Two-Incision Totally Thoracoscopic Approach for Mitral Valve Replacement

Guochang Zhao,1 MD, Jie Gao,1 MD, Yan Liu,1 MD, Song Gu,1 MD, Yulin Guo,1 MD, Bin Xie,2 MD and Pi Xiong Su,1 MD

Summary
Totally thoracoscopic mitral valve replacement (MVR) has been applied to mitral stenosis for many years. Three working ports are usually necessary, among which the longest port ranges from 6 to 8 cm. This study aimed to determine the safety and feasibility of the two-incision totally thoracoscopic approach for MVR, with the longest incision of 3 cm.

From January 2014 to February 2016, 90 patients with mitral valve stenosis were retrospectively analyzed. Thirty-six (40%) patients were included in the two-incision group and 54 patients were operated on using the sternotomy approach. Perioperative variables and postoperative 3-month follow-up data were analyzed.

All patients underwent MVR. Tricuspid valvuloplasty was performed in 23 (25.5%) patients with the Kay technique. The mean total surgery time, cardiopulmonary bypass, and cross-clamp times were longer in the two-incision group (266 ± 42 versus 200 ± 38 minutes; 156 ± 23 versus 121 ± 21 minutes; 100 ± 17 versus 80 ± 17 minutes, respectively) (P < 0.05). The mean postoperative mechanical ventilation time was shorter in the two-incision group (8.6 ± 2.5 versus 11.2 ± 2.6 hours, respectively) (P < 0.05). The mean volume of blood drainage was less in the two-incision group (497 ± 120 versus 730 ± 198 mL, respectively) (P < 0.05). Reopening occurred in one (sternotomy group, 1.8%) patient. No deaths, perivalvular leakage, infectious endocarditis, atelectasis of the lungs, or moderate tricuspid regurgitation were found at the 3-month follow-up.

The two-incision totally thoracoscopic approach for MVR is safe and feasible. Concomitant tricuspid valvuloplasty can be conveniently performed. However, further clinical data are needed in future studies.

Key words: Mitral stenosis

Mitral stenosis is a common cardiac disease worldwide, especially in developing countries. Because of severe valvular lesions, many patients need mitral valve replacement (MVR) rather than valve repair.1–3 Median sternotomy is a common surgical approach for MVR. Median sternotomy provides excellent exposure to the heart and great vessels, but because of a long incision in the sternum, patients might suffer from related complications. A minimally invasive approach for MVR has been reported to have low mortality and excellent postoperative outcomes, whose benefits are less surgical trauma, postoperative pain, better respiratory function, faster recovery, and better cosmesis.1–3 However, with or without video assistance, a relatively smaller incision of 6 cm is still necessary for the minimally invasive approach. MVR with the Da Vinci surgical method, which is thought to be the most minimally invasive technique, is safe and reproducible,4–6 but it is expensive and complex. Therefore, the Da Vinci surgical system cannot be widely used.6–8

The two-incision totally thoracoscopic approach is deployed through two small incisions with the longest incision of only 3 cm. Performance of this approach under thoracoscopy only has not been previously reported. A total of 36 patients have undergone MVR by the two-incision approach in Beijing Chaoyang Hospital since January 2014. In this study, we describe the two-incision totally thoracoscopic approach, and discuss the safety and feasibility of this modified approach.

Methods

Study design: The Clinical Review Board of our institution approved this study. Written informed consent and
Two-incision totally thoracoscopic approach:

Surgical technique:

