Original Article

Comparative Early and Long Term Results of Mitral Valve Surgery between Right Mini Thoracotomy and Full Sternotomy Approach

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Background: Conventional mitral valve surgery (MVS) requires median sternotomy. Right mini thoracotomy (RMT) MVS is an alternative non sternotomy approach aiming for less bleeding, pain reduction, rapid recovery, cosmetic satisfaction, safety and effectiveness of the procedure.

Objectives: To report early and late clinical results comparing RMT versus full sternotomy (FS) MVS.

Materials and Methods: 574 consecutive patients underwent MVS were prospectively non randomized reviewed during January 2002 to October 2018. There were 241 in FS group and 241 in RMT group by age and Euro II score matching. Baseline characteristics were compared. Early and late clinical outcomes of 30 days mortality, reoperation for bleeding, stroke, prolonged ventilation, renal failure, permanent pacemaker, and echocardiographic hemodynamic performance were assessed and compared between two groups. All patient follow-up to December 2020.

Results: Similar results were found between RMT and FS MVS groups including age 58.8±13.6, 57.2±14.2, p=0.2, new AF 5 (2%), 4 (1.7%), p=1.0), except for more degenerative valve pathology (79%, 50%, p<0.001). There were more re operation for bleeding 2 (0.8%), 1 (0.3%), p=0.9, less aortic cross clamp time (107±37.3, 115.4±36.4, p=0.017), less cardiopulmonary bypass time (157.6±51.2, 171.3±53.4, p=0.005), less bleeding and blood transfusion requirement in the RMT group. Early clinical results of 30 days mortality, stroke, renal failure, new pacemaker, and hemodynamic performance at one month, three to six month, and one year were comparable in both groups. Mean follow-up (year) was 5.2±2.5 (RMT) and 10.2±4.0 (FS). Survival probability and freedom from MACCE at ten years in RMT and FS group were 94.05%, 95.44% and 99.5%, 90.46%, p<0.001, respectively.

Conclusion: RMT approach for MVS is associated with cosmetic satisfaction, less bleeding, similar effective hemodynamic performance and non-inferiority early and late clinical results to FS approach.

Keywords: Mitral valve surgery; Right mini thoracotomy

J Med Assoc Thai 2021;104(Suppl.5): S133-9
Website: http://www.jmatonline.com

The surgical treatment of mitral valve disease is rapidly evolving and has progressively eliminated the need for full sternotomy (FS) approach[1-3]. Excellent results can be achieved through smaller incisions by endoscopic camera, new developed instruments, more advanced less invasive and robotic system[4-6]. We have progressively performed less invasive mitral valve surgery by right mini thoracotomy with video assisted camera in combination of endoscopic instruments since 2009. This article revealed our early and long term results in comparison to full sternotomy approach of mitral valve surgery.

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How to cite this article:

Chaiyaroj S, Lertsitthichai P. Comparative Early and Long Term Results of Mitral Valve Surgery between Right Mini Thoracotomy and Full Sternotomy Approach. J Med Assoc Thai 2021;104 (Suppl.5): S133-9

doi.org/10.35755/jmedassocthai.2021.S05.00091

Materials and Methods

From January 2002 to October 2018, 574 patients underwent mitral valve surgery in Ramathibodi hospital data base were prospective non randomized reviewed with approval of hospital ethics committee (No. MURA2013/564). RMT MVS was started in 2009 and increasingly becoming our preferred approach.

Concomitant procedures of tricuspid valve surgery and Cox Maze IV were included. There were 333 FS and 241 RMT. 241 FS from each group was matched by age, sex, Euro II score, and Left ventricular end diastolic pressure (LVEDP) (Table 1). Early and late clinical outcomes of 30 days mortality, reoperation for bleeding, stroke, prolonged ventilation, renal failure, permanent pacemaker, and echocardiographic hemodynamic performance were accessed and compared between two groups.

