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# Thoracoscope-Assisted Mitral Valve Replacement with a Small Incision in the Right Chest: A Chinese Single Cardiac Center Experience

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**Background:** The aim of this study was to investigate the safety, feasibility, and clinical effectiveness of thoracoscopy-assisted mitral valve replacement via thoracic right-anterior minimal incision.

**Material/Methods:** A retrospective analysis was conducted of 225 patients with mitral valve lesions who were treated in our hospital from August 2012 to August 2015. Group A included 105 patients undergoing thoracoscopy-assisted mitral valve replacement via a thoracic right-anterior minimal incision, and group B included 120 patients undergoing conventional mitral valve replacement. We collected and analyzed clinical data from both groups.





**Results:** The procedures were successful in patients of both groups. No severe complications or mortality were reported. Postoperative mechanical ventilation time ( $8.6 \pm 2.4$  h vs.  $12.4 \pm 3.2$  h), duration of intensive care ( $1.7 \pm 1.2$  d vs.  $2.8 \pm 1.3$  d), duration of postoperative analgesia use ( $28.7 \pm 8.9$  h vs.  $36.3 \pm 7.5$  h), postoperative length of hospital stay ( $8.2 \pm 2.2$  d vs.  $12.8 \pm 2.1$  d), pleural fluid drainage ( $210.5 \pm 60.5$  ml vs.  $425.4 \pm 75.6$  ml), blood transfusion amount ( $420.5 \pm 80.4$  ml vs.  $658.3 \pm 96.7$  ml), and operative incision length ( $4.7 \pm 1.1$  cm vs.  $22.4 \pm 2.5$  cm) were significantly shorter (or lower) in group A than in group B. There were different advantages and disadvantages in the 2 kinds of operative procedure in terms of postoperative complications.

**Conclusions:** Thoracoscopy-assisted mitral valve replacement via thoracic right-anterior minimal incision has the same clinical efficacy, safety, and feasibility as conventional mitral valve replacement.

**MeSH Keywords:** **Mitral Valve • Surgical Procedures, Minimally Invasive • Thoracic Surgery, Video-Assisted**

**Abbreviations:** **CPB** – cardiopulmonary bypass; **PISA** – proximal isovelocity surface area; **MVPG** – mitral valve pressure gradient

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## Background

Mitral valve lesion is the most common form of heart valve disease in clinical practice, and mitral valve replacement is a common surgical procedure for the treatment of mitral valve lesions. The earliest mitral valve replacement was performed in the mid-1960s with median sternotomy [1]. After several decades of development, mitral valve replacement via median sternotomy surgery has matured, with proven effectiveness. However, the drawbacks of this procedure include a massive operative wound bed, increased blood loss, slow postoperative recovery, and cosmetic-comprised incision. In recent years, peripheral cardiopulmonary bypass, thoracoscopic techniques in cardiac surgery, advanced imaging techniques, and improved surgical instruments have allowed heart surgery to be completed via minimal incisions instead of median sternotomy and have helped to achieve a true sense of minimally invasive heart surgery, which is reflected by a maximum reduction in the length of the surgical incision, minimal surgical trauma, fast postoperative recovery, and less pain [2–4]. We report our clinical experience in thoracoscopy-assisted mitral valve replacement in a single center.

## Material and Methods

The present study was approved by the ethics committee of Fujian Medical University, China and adhered to the Declaration of Helsinki. In addition, written informed consent was obtained from the patients or the patient's relatives.

### General data

A retrospective analysis was conducted of 225 patients with mitral valve lesions treated in our hospital from August 2012 to August 2015. Based on the surgical procedure, the patients were divided into 2 groups: group A included 105 patients undergoing thoracoscopy-assisted mitral valve replacement via a right-anterior thoracic minimal incision, and group B included 120 patients undergoing conventional open mitral valve replacement. We collected clinical data from both groups and analyzed these results.

The 225 patients presented with obvious clinical symptoms, including exertional palpitation, shortness of breath, and exercise intolerance. According to the patient history, symptoms, physical signs, electrocardiogram, X-ray, and echocardiogram, 87 patients were diagnosed with mitral stenosis, 35 patients with mitral regurgitation, and 103 patients with mitral stenosis and insufficiency. Of these patients, 135 were complicated with mild tricuspid insufficiency. The relatively larger proportion of cases were rheumatic heart disease. According to the procedure, patients were divided into 2 groups: group A,

the thoracoscopy-assisted surgery group and group B, the conventional thoracotomy group. Tables 1 and 2 show no significant differences in general data and preoperative complications between the 2 groups ( $P>0.05$ ). All the patients were relatively good condition, without cardiac function IV, low EF ( $<45\%$ ), advanced age and other serious complications which contained heart failure, renal inadequacy, severe hepatic insufficiency, chronic obstructive pulmonary disease, dyscrasia and so on. All the patients were used St Jude mechanical prosthetic valve (25 to 29#).