From January 2014 to February 2016, 90 patients underwent the two-incision totally thoracoscopic approach or the conventional sternotomy approach for MVR in Beijing Chaoyang Hospital, with or without tricuspid valvuloplasty. Thirty-eight (40%) patients were included in the two-incision group. The two-incision totally thoracoscopic approach for MVR is presented as an option in our cardiothoracic surgery center. The specific programs of the therapy were proposed to patients according to the patients’ preferences and certain criteria. The preoperative evaluation for the patients who preferred the two-incision totally thoracoscopic approach follows along the norms of patients undergoing standard MVR in the sternotomy approach group. Computed tomography angiography of the vascular tree in preoperative assessment is suggested for consideration of peripheral cannulation, and preoperative pulmonary function testing is necessary for single lung ventilation. We excluded patients who required concomitant cardiac procedures, but included patients who underwent concomitant tricuspid valvuloplasty. For the two-incision totally thoracoscopic approach, we selected patients with the following: 1) without a concomitant aortic valve operation or coronary artery bypass graft, 2) with an ejection fraction ≥ 40%, 3) no previous operations on the mitral valve and right chest, 4) preoperative pulmonary function testing suggesting slight dysfunction of the lungs or normal lungs, and 5) no femoral vein and artery malformations or thrombosis.

Surgical technique:

Two-incision totally thoracoscopic approach: After achievement of general anesthesia, all of the patients were ventilated with a double-lumen endotracheal tube with rate of respiration ranging from 18 to 25 breaths/minute and a tidal volume ranging from 8 to 10 mL/kg. A 28 FR catheter (Kangxin, Hangzhou, China) was then inserted into the superior vena cava from the jugular vein by an anesthesiologist for drainage of blood. Right subclavian vein cannulation was also achieved with a 14 F or 17 F DLP cannula (Medtronic DLP, Grand Rapids, MI) into the superior vena cava, and was performed under the guidance of transesophageal echocardiography (TEE). The probe of the TEE remained in the lumen of the esophagus. The patient was in the supine position with the right side of the body elevated to 15–20° for convenience. Blood pressure, pulse oxygen saturation, and an electrocardiogram were consecutively monitored throughout the operation. The right common femoral artery and vein were exposed through an oblique incision in the right groin. Double pledget purse-string sutures (4-0 polytetrafluoroethylene) were placed at the anterior side of the main femoral artery and the anterior side of the main femoral vein.

The first incision was located in the fourth intercostal space by the anterior axillary line for a working port. The incision was 3 cm long to facilitate manipulation of two surgical instruments, and it was usually performed after the right breast was pushed toward the left for female patients. A medium soft tissue lap-protector was inserted. A second incision was also made in the fourth intercostal space (Figure 1), but at the level of the midaxillary line, which was 1.5 cm long for inserting a camera, a carbon dioxide insufflation tube, and an aortic cross-clamp. Before introduction of the camera, the right lung was deflated, and carbon dioxide was applied as soon as the left atrium was open. In cases of entrance from the left atrium, to adequately expose the mitral valve, a blunt blade for retracting the left atrium was introduced through the working port and connected to a 2-mm shaft. This shaft was punctured into the right chest cavity through the right parasternal line of the fourth intercostal space. The right hemidiaphragm sometimes precluded the surgeons’ view. Therefore, a pledget-supported stitch was used to pull the dome down, which was also retrieved with a needle punctured from the sixth intercostal space. An oblique incision was made along the inguinal ligament and was approximately 2–3 cm long. After the patient was heparinized systematically, femoral artery cannulation was performed with a 21 F cannula (Edwards Lifesciences, Shanghai, China). A 28 FR catheter was then inserted into the femoral vein (Kangxin, China) for sole use of inferior vena cava blood drainage. The pericardium was opened in front of the right phrenic nerve longitudinally, ranging from the aortic arc to the inferior vena cava. The free edges were then suspended conventionally under the guidance of thoracoscopy. Double pledget purse-string sutures (4-0 polytetrafluoroethylene) were placed at the root of the ascending aorta after the systolic pressure was decreased to 90 mmHg. This was prepared for infusing a cardioplegic solution by a perfusion needle. After the heart was arrested, aortic cross-clamping was performed through the camera port. The left atrium was then opened along the side parallel to the interatrial sulcus by forceps and scissors through the working port. In case of concomitant tricuspid valvuloplasty, two band-blockades were placed round the superior and inferior vena cava in advance, and after tightening these band-blockades the right atrium was opened instead. The atrial septum was then cut through and the mitral valve was exposed with an atrial blade. The operative field was insufflated with carbon dioxide, and venting suction was used for removing blood.

