Right Minithoracotomy Versus Median Sternotomy for Mitral Valve Surgery: A Propensity Matched Study

Paul Tang, MD, PhD, Mark Onaitis, MD, MHS, Jeffrey G. Gaca, MD, Carmelo A. Milano, MD, Mark Stafford-Smith, MD, and Donald Glower, MD

Departments of Surgery and Anesthesia, Duke University Medical Center, Durham, North Carolina

Background. The efficacy of conventional median sternotomy versus a right minithoracotomy (RT) approach to mitral valve surgery was evaluated in a single high-volume institution.

Methods. A retrospective analysis of a single institution's experience was performed using propensity matching of 1,694 patients who underwent mitral valve surgery during a 15-year period. Patients who had procedures that were not usually performed through an RT approach were excluded. Using 1:1 propensity score matching, we obtained 215 matched patients in each group for outcomes analysis.

Results. There was no difference in the median year of operation between the two groups (2002 versus 2001; $p = 0.142$). The RT approach was not a predictor of postoperative mortality. Predictors of mortality included increasing age, diabetes, smoking, preoperative dialysis, lung disease, advanced congestive heart failure class, and peripheral vascular disease. The RT approach was associated with less new-onset atrial fibrillation (8% versus 16%; $p = 0.018$), pneumonia (1% versus 5%; $p = 0.049$), respiratory failure (3% versus 8%; $p = 0.036$), and acute renal failure (2% versus 7%; $p = 0.006$), lower chest tube output (350 versus 840 mL; $p < 0.001$), and fewer red blood transfusions (2 versus 3 units; $p = 0.001$).

Conclusions. Right minithoracotomy compared with median sternotomy for mitral valve surgery was associated with less postoperative atrial fibrillation, respiratory complications, acute renal failure, chest tube output, and use of packed red blood cells. Given study limitations, the RT approach for mitral valve surgery may have advantages over median sternotomy in selected patients.

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A right minithoracotomy (RT) approach to mitral valve surgery has been associated with potential advantages relative to conventional median sternotomy (MS), including less blood loss and transfusion, earlier hospital discharge and recovery, less mediastinitis, and less renal injury [1–4]. Conversely, concerns regarding the technique include a limited ability to remove air leading to greater risk of stroke, longer cardiopulmonary bypass and cross-clamp times, limited exposure of mitral valve leading to suboptimal outcomes, and a greater risk of aortic dissection during arterial cannulation [5–7].

To date, large randomized trials examining minithoracotomy mitral surgery are not available, and procedure volume may well influence outcomes in minimally invasive approaches to mitral valve surgery [8]. We therefore present the results from a propensity-matched analysis in a single high-volume institution to compare mortality and outcomes in mitral valve surgery conducted through an RT versus conventional MS.

Material and Methods

Study Population

Institutional review board approval was obtained. Retrospective review was performed of all 1,694 patients undergoing isolated mitral valve surgery with or without tricuspid, maze, or atrial septal surgery spanning a 15-year period. There were 16 surgeons who performed these cases (Table 1). We excluded patients who underwent operations that are not traditionally performed through an RT approach to the mitral valve. Operations that can be performed concomitantly through an RT approach were retained, including tricuspid valve surgery, maze procedure, and atrial septal defect closures. Group definitions are based on the operation that was actually performed and thus is not an intention-to-treat analysis.

Outcomes

The primary outcomes examined were operative mortality (defined as death during the index hospitalization or

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Address correspondence to Dr Glower, Box 3851, Duke University Medical Center, Durham, NC 27710; e-mail: glowe001@mc.duke.edu.

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within 30 days of surgery) and long-term survival. Secondary outcomes include postoperative complications. Acute postoperative renal insufficiency was defined as a rise in serum creatinine greater than 1.0 mg/dL or the need to initiate dialysis. Follow-up was obtained from the medical record, from the National Death Index, and from patient telephone contact.