**Selection criteria:** Patients presenting with isolated mitral valve lesions or mild tricuspid valve lesions that did not require simultaneous treatment were selected for both groups. **Exclusion criteria:** 1. Patients with accompanying aortic valve or coronary artery lesions; 2. Patients in which poor visualization of the operative field was expected due to the following factors, including excessive obesity, severe thoracic deformity, right pleural cavity adhesions, or right thoracic or cardiac surgery history; 3. Patients with femoral artery or venous malformations; 4. Patients with severe changes in cardiac structure and lower ejection fractions due to severe valvular lesions; and 5. Patients with poor body condition and class IV cardiac failure.

### Methods

#### *Thoracoscopy-assisted mitral valve replacement via a right-anterior thoracic minimal incision*

All patients in this group underwent intravenous and inhalation anesthesia with single-lumen endotracheal intubation. The patient was placed in the supine position, tilted ( $30^\circ$ ) to the left with a slight elevation of the right side using a pad. A 3-cm longitudinal incision was made in the right groin area to expose the femoral artery and vein, on which a purse-string suture was placed individually. (Incision 1) A 4- or 6-cm curved incision was made along with the lower margin of the right breast to gain access to the thoracic cavity via the fourth intercostal space. A rib spreader was used to expand the intercostal space. The pericardium was incised in the site 1 cm anterior to the phrenic nerve, and the aortic root was exposed. (Incision 2) A 2- or 3-cm right axillary incision was made to gain access to the thoracic cavity via the second intercostal space. This approach was used to place the superior vena cava cannula, superior vena cava occlusion tape, and ascending aorta cross-clamp. (Incision 3) A 2-cm incision was made at the right axillary midline in the fourth or fifth intercostal space to gain access to the thoracic cavity and was used to place the thoracoscope and left ventricular vent tube. (Incision 4) The pericardium was hung by sutures, which were introduced out of the thoracic cavity via incisions 3 and 4. Purse-string sutures were placed in the root of the superior vena cava and aorta. Systemic heparinization was achieved, and the femoral

**Table 1.** Preoperative data comparison between two group of patients.

Item	Thoracoscopy-assisted group	Conventional group	P
Age (year)	45.6±8.5	47.2±9.5	P>0.05
Gender (M/F)	40/55	53/67	P>0.05
Cardiac function			
I-II	62	68	
III	43	52	
IV	0	0	
Mitral lesion type			
Mitral stenosis	40	47	
Mitral insufficiency	23	22	
Mitral stenosis and insufficiency	42	51	
Mitral stenosis			
Valve orifice area (cm <sup>2</sup> )	1.10±0.29	1.08±0.22	P>0.05
Moderate stenosis (1.0< orifice area <1.5)	24	27	
Severe stenosis (0.5< orifice area <1.0)	46	52	
Mitral insufficiency			
Moderate	46	50	
Severe	11	18	
Combining tricuspid insufficiency	53	82	
Cardiothoracic ratio	0.67±0.09	0.71±0.08	P>0.05
End-systolic length of the left atrium (mm)	55.3±7.5	60.4±8.8	P>0.05
End-diastolic length of the left ventricle (mm)	50.2±5.6	52.5±7.4	P>0.05
End-systolic length of the right atrium (mm)	58.3±4.8	56.7±6.3	P>0.05
End-diastolic length of the right ventricle (mm)	45.8±7.4	47.2±5.6	P>0.05
Pulmonary hypertension (mmHg)	55.6±10.4	58.4±9.5	P>0.05
Ejection fraction (%)	52.2±8.3	51.5±7.3	P>0.05
Ejection fraction (%) <45	0	0	

artery and vein were cannulated with a femoral artery cannula (#18 to 22) and a vena cava cannula (#28–30), respectively. After initiation of the bypass, a right-angle superior vena cava cannula (#32–36) was inserted into the root of the superior vena cava. Following the full bypass, the superior and inferior venae cavae were clamped, and inferior vena cava occlusion tape was introduced out through incision 2. The cardioplegia cannula was inserted into the aortic root. When the body temperature dropped to 32°C, the ascending aorta was clamped. Antegrade cold blood cardioplegic solutions were administered. The left ventricle vent was started, the right atrium was opened, and the atrial septum was incised. Three sutures were used to hang the anterior incisional edge of the atrial septum and were sutured to the site at the para-sternum. One suture was used to hang the posterior incisional

edge of the atrial septum and was sutured to the pericardium. The mitral valve was then visualized. The lesioned valve was excised, and the valve replacement was performed with the use of an intermittent suture method. Continuous sutures were used to close the atrial septal incision and the right atrial incision. After rewarming, the clamps of the ascending aorta and the superior and inferior venae cavae were removed. The patient was eventually weaned off of the cardiopulmonary bypass (CPB). A chest tube was placed via incision 3 for closed-chest drainage [5].