Preoperative evaluation of mitral pathology and planning for mitral valve surgery were performed by trans

Table 1. Demographic datas of FS MVS versus RMT MVS

Characteristic	FS MVS (n=241)	RMT MVS (n=241)	p-value*
Age (years): mean±sd	57.0±14.3	58.8±13.6	0.209
Men: women (%)	128: 113 (53: 47)	121: 120 (50: 50)	0.585
Euro II score	2.4	2.1	0.261
LVEDP (mmHg): mean±sd	12.5±1.6	12.4±2.3	0.397
Preop NYHA class (%)			
2	71 (29.5)	87 (36)	<0.001*
3	138 (57.3)	129 (54)	
4	32 (13.3)	25 (10)	
AF (%)	162 (67.2)	151 (63)	<0.001*
CKD (%)	73 (30.3)	22 (9)	<0.001*
DM (%)	38 (15.8)	13 (5)	<0.001*
Previous operation (%)	12 (5)	0	
Emergency surgery (%)	5 (2.1)	2 (1)	<0.001*
HT (%)	144 (59.7)	208 (86)	0.450
MV pathology (%)			
1 (R)	112 (46.5)	22 (9)	<0.001*
2 (D)	102 (42.3)	191 (79)	<0.001*
3 (IE)	26 (10.8)	27 (11)	
4 (Congenital)	1 (0.4)	1 (0.4)	

AF = atrial fibrillation; MV = mitral valve; CKD = chronic kidney disease; R = rheumatic; DM = diabetes mellitus; D = degenerative; HT = hypertension; IE = infective endocarditis

thoracic echocardiography or trans esophageal echocardiography (TEE). All patients underwent Intraoperative TEE.

Patient selection was determined by preoperative echocardiogram and computerized scan of chest and whole aorta. Coronary angiogram was performed in patients over 40 years with aorto iliac femoral angiography.

Atherosclerosis and vascular anatomy of whole aorta and femoral arteries were optionally evaluated by plain contrast computer tomography for older age patients more than 70 years old or suspicion of calcification on chest x-ray.

Patients with peripheral vascular disease, calcified ascending aorta, femoral artery less than 6 mm in diameter, more than mild aortic regurgitation, mitral annular calcification, and previous sternotomy were excluded from RMT approach.

Right mini thoracotomy approach was performed with patient in supine position, double lumen intubation, 4 centimeter right lateral incision, right chest entering via fourth inter costal space, one 10 mm port for 10 mm 30 degree endoscopic camera (Karl Storz-Endoskope, Tuttlingen, Germany), another 10 mm port for right hand instrument, femero femoral bypass, augmented venous drainage, and additionally assisted right internal jugular venous drainage when necessary. Pericardial incision was made 3 cm form phrenic nerve to avoid injury. Three important landmarks were to identify and consisted of inter atrial groove, transverse sinus, and cardioplegia delivery site. Soft tissue retractor was used to prevent the fat emboli. Continuous carbon dioxide insufflation at 5 liters per minute is delivered in the operative field for better cardiac de airing. Performing safe cannulation technique is crucial to avoid injury to femoral nerve, lymphatic fistulas, and seroma by using atraumatic technique, ligation, and clipping of sizable vessels. TEE and fluoroscope were applied for visualization of guide wire tip in the superior vena cava (SVC) and descending thoracic aorta (DTA), preventing injury to right atrial (RA) wall and aorta. FA is inspected carefully for plaques before placing guide wire. Soft hydrophilic guide wire (Radiofocus® Guide wire, Terumo Corporation, Tokyo, Japa) is occasionally used in elderly patient with tortuous iliac artery to avoid retrograde aortic dissection(3,5,7,8). Apply a safe aortic cross clamping (V. Mueller® instruments Cosgrove flex clamps, CareFusion, San Diego, Calif) through transverse sinus or a space above pulmonary artery (PA). PA and left atrial appendage (LAA) were protected by placing a small gauze along the transverse sinus. Extension of left atriotomy with attention to avoid cutting into coronary sinus (CS), inter atrial septum (IAS), and pulmonic veins (PV). Tip of venous cannula in SVC is intermittently checked while the left atrial roof is elevated with LA retractor (The Adams-Yozu Depressor Blades, Geister, Tuttingen, Germany). The dislodgement of cannula will compromise the upper body venous drainage. Posterior lateral wall of LA may obstruct the visualization and cause poor exposure of MV. Exposure of MV leaflets, annulus, and sub-valvular tissue is obtained by placing simple retracting suture of 40 proline at adjacent LA wall, leaflets and chords[8,15]. Before closing, potential sites of bleeding including incisional wound, anterior chest wall stab incision, left internal mammary artery (LIMA), portal sites, cardioplegic needle puncture site, LAA, PA, and temporary pacing wire sites were routinely checked.