Surgical Technique

Patients were chosen for the RT versus MS approach largely based on the preferences of the surgeon, referring physicians, and the patient. The RT approach to the mitral valve was performed as previously described [9, 10]. Briefly, a 6-cm anterolateral skin incision in the right fourth intercostal space was made. A venous cannula was placed from the femoral vein into the right atrium. Arterial cannulation was performed through either the femoral artery or central aortic cannulation. Mitral valve procedures were performed using cardioplegic arrest or ventricular fibrillation. Ascending aortic occlusion for antegrade cardioplegic arrest was performed either by using an external Cosgrove clamp or by an aortic Endoclamp (Edwards Lifesciences, Irvine, CA).

Standard repair techniques were used with rigid ring annuloplasty in most patients and selective use of leaflet resection, chordal transfer or replacement, and edge-to-edge repair as previously described [11]. Sternotomy cases were performed with central cannulation of the ascending aorta; anesthetic and perfusion techniques were otherwise identical to those used in the concurrent minithoracotomy patients.

Statistics

Categorical outcomes were compared using the Pearson χ^2 or Fisher's exact test, and continuous outcomes were compared with a two-tailed Student's *t* test. The Mann-Whitney *U* statistics was used to assess ordinal variables such as congestive heart failure class and number of vessels with coronary atherosclerotic disease. Median with first and third quartiles were used for categorical variables such as operative factors and year of operation. Continuous variables were expressed as mean ± standard deviation. Survival was expressed and analyzed using a Kaplan-Meier survival plot with Mantel-Cox statistics. A Cox proportional hazards model using stepwise forward and reverse multivariate analysis was also performed to examine for preoperative predictors of mortality. Patient preoperative comorbidities were defined in accordance with The Society of Thoracic Surgeons national database.

A logistic regression of covariates was used to produce a propensity score for propensity toward RT versus MS approach. Then 1:1 greedy matching algorithm with a caliper width of 0.2 standard deviations of the linear predictor [12] was used for the preoperative variables of surgeon, age, sex, weight, height, hypertension, creatinine, dialysis status, cerebrovascular disease, peripheral vascular disease, lung disease, hepatic disease, diabetes, history of rheumatic fever, diagnosis of lymphoma or leukemia, history of a cancer diagnosis within the last 5 years from operation, atrial fibrillation, ejection fraction, redo status, smoking status, congestive heart failure class, and number of diseased coronary vessels (Tables 1, 2). Patients were also matched to the etiology of mitral valve disease and actual operations performed (Tables 3–5). All statistical evaluation was performed using SPSS version 21 software (SPSS, Inc, Chicago, IL) (Appendix Tables 1–3).

Results

Patient Group Characteristics

In the total cohort of 1,694 patients, the RT and MS groups differed significantly in a number of preoperative characteristics, which could bias a direct comparison of outcomes (Table 1). Importantly, the RT group had a higher age, more males, and a higher incidence of several comorbidities, but had a lower preoperative creatinine, a lower congestive heart failure class, less endocarditis, and later year of operation. Patients with degenerative valves were more commonly treated with the RT versus MS approach (531 of 613 [87%]versus 82 of 613 [13%]; $p < 0.0001$). Degenerative valves were also most likely to be treated by the busiest surgeon (575 of 613 [94%] versus 38 of 613 [6%]; $p < 0.0001$). The busiest surgeon performed 1,226 of 1,254 (98%) of all RT cases versus 156 of 440 (35%) of all MS cases ($p < 0.0001$).

After propensity matching (Tables 2, 3), the RT and MS group characteristics were comparable with 215 patients in each group. Importantly there was no difference in median operative year ($p = 0.142$), valve disease etiology (Table 3), or operating surgeon ($p = 0.284$).