#### *Conventional open mitral valve replacement*

All patients in this group underwent intravenous and inhalation anesthesia with single-lumen endotracheal intubation. A

**Table 2.** Preoperative complication comparison between two group of patients.

Item	Thoracoscopy-assisted group	Conventional group	P
Atrial fibrillation	85	103	P>0.05
Left atrial thrombus	10	14	P>0.05
Hypertension	23	21	P>0.05
Diabetes mellitus	18	23	P>0.05
Hepatic insufficiency	3	5	P>0.05
Emphysema pulmonum	0	2	P>0.05
Chronic obstructive pulmonary disease	0	0	
Pulmonary infection	15	17	P>0.05
New cerebral infarction	2	1	P>0.05
New hematencephalon	1	1	P>0.05
Heart failure	0	0	
Dyscrasia	0	0	

20-cm midline incision of the sternum was used to perform cannulation of the aorta and the superior and inferior venae cavae for establishment of CPB. During surgery, the mitral valve was exposed via the right atrium-septum approach. The lesioned mitral valve was removed, and an artificial mitral valve was placed with intermittent sutures. The pericardial and mediastinal drainage tubes were placed and introduced out via the lower site of the incision.

#### Monitoring parameters

The clinical parameters in the 2 groups included operative time, aortic clamping time, duration of cardiopulmonary bypass, incision length, duration of mechanical ventilation, length of intensive care unit stay, thoracic drainage amount, blood transfusion amount, duration of analgesic use, postoperative length of hospital stay, and hospitalization cost. The parameters for postoperative complications included cerebrovascular accident, pulmonary infection, pneumothorax, subcutaneous emphysema, poor wound healing, paravalvular leak, entrapment of prosthetic valve disc, arrhythmia, and re-thoracotomy for hemostasis. The parameters for 3- and 12-month follow-ups included the end-diastolic length of the right and the left ventricle, the end-systolic lengths of the right atrium and the left atrium, ejection fraction, mechanical valve function, and paravalvular leak. The EF of all the patients were measured by M-mode echocardiography. Left ventricular diameter and right ventricular diameter was measured from the anteroposterior diameter of heart chambers by the level of the left ventricle long axis. The end-diastolic length of the right ventricle, the end-diastolic lengths of the left ventricle, the end-systolic lengths of the right atrium and the left atrium were also measured by apical four-chamber view. We used the pressure half-time method to estimate mitral valve area. Using proximal

isovelocity surface area (PISA) method to estimate valve regurgitation, the degree of mitral regurgitation was graded as mild (PISA radius <4 mm), moderate (PISA radius 4–8 mm) or severe (PISA radius >8 mm). All of the TTE were performed by 2 sonographers with 20 years' experience. There were no significant differences in inter- and intra-observer variability.

#### Statistical analysis

The SPSS 19.0 package was used for statistical analysis. The quantitative data with normal distribution are expressed as means  $\pm$  standard deviations ( $\bar{x} \pm s$ ). The independent samples t-test was used to compare differences between the groups. Qualitative data were compared using the  $\chi^2$  test. A  $P < 0.05$  was considered significantly different.

#### Results

The procedures were successful in patients of both groups. No perioperative death, malignant arrhythmia, low cardiac output, or cerebrovascular events were reported. Compared with group B, group A did not have statistically significant differences in operative time, aortic cross-clamping time, and duration of cardiopulmonary bypass ( $P > 0.05$ ). Postoperative mechanical ventilation time, duration of intensive care, duration of postoperative analgesia use, postoperative length of hospital stay, pleural fluid drainage, blood transfusion amount, and incision length were shorter (or lower) in group A than in group B ( $P < 0.05$ ). Hospitalization cost was not significantly different between the 2 groups ( $P > 0.05$ ). (Table 3)

No death, cerebrovascular accidents, low cardiac output, acute heart failure, delayed recovery, severe renal failure, severe

**Table 3.** Peri-operative and post-operative data comparison between two group of patients.

Item	Thoracoscopy-assisted group	Conventional group	P
Operative time (min)	153.4±25.3	176.2±30.4	P>0.05
Aortic occlusion clamping time (min)	48.3±15.5	42.4±12.8	P>0.05
Cardiopulmonary bypassing time (min)	65.6±18.3	70.5±16.2	P>0.05
Mechanical ventilation time (h)	8.6±2.4	12.4±3.2	P<0.05
Intensive care unit time (d)	1.7±1.2	2.8±1.3	P<0.05
Drainage (ml)	210.5±60.5	425.4±75.6	P<0.05
Blood transfusion volume (ml)	420.5±80.4	658.3±96.7	P<0.05
Postoperative analgesia time (h)	28.7±8.9	36.3±7.5	P<0.05
The incision length (cm)	4.7±1.1	22.4±2.5	P<0.05
Postoperative hospital stay (d)	8.2±2.2	12.8±2.1	P<0.05
Hospital costs (10000RMB)	7.05±1.62	6.65±1.83	P>0.05