All patients were followed-up to December 2020 with mean follow-up (year) of 5.2±2.5 (RMT) and 10.2±4.0 (FS).

Statistical analysis

Data analysis was performed by using STATA version 14.1 (STATA Corp., TX, USA). The data was analyzed among the groups. Categorical variables were evaluated using the Chi-square test. Data reported as number and percentages. Continuous and normal distribution variables compared using the two-sample Independent t-test. Data reported as mean ± standard deviation. For Continuous and non-normal distribution variables compared using the Wilcoxon rank-sum (Mann-Whitney) test. Data reported as median (min, ma). Follow-up time were calculated in years from the date of operation until the date of death or clinical event. A p-value less than 0.05 was considered statistically significant.

Results

In FS group, there were more incidence of preoperative atrial fibrillation (AF), chronic kidney disease (CKD), diabetes mellitus (DM), re sternotomy, and rheumatic pathology (Table 1).

CCT and BT were less in RMT group but no significant statistical different. There was less number of MV repair in FS group (39% versus 66%). More concomitant surgery including MAZE in FS group (68% versus 17%). Rate of pacemaker, new AF, stroke were similar in both group (Table 2).

Complications related to RMT MVS were summarized (Table 3). Conversion to sternotomy was necessary in six cases. The injury and bleeding were from left atrial appendage (2 cases), right pulmonary artery (one case), right ventricle at pacemaker insertion site (one case), aorta at cardioplegia needle punctured site (one case), and one case of retrograde aortic dissection (RAD) (Table 3). There were two cases of RAD. Only one case needed conversion. Good hemostasis in five cases were secured during intra operative period. RAD was initiated from right femoral artery cannulation site, extended and confined to below renal arteries level. Cardiopulmonary bypass (CPB) was switched to antegrade perfusion via ascending aorta. All six patients had

Table 2. Operative data and early results of FS MVS versus RMT MVS

Characteristic	FS MVS (n=241)	RMT MVS (n=241)	p-value*
MV replacement (%)	144 (59.8)	81 (34)	0.052
Repair (total, D)	96 (39.8, 94)	160 (66, 84)	
Mechanical valve	117 (81.2)	59 (72.8)	
Pericardial valve	26 (19.4)	22 (27.1)	
Concomitant surgery (%)	164 (68)	41 (17)	<0.001*
Maze procedure (%)	114 (47.3)	75 (31)	<0.001*
Cross-clamp time (min): mean±sd	116.2±35.7	107.3±37.3	0.017
Bypass time (min): mean±sd	170.9±53.1	157.6±51.7	0.005
Conversion to sternotomy (%)	0	6 (2)	0.227
Operative death (%)	4 (1.7)	2 (0.8)	0.686
New AF (%)	4 (1.7)	5 (2.1)	1.000
Prolonged intubation (%)	10 (4.1)	4 (1.6)	0.001*
ARF (%)	5 (2.1)	4 (1.6)	0.751
New Pacemaker (%)	0	1 (0.4)	1.000
Stroke (%)	0	0	-
Reop for Bleeding (%)	1 (0.4)	2 (0.8)	0.499
All early events (%)	11 (4.6)	11 (4.6)	1.000
PO NYHA class (%)			
1	208 (86.3)	124 (95)	0.388
2	31 (12.9)	6 (5)	

ARF = Acute renal failure

continuing smooth peri operative course without further complications.

Operative mortality was 4 (1.7%) in FS and 2 (0.8 %) in RMT group (Table 2). Causes of death were low cardiac output from multiple organ failure in combination of preoperative poor LVEF, ESRD on HD, and pneumonic sepsis. There were less blood loss and transfusion in RMT group (Table 5). All early major adverse cardio cerebral vascular event (MACCE) was 4.6% in both group (Table 2).

