27]. Data-derived, post hoc analyses in our cohort of patients showed a trend toward increased mortality in women overall, and a significant mortality benefit with the minimally invasive approach; again suggesting increased benefit in higher risk groups.

Although, this study did not analyze cost data, length of stay may be considered a surrogate for resource use, thereby a prolonged length of stay increases hospital costs at all levels [28]. Therefore, the reduction in hospital stay by a median of 5 days may reflect a desirable impact on resource utilization.

Our study is limited as it was a single-center, retrospective study of a heterogeneous group of patients who had their operations over a multiyear span. Furthermore, the surgical teams that performed the cases for each approach were different, introducing a potential uncontrollable confounder. Additional analyses of both teams' performance in isolated coronary artery bypass surgery by means of median sternotomy demonstrated no difference in hospital morbidity or mortality (unpublished data). This may suggest that the right minithoracotomy approach, not the surgical team, is the proximate cause of the superior outcomes. We pooled all mitral and aortic surgery together to allow for a larger sample and greater statistical power. This potentially allowed confounders to be introduced, although both groups had similar distributions of each valve procedure, essentially balancing any bias. Pooling both surgery, however, does not allow us to identify if right minithoracotomy benefits either more than the other, or if mitral valve repair differences played a role in the outcome. Moreover, this was a small study and only had short-term follow up available for analysis. Finally, it is important to mention that our results are exclusive to minimally invasive surgery by a right minithoracotomy as described in the methods, and cannot be extrapolated to other techniques.

Granted these limitations our results are in accord to prior reports, and furthermore show that minimally invasive aortic or mitral valve surgery by means of a right minithoracotomy when treating isolated valve lesions in elderly patients is feasible and has a significantly lower morbidity and mortality when compared to the standard median sternotomy. In conjunction with the significant resource utilization reduction and the evidence of safety, minimally invasive surgery should be considered for elderly patients undergoing isolated valve surgery.

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References

1. Greengross S, Murphy E, Quam L, Rochon P, Smith R. Aging: a subject that must be at the top of world agendas: the aging of populations demands major changes across society and health care. BMJ 1997;315:1029–30.
2. Nkomo VT, Gardin JM, Skelton TN, Gottdiener JS, Scott CG, Enriquez-Sarano M. Burden of valvular heart diseases: a population-based study. Lancet 2006;368:1005–11.
3. Singh JP, Evans JC, Levy D, et al. Prevalence and clinical determinants of mitral, tricuspid, and aortic regurgitation (The Framingham Heart Study). Am J Cardiol 1999:83:897–902.
4. Cosmi JE, Kort S, Tunick PA, et al. The risk of the development of aortic stenosis in patients with “benign” aortic valve thickening. Arch Intern Med 2002;162:2345–7.
5. Kolh P Kerzmann A, Lahaye L, Gerard P, Limet R. Cardiac surgery in octogenarians: peri-operative outcome and long-term results. Eur Heart J 2001;22:1235–43.
6. Cohn LH, Adams DH, Couper GS, et al. Minimally invasive cardiac valve surgery improves patient satisfaction while reducing costs of cardiac valve replacement and repair. Ann Surg 1997;226:421–6.
7. Estrera AL, Reardon MJ. Current approaches to minimally invasive aortic valve surgery. Curr Opin Cardiol 2000;15: 91–5.
8. Mihaljevic T, Cohn LH, Unic D, Aranki SF, Couper GS, Byrne JG. One thousand minimally invasive valve operations: early and late results. Ann Surg 2004;240:529–34.
9. Doll N, Borger MA, Hain J, et al. Minimal access aortic valve replacement: effects on morbidity and resource utilization. Ann Thorac Surg 2002;74:S1318–22.
10. Raja SG, Navaratnarajah M. Impact of minimal access valve surgery on clinical outcomes: current best available evidence. J Card Surg 2009;24:73–9.
11. Bakir I, Casselman FP, Wellens F, et al. Minimally invasive versus standard approach aortic valve replacement: a study in 506 patients. Ann Thorac Surg 2006;81:1599–604.
12. Brown ML, McKellar SH, Sundt TM, Schaff HV. Ministernotomy versus conventional sternotomy for aortic valve replacement: a systematic review and meta-analysis. J Thorac Cardiovasc Surg 2009;137:670–9.
13. Murtuza B, Pepper JR, Stanbridge RD, et al. Minimal access aortic valve replacement: is it worth it? Ann Thorac Surg 2008;85:1121–31.
14. Scarci M, Young C, Fallou H. Is ministernotomy superior to conventional approach for aortic valve replacement? Interact Cardiovasc Thorac Surg 2009;9:314–7.
15. Modi P, Hassan A, Chitwood WR Jr. Minimally invasive mitral valve surgery: a systematic review and meta-analysis. Eur J Cardiothorac Surg 2008;34:943–52.
16. Edmuds LH Jr, Clark RE, Cohn LH, Grunkemeier GL, Miller C, Weisel RD. Guidelines for reporting morbidity and mortality after cardiac valvular operations. The American Association for Thoracic Surgery, Ad Hoc Liaison Committee for Standardizing Definitions of Prosthetic Heart Valve Morbidity. Ann Thorac Surg 1996;62:932–5.
17. Gammie JS, Bartlett ST, Griffith BP. Small-incision mitral valve repair. Safe, durable, and approaching perfection. Ann Surg 2009;250:409–15.
18. Bloomstein LZ, Gielchinsky I, Bernstein AD, et al. Aortic valve replacement in geriatric patients: determinants of in-hospital mortality. Ann Thorac Surg 2001;71:597–600.
19. Enriquez-Sarano M, Schaff HV, Orszulak TA, Tajik AJ, Bailey KR, Frye RL. Valve repair improves the outcome of surgery for mitral regurgitation. Circulation 1995:91;1022–8.
20. Mistiaen WP, Van Cauwelaert P, Muylaert P, et al. Determinants of survival after aortic valve replacement as treatment for symptomatic aortic valve disease in the elderly. J Heart Valve Dis 2001;10:354–60.
21. Brandrup-Wognsen G, Haglid M, Karlsson T, Berggren H, Herlitz J. Mortality during the two years after coronary artery bypass grafting in relation to perioperative factors and urgency of operation. Eur J Cardiothorac Surg 1995;9:685–91.
22. Grossi EA, Galloway AC, Ribakove GH, et al. Minimally invasive port access surgery reduces operative morbidity for valve replacement in the elderly. Heart Surg Forum 1999;2: 212–5.
23. Tabata M, Cohn LH. Minimally invasive mitral valve repair with and without robotic technology in the elderly. Am J Geriatr Cardiol 2006;15:306–10.
24. Sharony R, Grossi EA, Saunders PC, et al. Minimally invasive aortic valve surgery in the elderly: a case-control study. Circulation 2003;108[Suppl II]:II-43-7.
25. Tabata M, Umakanthan R, Cohn LH, et al. Early and late outcomes of 1000 minimally invasive aortic valve operations. Eur J Cardiothorac Surg 2008;33:537–41.
26. Iung B, Cachier A, Baron G, et al. Decision-making in the elderly patients with severe aortic stenosis: why are so many denied surgery? Eur Heart J 2005;26:2714–20.
27. Bukkapatnam RN, Yeo KK, Li Z, Amsterdam EA. Operative mortality in women and men undergoing coronary artery bypass grafting (from the California Coronary Artery Bypass Grafting Outcomes Reporting Program). Am J Cardiol 2010; 105:339–42.
28. Black D, Pearson M. Average length of stay, delayed discharge, and hospital congestion. BMJ 2002;325:610–1.