Operative Characteristics in Matched Patients

In the propensity-matched patients, there was no difference in total cardiopulmonary bypass time and whether fibrillatory arrest was used more often in the RT group (Table 4). Of the cases using fibrillatory arrest, 51% were performed in redo surgeries. In those who underwent cardioplegic arrest with aortic cross-clamping, there was no difference in cross-clamp time ($p = 0.541$). Packed red blood cell utilization was lower in the RT group, corresponding to lower chest tube outputs in this population (Table 4). Femoral cannulation was used more often in the RT group. The propensity-matched groups had no differences in mitral or tricuspid valve replacements versus repair and concomitant maze operations. The mitral valve repair rate for the RT versus MS groups, respectively, were 59 of 69 (86%) versus 56 of 82 (68%) for degenerative valves ($p = 0.02$), 12 of 15 (80%) versus 8 of 11 (73%) for functional ischemic disease, 21 of 27 (78%) versus 24 of 32 (75%) for functional nonischemic disease, and 0 of 56 (0%) versus 2 of 54 (4%) for rheumatic etiology. For degenerative valves, the mitral repair rate for the busiest surgeon was 54 of 59 (92%) for RT and 41 of 47 (87%) for MS ($p = 0.5$) in the matched series and 493 of 530 (93%) for RT and 58 of 65 (89%) for MS in the unmatched series ($p = 0.3$).

Postoperative Complications in Matched Patients

Right minithoracotomy was associated with less new postoperative atrial fibrillation and a lower incidence of

Table 1. Unmatched Patient Characteristics[a]

Variable	Thoracotomy (n = 1,254)	Median Sternotomy (n = 440)	p Value
Age (y)	59.4 ± 13.4	56.7 ± 14.3	<0.001
Sex (male)	564 (45%)	170 (39%)	0.021
Weight (kg)	77.0 ± 13.4	77.1 ± 17.9	0.864
Height (cm)	168.9 ± 9.1	168.0 ± 8.5	0.096
Preoperative creatinine (mg/dL)	1.1 ± 1.1	1.5 ± 1.8	<0.001
Ejection fraction	0.520 ± 0.109	0.502 ± 0.142	0.006
Hypertension	762 (61%)	277 (63%)	0.417
Smoking	153 (12%)	385 (88%)	0.115
Dialysis	35 (3%)	30 (7%)	<0.001
Cerebrovascular disease	126 (10%)	60 (14%)	0.038
Peripheral vascular disease	53 (4%)	18 (4%)	0.903
Lung disease	154 (12%)	65 (15%)	0.180
Liver disease	24 (2%)	15 (3%)	0.072
Diabetes	137 (11%)	72 (16%)	0.003
Endocarditis	66 (5%)	72 (16%)	<0.001
Degenerative etiology	531 (42%)	82 (19%)	<0.001
Rheumatic fever	126 (10%)	61 (14%)	0.028
Lymphoma or leukemia	20 (2%)	2 (0.5%)	0.069
Cancer within 5 years of surgery	128 (10%)	41 (9%)	0.592
Atrial fibrillation	464 (37%)	161 (37%)	0.878
Redo surgery	245 (20%)	95 (22%)	0.355
Heart failure class			<0.001
1	44 (4%)	10 (2%)	
2	416 (33%)	96 (22%)	
3	532 (42%)	173 (39%)	
4	262 (21%)	161 (37%)	
Coronaries with significant stenosis			0.329
0	1,072 (85%)	383 (87%)	
1	61 (5%)	23 (5%)	
2	37 (3%)	15 (3%)	
3	84 (4%)	19 (4%)	
Operation year	2005 (6, 2002–2008)*	2002 (8, 1998–2006)*	<0.001

* Median, 1st quartile-3rd quartile. [a] All nominal data expressed as presented as n and percentage of total population and compared with Pearson χ^2 or Fisher's exact test. Continuous data expressed as mean ± standard deviation with comparisons calculated with two-tailed paired Student's t test. Comparison of congestive heart failure class and number of diseased coronary vessels were performed using the Mann-Whitney U test. Year of operation is expressed as median with interquartile range and analyzed with median test.

pneumonia as well as respiratory failure (Table 4). Despite longer cardiopulmonary bypass times in the RT group, there was less acute renal failure with no difference in subsequent dialysis. There were no mediastinitis or sternal infections in the RT group. There was no difference in the incidence of stroke, respiratory failure, subsequent tracheostomy, gastrointestinal complications, or 30-day operative mortality.