With longer mean follow up time of 10 years versus 5 years in RMT group, there were more incidence of late death, thromboembolism. bleeding complication, late pacemaker implantation, and re operation in FS group. Late MACCE was also higher in FS group, 11.2% versus 4.6% (Table 4).

Preoperative NYHA FC of 3-4 was improved to 1-2 in both groups (Table 1). In addition, LVEF, LVEDD, LVESD, LAD were better at six month postoperatively (Table 6, 7).

Causes of re operative MVS in FS group were recurrent severe mitral regurgitation (one case) and mechanical valve dysfunction from tissue in growth (two cases) at 10, 5, and 6 years postoperatively. While two cases in RMT group needed re operation because of recurrent severe mitral regurgitation at 10 years and failed bio prosthesis at 10 years postoperatively.

Survival probabilities at 10 years were 94 and 95% with event free probabilities of 99 and 90% (Figure 1, 2).

Discussion

MVS via median sternotomy is proved to be standard approach for effective and excellent outcomes[7-9]. RMT MVS is not inferior to midline approach but no proven superiority in operative mortality, freedom from cardiac death, and re operation[10-12]. Other advantages were shorter hospital stay, less blood loss-transfusion, less pain. However there was caution against perfusion related complications and quality of VS[1,4,14]. Successful of RMT MVS is crucial to focus on stable CPB, secure myocardial protection, and good exposure of MV[8,13,14].

Different risks, benefits and other aspects between two approaches including anesthetic management, surgical incision, intra operative exposure, aortic cross clamping, myocardial protection, CPB, cardioplegic solution type and delivery route were already well documented and discussed[1,3,5,8]. In addition, using of camera and endoscopic instruments were necessary strategies in less invasive MVS[5,8,15,16].

Complications and conversion to sternotomy did occur during the authors' early experiences. This could be

Table 3. Complications of RMT MVS (n=241)

Mortalities-Sepsis-MOF	2 (0.8%)
Conversion to sternotomy	6 (2.4%)
LAA	2 (0.8%)
PA	1 (0.4%)
RV (pacing wires)	1 (0.4%)
Aorta-Cardioplegia	1 (0.4%)
RAD	1 (0.4%)
Re op-chest wall	2 (0.8%)
RAD	2 (0.8%)
Inadequate venous drainage	2 (0.8%)
Myocardial protection-low CO	2 (0.8%)
Subcutaneous emphysema	4 (1.6%)
Phrenic nerve injury	4 (1.6%)
Groin seroma	4 (1.6%)
Prolonged intubation (>48 hours)	4 (1.6%)
Prolonged effusion (>72 hours)	6 (2.4%)
ARF	4 (1.6%)
New pace maker	1 (0.4%)
New AF	5 (2.1%)

RMT = right mini thoracotomy; RAD = retrograde aortic dissection; MVS = mitral valve surgery; CO = cardiac output; RV = right ventricular

Table 4. Long term outcomes of FS MVS versus RMT MVS

Characteristic	FS MVS (n=241)	RMT MVS (n=241)	p-value*
Follow-up time (years)			
Median (range)	11 (0 to 16)	5 (0 to 10)	<0.001*
Mean±SD	10.2±4.0	5.2±2.5	<0.001*
Late death (%)	8 (3.3)	2 (0.8)	0.106
All deaths (%)	12 (5.0)	4 (1.7)	0.072
Thromboembolic events (%)	7 (2.9)	2 (0.8)	0.176
Bleeding events (%)	3 (1.2)	0	0.248
Renal failure (%)	2 (0.8)	1 (0.4)	1.000
Pacemaker placement (%)	5 (2.1)	5 (2.1)	1.000
Reoperative MV surgery (%)	3 (1.2)	2 (0.8)	1.000
All late events (%)	27 (11.2)	11 (4.6)	0.010*
Follow-up time (years)	11 (0 to 16)	5 (0 to 10)	<0.001*