**Table 4.** Post-operative complications comparison between two group of patients (%).

Item	Thoracoscopy-assisted group	Conventional group	P
Death	0	0	
Cerebrovascular accident	0	0	
Delayed recovery	0	0	
Low cardiac output syndrome	0	0	
Actual heart failure	0	0	
Pulmonary infection	10	35	P<0.05
Surgical wound bad healing	2	12	P<0.05
Pneumothorax	12	1	P<0.05
Subcutaneous emphysema	12	0	P<0.05
Severe renal failure	0	0	
Severe hepatic failure	0	0	
Mediastinal infection	0	0	
Perivalvular leakage	0	0	
Mechanical valve flap	0	0	
Reoperation for bleeding	0	2	P<0.05
Arrhythmia	12	20	P>0.05
Reoperation for valve replacement	0	0	

hepatic failure, mediastinal infection, re-operation for valve replacement, or entrapment of mechanic valve disc were reported in either group. The incidence rates of postoperative pulmonary infection, poor wound healing, and re-thoracotomy for hemostasis were significantly lower in group A than in group B (P<0.05); the incidence rates of postoperative pneumothorax and subcutaneous emphysema were significantly higher in group A than in group B (P<0.05); the incidence

rate of arrhythmia was not significantly different between the 2 groups. During postoperative follow-up, no abnormal positions or dysfunctions of the mechanical valves or paravalvular leaks were reported. (Table 4)

In terms of the color Doppler ultrasound examination, the left atrial diameter, left ventricular diameter, right atrial diameter, right ventricular diameter, left ventricular ejection fraction,

**Table 5.** 3 months follow-up data comparison between two group of patients.

Item	Thoracoscopy-assisted group	Conventional group	P
End-systolic length of the left atrium (mm)	50.2±6.3	56.3±5.4	P>0.05
End- diastolic length of the left ventricle (mm)	52.4±3.5	55.2±6.1	P>0.05
End-systolic length of the right atrium (mm)	46.2±5.2	45.5±4.2	P>0.05
End-diastolic length of the right ventricle (mm)	47.5±6.5	48.3±5.5	P>0.05
Ejection fraction (%)	50.3±6.8	52.5±7.2	P>0.05
Pulmonary hypertension (mmHg)	40.5±8.4	42.4±7.8	P>0.05
Max MV PG (mmHg)	11.2±3.1	12.4±2.5	P>0.05
Mechanical valve flap	0	0	
Perivalvular leakage	0	0	

**Table 6.** 1 year follow-up data comparison between two group of patients.

Item	Thoracoscopy-assisted group	Conventional group	P
End-systolic length of the left atrium (mm)	48.8±5.9	53.1±4.3	P>0.05
End- diastolic length of the left ventricle (mm)	51.5±2.9	53.2±3.2	P>0.05
End-systolic length of the right atrium (mm)	46.4±4.8	46.2±3.9	P>0.05
End-diastolic length of the right ventricle (mm)	48.5±5.2	47.6±4.9	P>0.05
Ejection fraction (%)	51.2±7.3	52.4±6.6	P>0.05
Pulmonary hypertension (mmHg)	25.6±6.4	26.8±7.6	P>0.05
Max MV PG (mmHg)	12.2±2.3	12.5±1.8	P>0.05
Mechanical valve flap	0	0	
Perivalvular leakage	0	0	

pulmonary hypertension and max MV PG were not significantly different (P>0.05). In the 3-month and 1-year follow-up visits, all ultrasound measurements were improved to different degrees compared with the preoperative measurements. Some of the measurements were significantly different. However, no significant differences were observed between the groups (details are shown in Tables 5 and 6). We used the creatinine and GFR to evaluate the renal function before the operation, and assessed the renal function mainly based on creatinine values and their trends postoperation. All of patients with normal preoperative creatinine level, and the total GFR was higher than 60 ml/min. Only a small number of patients with high creatinine in the postoperation, the highest record was 257 umol/l, and they were returned to normal during one week with medical intervention. There were no significantly different between the 2 groups in the preoperative and postoperative renal function (details are shown in Table 7).