Late Outcomes

Although the RT group in the unmatched population had a 20% improvement in survival when compared with MS ($p < 0.001$), this survival difference was no longer present after analysis of a propensity-matched population ($p = 0.146$; Fig 1). Using a multivariate Cox proportional hazards model, the predictors of death (Table 5) were older age, diabetes mellitus, smoking, preoperative dialysis, lung disease, higher congestive heart failure class, and peripheral vascular disease.

Comment

This study is relatively unique in using propensity matching in a large data set at a single institution. Other studies with matching have not had consistent findings, perhaps owing to small patient numbers and confounding influences of variables like patient selection and institutional volume, which may affect outcome at least as much as the surgical approach. Individual matched studies have found RT to be associated with less transfusion [1, 4, 13], fewer permanent pacemakers [4], less atrial fibrillation [1, 4], less renal insufficiency [4], less infection [14], shorter ventilation time [15], shorter length of stay [14–16], less cost [14], less readmission [13, 14], less residual regurgitation in repair patients [13], and lower

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Table 2. Patient Characteristics After Propensity Matching[a]

Variable	Thoracotomy (n = 215)	Median Sternotomy (n = 215)	*p* Value
Age (y)	58.0 ± 14.2	58.1 ± 14.2	0.936
Sex (male)	96 (45%)	91 (42%)	0.627
Weight (kg)	76.0 ± 18.1	78.5 ± 19.0	0.167
Height (cm)	168.5 ± 9.9	168.2 ± 8.7	0.766
Preoperative creatinine (mg/dL)	1.38 ± 1.9	1.27 ± 1.1	0.489
Ejection fraction	0.516 ± 0.114	0.522 ± 0.121	0.620
Hypertension	126 (59%)	121 (56%)	0.626
Smoking	79 (37%)	74 (34%)	0.615
Dialysis	10 (5%)	8 (4%)	0.630
Cerebrovascular disease	28 (13%)	28 (13%)	1.000
Peripheral vascular disease	11 (5%)	8 (4%)	0.481
Lung disease	32 (15%)	38 (18%)	0.433
Liver disease	7 (3%)	4 (2%)	0.359
Diabetes	29 (13%)	30 (14%)	0.889
Endocarditis	27 (13%)	25 (12%)	0.767
Rheumatic fever	30 (14%)	24 (11%)	0.383
Lymphoma or leukemia	3 (1%)	0 (0%)	0.082
Cancer within 5 years of surgery	18 (8%)	22 (10%)	0.507
Atrial fibrillation	78 (36%)	86 (40%)	0.427
Redo surgery	61 (28%)	52 (24%)	0.324
Heart failure class			0.143
1	10 (5%)	6 (3%)	
2	62 (29%)	46 (21%)	
3	86 (40%)	90 (42%)	
4	57 (27%)	73 (34%)	
Coronaries with significant stenosis			0.404
0	174 (81%)	180 (84%)	
1	12 (6%)	14 (7%)	
2	9 (4%)	10 (5%)	
3	20 (9%)	11 (5%)	
Operation year	2002 (7, 1999–2006)*	2001 (9, 1998–2007)*	0.142

* Median, 1st quartile-3rd quartile. [a] All nominal data expressed as presented as n and percentage of total population and compared with Pearson χ^2 or Fisher's exact test. Continuous data expressed as mean ± standard deviation with comparisons calculated with two-tailed paired Student's *t* test. Comparison of congestive heart failure class and number of diseased coronary vessels were performed using the Mann-Whitney *U* test. Year of operation is expressed as median with interquartile range and analyzed with median test.

mortality in renal patients [4] or mitral replacements [15], but variably longer pump time [1, 16] and cross-clamp time [1, 15]. Similar to the findings in this study, other retrospectively matched studies found no difference in long-term survival [1, 13, 16].