Table 5. Blood loss and blood transfusions of FS MVS versus RMT MVS

Characteristic	FS MVS (n=241)	RMT MVS (n=241)	p-value*
Blood loss (mL): mean±SD	421.6±18.1	180.4±6.0	<0.001*
RBC (mL): mean±SD	363.2±10.2	220.2±5.0	<0.001*
Plt (mL): mean±SD	119.3±5.7	115.3±5.9	<0.001*
FFP (mL): mean±SD	64.6±2.1	50.0±4.5	<0.001*
Cryoprecipitate (mL): mean±SD	25.1±2.2	15.2±2.3	<0.001*

RBC = red blood cell; Plt = Platelet; FFP = Fresh frozen plasma

Table 6. Pre-operative echocardiographic variables

Characteristic	FS MVS (n=241)	RMT MVS (n=241)	p-value*
LVEF (%), mean±SD	40.7±7.2	41.3±6.8	0.335
LVEDD (mm), mean±SD	56.6±5.8	55.5±4.5	0.089
LVESD (mm), mean±SD	36.2±2.2	36.9±3.0	0.017*
LAD (mm), mean±SD	64.1±54.2	50.0±4.8	0.003*

LVEF = left ventricular ejection fraction; LVEDD = left ventricular end-diastolic diameter; LVESD = left ventricular end-systolic dimension; LAD = left atrial diameter

Table 7. Post op echocardiographic variables

Characteristic	FS MVS (n=237)	RMT MVS (n=239)	p-value*
LVEF (%), mean±SD	50.6±9.1	46.4±8.8	<0.001*
LVEDD (mm), mean±SD	52.8±6.7	52.2±4.4	0.290
LVESD (mm), mean±SD	31.7±3.6	33.2±2.9	<0.001*
LAD (mm), mean±SD	50.1±7	45.4±4.5	<0.001*

avoided by meticulously and carefully step by step strategic planning[6,8,15]. Maneuvering aortic cross clamp with clear vision of surrounding structures such as left atrial appendage and pulmonary artery in the transverse sinus space. It was our routine practice at present to use small gauze placing along the transverse sinus space protecting incidental injury to the left atrial appendage. Retrograde aortic dissection from cannulation site could be prevented by mastering catheter skills with fluoroscopic or trans esophageal echocardiographic imaging[5,7,8,16-19].

Complications related RMT MVS procedures incidentally occurred and could be Improved by increasing experiences with time[5,7,8] (Table 3).

There were limitations in the present study due to non-randomize methodology, heterogeneity of valve pathology, and selection bias. Longer CCT and CBT in FS group were associated with more concomitant procedures (Table 2). Nevertheless benefits of small incision, cosmetic satisfaction, less bleeding, less blood transfusion, acceptable low MACCE, excellent early and long term outcomes were clearly shown in RMT group (Table 2, 4, 5).

The authors demonstrated the alternative approach in a prospective non randomized fashion comparing to conventional surgery. There seemed to be more complexities in FS group despite of comparable preoperative risk score. However MACCE in both groups were low, similar, and acceptable (Table 1, 2).

Experience of MVS via FS is necessary and becoming important fundamental basics for less invasive approach[1,2,15,18,19]. Our set up in minimally invasive MVS was initially started with anterior thoracotomy incision with small rib spreader through fourth intercostal space. The surgery in the early period was performed mainly under direct vision along with endoscopic visualization of all procedures. At present the skin incision was moved to the lateral part. Surgical skills were gradually developed towards less invasive techniques. Currently the authors mainly performed MVS under endoscopic vision.

RMT approach for MVS is associated with cosmetic satisfaction, less bleeding, less blood transfusion

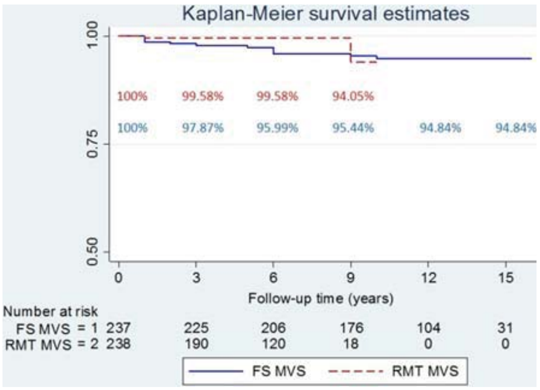

Figure 1. Survival Probabilities of FS MVS versus RMT MVS.