Using the operative methods (0=thoracoscopy-assisted method,1=conventional method) as the independent variable of the multivariate regression analysis, the demographic factors of age, gender(0=male,1=female), cardiac function, cardiothoracic ratio, left atrial diameter, left ventricular diameter, right atrial diameter and right ventricular diameter as correction factors, analyze the influence factors of the postoperative clinical parameters. According to the results in Table 8, operative methods were the independent influencing factors of mechanical ventilation time, intensive care unit time, drainage, blood transfusion volume, postoperative analgesia time, hospital stay and the incision length. Compared with the thoracoscopy-assisted method, the conventional method had longer data in mechanical ventilation time, intensive care unit time, drainage, blood transfusion volume, postoperative analgesia time, hospital stay and the incision length.



**Table 7.** Preoperative and postoperative renal function comparison between two group of patients.

Item	Thoracoscopy-assisted group	Conventional group	P
Preoperative Creatinine (umol/L)	75.8±9.5	72.5±7.8	P>0.05
Preoperative left kidney GFR (ml/min)	35.64±5.23	38.14±3.58	P>0.05
Preoperative right kidney GFR (ml/min)	38.59±4.02	36.26±4.31	P>0.05
Creatinine in the first days after operation (umol/L)	110.5±10.3	115.8±12.5	P>0.05
Creatinine in the third days after operation (umol/L)	93.5±7.6	89.8±9.7	P>0.05
Creatinine in the seventh days after operation (umol/L)	75.5±8.9	72.6±9.6	P>0.05
Creatinine in the fourteenth days after operation (umol/L)	49.2±5.8	50.5±6.6	P>0.05
Perivalvular leakage	0	0	

**Table 8.** Multivariate regression analysis of postoperative clinical parameters.

Dependent variable	Independent variable	Regression coefficient			R <sup>2</sup>
		B	t	P	
Mechanical ventilation time	Constant	8.457	29.398	0.000	0.325
	Operative methods	4.085	10.369	0.000	
Intensive care unit time	Constant	2.505	25.602	0.000	0.507
	Operative methods	2.029	15.143	0.000	
Drainage	Constant	212.048	31.359	0.000	0.691
	Operative methods	207.002	22.356	0.000	
Blood transfusion volume	Constant	424.505	50.580	0.000	0.635
	Operative methods	226.170	19.680	0.000	
Postoperative analgesia time	Constant	26.257	35.749	0.000	0.334
	Operative methods	10.635	10.574	0.000	
The incision length	Constant	4.629	23.189	0.000	0.948
	Operative methods	17.446	63.834	0.000	
Postoperative hospital stay	Constant	8.019	36.089	0.000	0.507
	Operative methods	4.606	15.138	0.000	

**Discussion**

Cardiac valve disease is a common acquired heart disease, especially in developing countries. Mitral valve lesion is predominant among the valve diseases. Mitral valve replacement has become a routine procedure in cardiac surgery which, to date, includes both open thoracic and minimally invasive approaches. The advantages of conventional thoracotomy include better visualization of the heart and great vessels and more working space in the operative field; it also allows surgeons to more easily address accidental events during surgery. The disadvantages include splitting of the sternum and the large surgical wound bed, which increase the degree of

pain, the incidence of infection, and the duration of postoperative recovery. In recent years, the popularity of endoscopic surgery and advanced surgical instruments have contributed to the rapid development of minimally invasive surgery. Notwithstanding, heart surgery is the latest surgical procedure to involve minimally invasive techniques because of its unique surgical requirements, including CPB, cardiac arrest, myocardial protection, and intraoperative challenges, such as “excise” and “suture” [6].

In recent years, we have summarized the advantages and disadvantages of various surgical methods and decided to employ the right thoracic minimal incision (operating incision), 2 other

thoracic incisions (for placement of a thoracoscope, an ascending aorta cross-clamp, and a superior vena cava cannula), and minimal incision in the groin area (for placement of femoral artery and vein cannulas) for mitral valve replacement. Using this strategy, we have achieved better clinical effectiveness.

In the mid-1990s, Navia performed right thoracic minimally invasive mitral valve replacement for the first time and showed that minimally invasive mitral valve replacement is as safe and effective a procedure as conventional valve replacement [7]. In February 1996, Carpentier et al. performed a video-assisted minimally invasive mitral valvuloplasty by inducing ventricular tachycardia for the first time. Immediately subsequently, a team performed the first thoracoscopy-assisted minimally invasive mitral valve replacement with clamping the aorta and retrograde cardioplegia [8]. Falk et al. reported 16 cases of video-assisted thoracic mitral valvuloplasty and 8 cases of mitral valve replacement with satisfactory effectiveness [9]. Because the procedure has several advantages, including minimal surgical trauma, less postoperative pain, quick recovery, short hospital stay, good cosmetic appearance of the healed wound, and higher patient satisfaction, minimally invasive mitral valve surgery has become a routine procedure all cardiac surgeons prefer worldwide. McClure et al. analyzed early and late clinical outcomes and follow-up images of cardiac color Doppler ultrasonography in 1000 patients undergoing minimally invasive mitral valve surgery over a period of 15 years in Bridgden Women's Hospital and reported that the long-term clinical effect of minimally invasive mitral valve surgery was favorable and affirmed [10]. Comparable results were reported by Modi et al. after performing a 12-year follow-up in 1178 patients undergoing thoracoscopy-assisted mitral valve surgery in 2 medical centers [11]. Many researchers have studied the effect of this procedure and have found that it has the same safety and clinical efficacy as conventional thoracotomy [12–14].