A number of randomized studies between RT and MS involving smaller numbers of patients confirmed the advantages of RT approach including less blood loss, shorter hospital stay, ICU stay and less need for mechanical ventilation [17, 18]. In these smaller randomized trials, adverse cardiac and cerebrovascular events as well as operative mortality were found to be comparable between the RT and MS groups [17–19]. In unmatched studies, RT also had advantages of earlier return to normal activity [20], less reoperation for bleeding [6], decreased pain [3], but increased risk of aortic dissection [5], while other unmatched studies found little effect of the RT approach on outcomes [21, 22].

Like prior studies, our results in a single tertiary referral institution confirm that a minimally invasive approach to mitral valve surgery was associated with less blood loss and transfusion requirements [1, 4, 13], less postoperative atrial fibrillation [4, 5], less pneumonia and respiratory failure [4, 5, 15], less infection [5, 14], and less renal injury [4, 23]. Unlike prior studies, the current matched series did not find difference in clamp time [1, 5, 15] or pump times [5, 15], possibly related to use of ventricular fibrillation in some RT cases and the extensive RT experience. Despite prior reports of stroke being increased [5, 24, 25] or decreased [4] by a thoracotomy approach to the mitral valve], we found no difference in the stroke incidence in this study. As noted in a prior study [26], avoiding femoral arterial cannulation may have decreased retrograde embolic events from aortic debris. The decreased incidence of postoperative atrial fibrillation with the RT approach could result from less atrial injury with less cardioplegic arrest, lower

Table 3. Etiology of Mitral Valve Disease for Matched Patients[a]

Variable	Thoracotomy (n = 215)	Median Sternotomy (n = 215)	*p* Value
Functional ischemic	15 (7%)	11 (5%)	0.418
Functional nonischemic	27 (13%)	32 (15%)	0.483
Degenerative	61 (28%)	60 (28%)	0.999
Rheumatic	56 (26%)	52 (24%)	0.656
Prosthetic valve dysfunction	14 (7%)	9 (4%)	0.284
Endocarditis	32 (15%)	25 (12%)	0.319
Hypertrophic cardiomyopathy	2 (1%)	4 (2%)	0.411

[a] Expressed as n and percentage and compared with Pearson χ^2 test or Fisher's exact test.

inflammatory response in the thoracotomy approach [27], less air-drying of the atrial epicardium, and perhaps better drainage of the inferior vena cava by means of femoral venous cannulation.

Less impairment of renal function in RT versus MS patients was previously described [4, 23]. Decreased postoperative renal dysfunction with the RT approach could have resulted from less inflammation from transfusion and bone marrow aspiration into the pump circuit, and perhaps lower abdominal venous pressures with femoral venous cannulation. Renal effects may also be confounded by undetected differences between groups, such as perioperative vancomycin use, preoperative hydration, and timing of catheterization relative to surgery.

The association of the RT approach with reduced sternal and mediastinal infection has been noted by prior

Table 4. Operative Parameters and Postoperative Outcomes for Matched Patients[a]