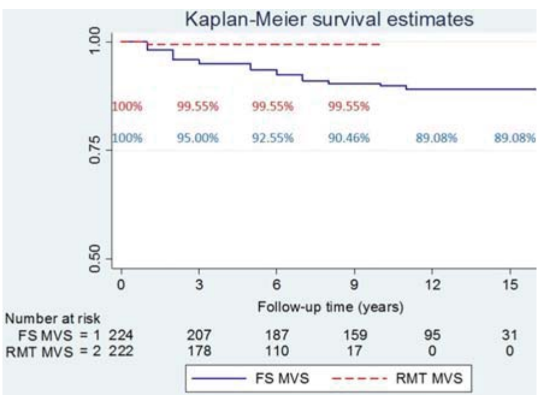

Figure 2. MACCE Free Probabilities of FS MVS versus RMT MVS.

requirement, similar effective hemodynamic performance, 84% MV repair, 17% TV repair, 31% MAZE, 0.8% operative mortality, 2% conversion rate, 4.6% MACCE, 0.8% re operative MVS, comparable early and late clinical results to FS approach at mean follow of 5 years.

There were limitations of the study. Firstly, the authors used age, sex, LV size, and pre operative risk score as matching parameters. Other confounding factors were not included. The comparison between two groups were mainly on overall risk score basis but might have left some selection biases. Secondly, subgroup analysis of concomitant TV surgery and its effect on pulmonary hypertension was not included due to insufficient datas. Thirdly, the follow-up echocardiographic study revealed similar improvements of LV function and LV size but could not differentiate nor explain the differences between two groups. Nevertheless the study did show good non inferiority results of RMT MV surgery in selected group of patients based on risk score matching. Further randomized controlled trail would definitely give more precise informations on benefits and advantages between two approaches.

Conclusion

RMT MVS is safe, effective, and feasible. Less invasive technique is associated with less bleeding, more patient satisfaction, similar effective hemodynamic performance, early and long term survival comparable to conventional FS approach.

What already know about this topic?

Surgical and interventional treatments of mitral valve disease (MVD) are rapidly evolving and has progressively eliminated the need for full sternotomy (FS) approach[3,10,20]. Excellent results can be achieved through smaller incisions by endoscopic camera, new developed instruments, and robotic system[1-3,6].

Minimally invasive chordal replacement using NeoChord is becoming an innovative real time mitral valve repair on a beating heart under echocardiographic guidance[22,23]. Furthermore, another advanced minimally invasive trans catheter therapies such as the MitraClip and transcatheter mitral valve replacement (TMVR) are currently available and been used in high risk and inoperable[6,24]. Cardiac surgeons and interventional cardiologists will have more options of different approaches tailoring for each individual MVS patient[1,6,8,23].

Currently minimal access via RMT approach have shown better cosmetic satisfaction, less bleeding, less blood transfusion, improving post-operative pain, better recovery, similar early and late clinical results comparable to FS approach[1-3,10,15].

What this study adds?

RMT MVS definitely requires special surgical skills, multidisciplinary team, and mindsets[5,8,15,21]. The authors expertise not only effective running of CPB focusing on adequate arterial flow and venous drainage but also respecting patient selection criteria. Currently less invasive approach is applied to more complex mitral valve pathology and higher risk patients. The authors always put priorities on principles of surgery over the small incisions. This study reported the safety, precautions, and benefits of RMT MVS including cosmetic satisfaction, less bleeding, less blood transfusions, comparable good hemodynamic performance, good early and long term outcomes.

Acknowledgements

The authors wound like to thank Mrs. Yada Phengsalae and Ms.Wijittra Matang for assisting statistical analysis and proofreading.

Potential conflicts of interest

The authors declare no conflict of interest.

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