In our hospital, we have been performing thoracoscopy-assisted right thoracic minimal incision mitral valve replacement since 2006. The surgical operations in this procedure, including excising, suturing, dissecting and hemostasis, are more difficult because the minimally invasive surgery is completely different from the conventional surgery in terms of visualization of the operative field, the depth of operation, positioning, and hand coordination. In the early period, prolonged operative and CPB times were due to the difficulty involved in the establishment of peripheral CPB and limited visualization of the operative field. The development of surgical techniques, tacit collaboration in teamwork, and improved techniques of CPB have allowed this procedure to become mature, with affirmed surgical effectiveness [15,16].

We summarized the advantages of our surgical techniques as follows: modified and optimal techniques for CPB, i.e., femoral

artery and vein cannulation and use of a right-angle superior vena cava cannula (induced out with the ascending aorta clamp from a small incision) that does not interfere with visualization of operative field. Compared with cannulation of the femoral and internal jugular veins, our approach can provide a more stable CPB status. The fourth intercostal incision along the lower edge of the right breast is sufficient to expose the operative field without rib excision. This incision, which is located in the skin folds below the breast, does not affect the cosmetic appearance, is especially suitable for female patients, and can greatly reduce the psychological shadow and psychological barriers caused by postoperative scarring [17,18]. The length of the thoracic incision in complete thoracoscopic surgery equals the minimally required length that allows the prosthetic valve into the thoracic cavity. The incision should meet the minimally invasive and cosmetic criteria. We slightly extended the surgical incision to facilitate operation under either direct visualization or thoracoscope. Moreover, thoracoscopic instruments are not required for intraoperative suture and ligation, which can help to reduce the operative difficulty and time. In our experience, the operative times were similar between thoracoscopy and conventional surgery. In addition, the slightly extended incision can help address various surgical accidents, and the ribs adjacent to the incision can be excised when necessary. During surgery, careful and gentle dissections are required to place the superior or inferior vena cava occlusion tape because it is difficult to repair damage in the posterior wall of the vena cava. Immediate conversion to open surgery may be needed in the event of posterior wall damage. At the end of the procedure, attention should be paid to hemostasis in the operative field and surgical wound, especially in the intercostal vessels and the axillary and thoracic incisions.

Based on the data analysis of this study, postoperative durations of mechanical ventilation and time in intensive care, use of analgesia, postoperative length of hospital stay, pleural fluid drainage amount, blood transfusion amount and incision length were significantly better in the thoracoscopy group than in the thoracotomy group. Compared with conventional thoracotomy, thoracoscopy-assisted mitral valve replacement does not require splitting the sternum and thus includes the following advantages: small surgical wound, less intraoperative blood loss, easier intraoperative hemostasis, less time consumption for hemostasis, and less postoperative exudates [19]. In this study, the thoracic drainage amount, the blood transfusion amount, and the number of patients undergoing re-thoracotomy for hemostasis were significantly lower in the thoracoscopic surgery group. Sternal and posterior sternal bleeding are common and persistent after thoracic surgery. Most bleeders requiring re-operation are hidden in the posterior area of the sternum where the wire passes through and are easy to miss. Intercostal vessels and subcutaneous small vessels in the right axillary and thoracoscopic incisions are common



sites of bleeders in thoracoscopic surgery. Special attention should be paid to these sites, especially the thoracoscopic incision, during closure.

A stable thoracic wall can reduce pain caused by the patient's movement and coughing and is helpful to encourage patient ambulation and coughing for sputum elimination and to achieve a quicker recovery. In the thoracoscopic group, the minimal incision, the intact sternum, the lower amount of pain, and the short period of analgesic use can help the patient to perform coughing exercises. Therefore, these patients can achieve a faster postoperative recovery of pulmonary function and can wean off of mechanical ventilation very quickly. The chances of postoperative lung infection, the length of intensive care unit stay, and the hospitalization time are reduced accordingly [20,21]. In conventional thoracotomy, the use of steel wire is required; therefore, there is a possibility of wound infection caused by wire rejection. Moreover, a midline incision of the sternum has a higher risk of incisional fat liquefaction and poor wound healing due to the lack of subcutaneous tissue. Postoperative persistent pain can affect the patient's appetite and desire for ambulation, potentially prolonging the patient's recovery and increasing the frequency of adverse events related to poor wound healing.