Variable	Thoracotomy (n = 215)	Median Sternotomy (n = 215)	*p* Value
XC time (min)	107 (49, 86–134)*	107 (50, 82–132)*	0.541
CPB time (min)	175 (80, 145–225)*	174 (59, 147–206)*	0.923
CT output (mL)	350 (510, 200–710)*	840 (1,125, 410–1,535)*	<0.001
PRBC (units)	2 (4, 0–4)*	3 (4, 2–6)*	0.001
Aortic cross-clamp	153 (71%)	199 (93%)	<0.001
Fibrillatory arrest	62 (29%)	16 (7%)	<0.001
Central or axillary cannulation	188 (87%)	210 (98%)	<0.001
Femoral cannulation	27 (13%)	5 (2%)	<0.001
Mitral repair	103 (48%)	98 (46%)	0.629
Mitral replacement	112 (52%)	117 (54%)	0.629
Tricuspid repair	33 (15%)	31 (14%)	0.786
Tricuspid replacement	6 (3%)	8 (4%)	0.587
PFO closure	2 (1%)	9 (4%)	0.033
Maze procedure	12 (6%)	15 (7%)	0.551
Other operations	48 (22%)	57 (27%)	0.312
Atrial fibrillation	18 (8%)	34 (16%)	0.018
Operative mortality (30 days)	4 (2%)	8 (4%)	0.242
Myocardial infarction	0 (0%)	0 (0%)	1.000
Pacemaker insertion	9 (4%)	16 (7%)	0.149
Endocarditis	3 (1%)	2 (1%)	0.653
Mediastinitis	0 (0%)	3 (1%)	0.082
Pneumonia	3 (1%)	10 (5%)	0.049
Stroke	3 (1%)	7 (3%)	0.201
Any infective complication	11 (5%)	25 (12%)	0.015
Acute renal failure	4 (2%)	16 (7%)	0.006
Dialysis	0 (0%)	3 (1%)	0.082
Gastrointestinal	7 (3%)	6 (3%)	0.778
Tracheostomy	2 (1%)	6 (3%)	0.153
Respiratory failure	7 (3%)	17 (8%)	0.036

* Median, 1st quartile-3rd quartile. [a] Data expressed as median and interquartile range with comparisons performed with median test, or are expressed as n and percentage and compared with Pearson χ^2 test or Fisher's exact test. Cross-clamp time calculated for patients without fibrillatory arrest.

CPB = cardiopulmonary bypass; CT = chest tube output; PFO = patent foramen ovale; PRBC = packed red blood cell; XC = cross-clamp.

Table 5. Conditional Forward and Backward Analysis in Multivariate Cox Proportional Hazards Model of the Preoperative Predictors of Death[a]

Predictor	B	SE	Wald	Hazard Ratio (CI)	*p* Value
Age	0.042	0.008	27.995	1.043 (1.027–1.060)	<0.001
Diabetes mellitus	0.888	0.216	16.958	2.430 (1.592–3.708)	<0.001
Smoking	0.599	0.186	10.339	1.821 (1.264–2.624)	0.001
Dialysis	0.982	0.353	7.738	2.669 (1.336–5.330)	0.005
Lung disease	0.560	0.213	6.931	1.751 (1.154–2.656)	0.008
Heart failure class	0.306	0.119	6.611	1.358 (1.075–1.714)	0.010
Peripheral vascular disease	0.638	0.326	3.816	1.892 (0.998–3.588)	0.051

[a] All 24 preoperative variables were placed in a univariate Cox regression analysis. Significant factors were then placed into a multivariate Cox regression model; forward and backward analysis produced similar results. Significant predictive factors for mortality are shown.

CI = confidence interval; SE = standard error.

authors [28, 29]. A limited thoracotomy also did not increase pulmonary morbidity in terms of pneumonia, respiratory failure, or the need for tracheostomy. The lower transfusion and chest tube output with the RT approach are well accepted as related in part to avoidance of sternotomy blood loss. As expected, the matched population did not demonstrate any survival differences between RT versus MS. This suggests that uncorrected differences in patient selection were responsible for early postoperative recovery and differences in raw survival that occurred mostly in the first 3 months.