The valve complex was closely examined, all of the lesions were cut off without preservation of the posterior
leaflet, and the valve ring was preserved for at least 3 mm for stitching. A prosthetic valve was chosen according to the measurement of the orifice. First the valve stitches (Housheng, Hangzhou, China) were equally placed around the ring (Figure 2) with all of the tips of the stitches pulled out of the working port, then the prosthetic valve was sutured extracorporeally (Figure 3), and after the prosthetic valve was pushed down to the ring (Figure 4), all of the knots were tightened with a knot pusher, and finally, the prosthetic valves were examined again to ensure that they were working well. Once this procedure inside of the heart was completed, the atrium was sutured, leaving venting suction in place for continual deairing. In addition, the infusion needle could be used to remove air from the aorta, and the left lung was inflated before the final atrial suture was completed. A bipolar ventricular pacing wire (bipolar pacing lead; Medtronic France, Fourmiss, France) was routinely placed before the aortic clamp was released. TEE was used to test the prosthetic valve just before the patient was weaned from cardiopulmonary bypass. Only one tube was placed through the camera port for inspecting drainage after adequately inflating the right lung. Finally, the remaining incisions were sutured intracutaneously.

**Sternotomy approach:** Patients in the sternotomy approach group underwent a standard midline sternotomy for surgical exposure, by which extracorporeal circulation was deployed with central arterial and venous cannulation. With conventional instruments, mitral replacement was performed through an atrial incision similar to the two-incision totally thoracoscopic approach under direct vision. TEE was used in all of the patients.

**Statistical analysis:** SPSS version 17.0 software was used for statistical analysis. Continuous data are presented as the mean with standard deviation. Categorical data are presented as absolute numbers and percentages. Comparisons of patients’ characteristics between groups were performed using the chi-square test for categorical variables and Student’s t-test for continuous variables.

**Results**

All of the patients successfully underwent MVR and survived. Tricuspid valvuloplasty was performed in 23 (25.6%) patients with the Kay technique and eight of these patients had the two-incision totally thoracoscopic approach. The demographic and clinical characteristics of the patients are shown in Table I. There was no difference between the 2 groups. The mean total surgery time, cardiopulmonary bypass, and cross-clamp times were longer in the two-incision group (266 ± 42 versus 200 ± 38 minutes; 156 ± 23 versus 121 ± 21 minutes; 100 ± 17 versus 80 ± 17 minutes, respectively) ($P < 0.05$). The mean postoperative mechanical ventilation time was shorter in the two-incision group (8.6 ± 2.5 versus 11.2 ± 2.6 hours, respectively) ($P < 0.05$). The mean volume of blood drainage was less in the two-incision group (497 ± 120 versus 730 ± 198 mL, respectively) ($P < 0.05$). Reopening occurred in one (sternotomy group, 1.8%) patient. There were two cases of poor healing of incisions in the sternotomy group. Both of them were treated with frequent dressing changes and eventually coalesced (Table II).

The 3-month follow-up was performed at an outpatient clinic. All of the patients had echocardiography, a chest X-ray, a blood test, and a physical examination performed. No deaths, perivalvular leakage, infectious endocarditis, atelectasis of the lungs, or moderate tricuspid regurgitation were found.
MINIMALLY INVASIVE MITRAL VALVE REPLACEMENT