As shown in Table 4, the incidence rates of pneumothorax and subcutaneous emphysema were significantly higher in the thoracoscopy group than in the thoracotomy group. In the thoracoscopy group, the right thoracic approach requires access to the right pleural cavity and compressing the right lung during surgery, which may cause damage to the lung. The incisions made are particularly associated with this type of damage. The incision for thoracoscope placement is used to place the thoracic drainage tube. At the time of drainage tube removal, inappropriate incisional management can cause secondary pneumothorax and subcutaneous emphysema. In contrast, in the conventional surgery group, the pleural cavity is left intact, and a thoracic drainage tube is rarely placed. These adverse events described above are rare. To this end, careful attention should be paid when making incisions during thoracoscopy-assisted mitral valve replacement to avoid pulmonary damage. Moreover, gentle intraoperative operations are required to avoid damaging the right lung.

Thoracoscopic equipment, supplies, and relatively expensive femoral artery and vein cannulas are the major sources for the higher medical cost in the thoracoscopy group. Less time spent in the intensive care unit, less postoperative hospitalization time, and fewer postoperative complications reduced the corresponding costs in the thoracoscopy group. Although the overall medical cost was higher in the thoracoscopy group than in the conventional surgery group, the difference was not statistically significant. As shown in Tables 5

and 6, the follow-up echocardiogram results were not significantly different between the thoracoscopy and conventional thoracotomy groups, indicating that the 2 surgical approaches had similar long-term results and that the selection of the approach did not affect the long-term results. During the follow-up, cardiologists and care managers should be in charge of the patient health and self-management. The proper partnership between the care manager and the patient may improve the long-term prognosis [22,23].

There were some shortcomings in this study. Compared with other studies, the postoperative complications in our study were significantly lower, this is mainly because our cases were selective [254,25]. Rheumatic heart disease is one of the most common adult heart disease in our country, with a large number of severe valvular heart disease, including big left ventricular diameter (ESD >60 mm or EDD >75 mm), and/or left ventricular dysfunction (EF <40%), and/or complicating serious renal inadequacy, and/or hepatic insufficiency or dyscrasia. We usually chose conventional open surgery for these patients. The postoperative complications of these patients were similar to other reports. Another reason resulted in low postoperative complications was our cases were younger than those reports. As we mentioned, the relatively larger proportion of cases were rheumatic heart disease, which were different with other country. Relatively good physical condition, without severe preoperative complication, and other conditions which may lead to better prognosis and lower postoperative complication. Because of starting this operation in a relatively short time, we had a certain bias in the patient selection, excluding the severe cases. In the future, we will further expand the indications for surgery and we will report our experiences about those severe cases. As in any retrospective study which was not randomized, there was bias associated with data collection and enrolling patients in the 2 groups. As a result, our experience was limited to the 225 cases in both groups, and longer-term follow-up is needed. Thirdly, this study was limited to a single institution, and other institutions may find different results.

## Conclusions

Thoracoscopy-assisted mitral valve replacement via a right-anterior thoracic minimal incision has the same clinical efficacy, safety, and feasibility as conventional open mitral valve replacement. The thoracoscopic surgery group had the following advantages: less surgical trauma, less postoperative pain, quick recovery, short hospitalization time, good cosmetic effect of incision, and higher patient satisfaction. However, the history of thoracoscopic surgery is short, and thoracoscopic operations are difficult due to the limited nature of the visualization and working space in the operative field. It is wise

to convert thoracoscopic surgery to open surgery in cases with urgent events. Meanwhile, carefully selecting appropriate case and maximum degree adjusting the patient's preoperative physical condition are the key to success of the thoracoscopic surgery.

### Conflict of interests

None.

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### References:

1. Sezai A, Hata M, Niino T et al: Fifteen years of experience with ATS mechanical heart valve prostheses. *J Thorac Cardiovasc Surg*, 2010; 139(6): 1494–500
2. Woo YJ, Seeburger J, Mohr FW: Minimally invasive valve surgery. *Semin Thorac Cardiovasc Surg*, 2007; 19(4): 289–98
3. Schmitto JD, Mokashi SA, Cohn LH: Minimally-invasive valve surgery. *J Am Coll Cardiol*, 2010; 56(6): 455–62
4. Padala M, Jimenez JH, Yoganathan AP et al: Transapical beating heart cardioscopy technique for off-pump visualization of heart valves. *J Thorac Cardiovasc Surg*, 2012; 144(1): 231–34
5. Cao H, Chen Q, Li QZ et al: A clinical study of thoracoscopy-assisted mitral valve replacement concomitant with tricuspid valvuloplasty, with domestically manufactured pipeline products for cardiopulmonary bypass. *J Cardiothorac Surg*, 2014; 9: 160
6. Al Otaibi A, Gupta S, Belley-Cote EP et al: Mini-thoracotomy vs. conventional sternotomy mitral valve surgery: A systematic review and meta-analysis. *J Cardiovasc Surg (Torino)*, 2017; 58(3): 489–96
7. Navia JL, Cosgrove DM 3<sup>rd</sup>: Minimally invasive mitral valve operations. *Ann Thorac Surg*, 1996; 62(5): 1542–44
8. Carpentier A, Loumet D, Carpentier A et al: Open heart operation under video surgery and minithoracotomy. First case (mitral valvuloplasty) operated with success. *C R Acad Sci III*, 1996; 319(3): 219–23
9. Falk V, Walther T, Diegeler A et al: Echocardiographic monitoring of minimally invasive mitral valve surgery using an endoaorticclamp. *J Heart Valve Dis*, 1996; 5(6): 630–37
10. McClure RS, Athanasopoulos LV, McGurk S et al: One thousand minimally invasive mitral valve operations: early outcomes, late outcomes, and echocardiographic follow-up. *J Thorac Cardiovasc Surg*, 2013; 145(5): 1199–206
11. Modi P, Rodriguez E, Hargrove WC 3<sup>rd</sup> et al: Minimally invasive video-assisted mitral valve surgery: A 12-year, 2-center experience in 1178 patients. *J Thorac Cardiovasc Surg*, 2009; 137(6): 1481–87
12. 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(4): 421–26; discussion 427–28
13. Cosgrove DM 3<sup>rd</sup>, Sabik JF, Navia JL: Minimally invasive valve operations. *Ann Thorac Surg*, 1998; 65(6): 1535–38; discussion 1538–39
14. Vanermen H, Farhat F, Wellens F et al: Minimally invasive video-assisted mitral valve surgery: From Port-Access towards a totally endoscopic procedure. *J Card Surg*, 2000; 15(1): 51–60
15. Schroevers P, Wellens F, De Geest R et al: Minimally invasive video-assisted mitral valve surgery: Our lessons after a 4-year experience. *Ann Thorac Surg*, 2001; 72(3): S1050–54
16. Greco E, Zaballos JM, Alvarez L et al: Video-assisted mitral surgery through a micro-access: A safe and reliable reality in the current era. *J Heart Valve Dis*, 2008; 17(1): 48–53
17. Ito T: Minimally invasive mitral valve surgery through right mini-thoracotomy: Recommendations for good exposure, stable cardiopulmonary bypass, and secure myocardial protection. *Gen Thorac Cardiovasc Surg*, 2015; 63(7): 371–78
18. Sündermann SH, Sromicki J, Rodriguez Cetina Bieffer H et al: Mitral valve surgery: Right lateral minithoracotomy or sternotomy? A systematic review and meta-analysis. *J Thorac Cardiovasc Surg*, 2014; 148(5): 1989–95
19. Koch CG, Li L, Duncan AI et al: Morbidity and mortality risk associated with red blood cell and blood-component transfusion in isolated coronary artery bypass grafting. *Crit Care Med*, 2006; 34(6): 1608–16
20. Schroevers P, Wellens F, De Geest R et al: Minimally invasive video-assisted mitral valve repair: Short and mid-term results. *J Heart Valve Dis*, 2001; 10(5): 579–83
21. Modi P, Hassan A, Chitwood WR Jr.: Minimally invasive mitral valve surgery: A systematic review and meta-analysis. *Eur J Cardiothorac Surg*, 2008; 34(5): 943–52
22. Ciccone MM, Aquilino A, Cortese F et al: Feasibility and effectiveness of a disease and care management model in the primary health care system for patients with heart failure and diabetes (Project Leonardo). *Vasc Health Risk Manag*, 2010; 6: 297–305
23. Ciccone M, Scicchitano P, Aquilino A et al: Waiting lists in coronary artery bypass graft patients and role of coronary angiography: The Apulian experience. *Clinical Audit*, 2013; 2013: 49–55
24. Russell EA, Tran L, Baker RA et al: A review of outcome following valve surgery for rheumatic heart disease in Australia. *BMC Cardiovasc Disord*, 2015; 15: 103
25. Kim JB, Kim HJ, Moon DH et al: Long-term outcomes after surgery for rheumatic mitral valve disease: Valve repair versus mechanical valve replacement. *Eur J Cardiothorac Surg*, 2010; 37(5): 1039–46