The repair rate of 86% for the RT approach in degenerative patients is comparable to the repair rates reported in other large centers. The repair rate of 68% for the MS approach in nominally degenerative patients probably reflects a greater degree of underlying mitral valve disease not measured in this data set. Gammie and colleagues [25] reported a higher repair rate with a minimally invasive approach, perhaps because of the association between minimally invasive approaches and higher volume centers. Similarly, at this institution (as evidenced by the unmatched data set), patients with degenerative (potentially repairable) valves tended to be referred for the RT approach (87%) and to the busiest surgeon (94%). Thus, in the unmatched data set, as with the data reported by Gammie and colleagues [25], the RT approach was associated with surgeons who performed the most mitral procedures and who attracted disproportionate numbers of degenerative valves. Because the matched data set corrected for both surgeon and nominal valve disease etiology, differences in mitral repair rates in the matched data set probably result from differences in patient or valve characteristics not captured in this analysis. Few would argue that the RT versus MS approach is inherently more likely to result in mitral repair versus replacement.

Standardization of comparison populations with propensity matching is a well-established technique for adjusting retrospective data [12]. Although there may be unidentified confounding factors that influence study outcome, the application of this statistical technique in a single institution with relatively standardized preoperative and postoperative patient care protocols may have minimized biases that can occur in a multiinstitutional study.

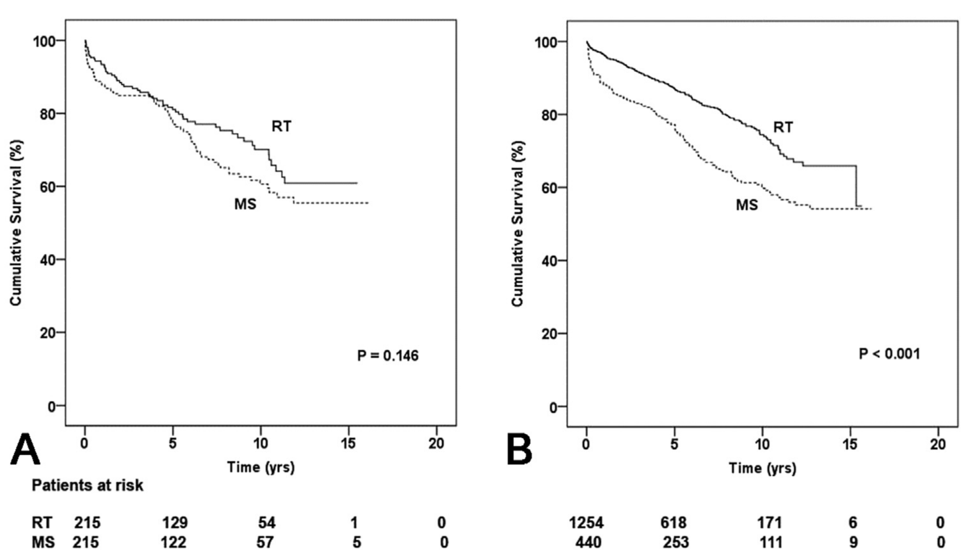

Fig 1. Unadjusted survival in (B) unmatched patients and adjusted survival in (A) matched patients after sternotomy (MS; gray line) versus right minithoracotomy (RT; black line).

This study has imitations that include its retrospective nature and adjustment for identified variables only, as well as having multiple surgeons involved, that may have subtly different practices. We cannot exclude other confounding variables that were not matched, such as patient selection biases, although we accounted for etiology of mitral valve disease and actual operation performed in the propensity matching. This series did not address the reproducibility of the RT approach among surgeons, which may require larger multiinstitutional series [8].

Given the limitations of a retrospective analysis, these data using propensity matching in a relatively large data set suggest that a thoracotomy approach to mitral valve surgery may be associated with less postoperative atrial fibrillation, transfusion, chest tube output, renal dysfunction, pneumonia, and respiratory failure. However, long-term survival is not significantly affected. Whether these findings are affected by institutional volume is not clear [8].

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