Table I. Preoperative Characteristics of the Two Groups of Patients

| Characteristic                        | Two-incision totally thoracoscopic approach group (n = 36) | Sternotomy approach group (n = 54) | P  
|--------------------------------------|-----------------------------------------------------------|-----------------------------------|------
| Age (years)                          | 48.8 ± 7.4                                                | 50.3 ± 7.4                        | 0.35 |
| Male (%)                             | 29 (76.6)                                                 | 42 (77.8)                         | 0.69 |
| Height (cm)                          | 168.0 ± 7.4                                               | 166.6 ± 7.3                       | 0.39 |
| Weight (kg)                          | 69.7 ± 10.9                                               | 70.3 ± 11.9                       | 0.79 |
| NYHA class III-IV (%)                | 31 (86.1)                                                 | 49 (90.7)                         | 0.49 |
| LVEF (%)                             | 54.5 ± 9.9                                                | 56.1 ± 8.8                        | 0.43 |
| LVEDD (mm)                           | 48.3 ± 6.7                                                | 47.9 ± 4.9                        | 0.74 |
| LVESD (mm)                           | 30.0 ± 6.4                                                | 29.6 ± 4.2                        | 0.71 |
| LA diameter (mm)                     | 56.9 ± 7.4                                                | 57.2 ± 7.2                        | 0.84 |
| T2DM (%)                             | 5 (13.9)                                                  | 6 (11.1)                          | 0.69 |
| Atrial fibrillation (%)              | 31 (86.1)                                                 | 48 (88.9)                         | 0.69 |

NYHA indicates New York Heart Association; LVEF, left ventricular ejection fraction; LVEDD, left ventricular end diastolic diameter; LVESD, left ventricular end systolic diameter; LA, left atrium; and T2DM, type 2 diabetes mellitus.

Table II. Perioperative Variables in Each Group

| Variable                                                   | Two-incision totally thoracoscopic approach group (n = 36) | Sternotomy approach group (n = 54) | P  
|------------------------------------------------------------|-----------------------------------------------------------|-----------------------------------|------
| Mean total surgery time (minutes)                          | 266 ± 42                                                  | 200 ± 38                          | < 0.05 |
| Mean cardiopulmonary bypass time (minutes)                 | 156 ± 23                                                  | 121 ± 21                          | < 0.05 |
| Mean cross-clamp time (minutes)                            | 100 ± 17                                                  | 80 ± 17                           | < 0.05 |
| Mean postoperative mechanical ventilation time (hours)     | 8.6 ± 2.5                                                 | 11.2 ± 2.6                        | < 0.05 |
| Mean volume of blood drainage (mL)                         | 497 ± 120                                                 | 730 ± 198                         | < 0.05 |
| Tricuspid valvuloplasty (%)                                | 8 (22.2)                                                  | 15 (27.8)                         | 0.55 |

Discussion

Rheumatic heart disease remains the leading cause of valvular disease. Mitral stenosis is the most common type of rheumatic mitral lesion. Patients with mitral stenosis are mainly distributed in developing countries and in a few developed countries. Repair of rheumatic mitral stenosis is not common in patients with major calcification and fibrosis of the subvalvular apparatus. It was reported that MVR obtained a higher freedom from reoperation than repair or commissurotomy.

The totally endoscopic approach with the Da Vinci surgical system is safe for mitral valve operations. However, this approach is expensive and complex, and cannot be widely used, especially in some developing countries. Minimally invasive MVR is performed through a microincision of 6 cm with direct vision. Long and large incisions are made to facilitate performance of this procedure, causing damage by cutting ribs and muscles. The use of a rigid retractor injures the tissue around the incision, which may increase the rate of poor healing. Accompanied by modified bypass strategies for draining venous blood from femoral and jugular veins, the totally thoracoscopic technique for MVR was developed from the minimally invasive method. This technique reduces injury to the ribs and muscles, avoiding severing and separation of surrounding tissues, but an intercostal incision of 6-8 cm is still necessary for the main working port. Additionally, two additional incisions must be made during this technique. The surgeon has direct vision from the long incision. Therefore, the totally thoracoscopic approach is controversial.

Cosmetically, a 3-cm long main incision in the two-incision technique reduces additional injury to a great extent, which supports a totally thoracoscopic approach. Before the two-incision totally thoracoscopic approach was performed, our team had a lot of experience with minimally invasive direct procedures. We manipulated extracorporeal circulation through the superior and inferior vena cava drainage, rather than single, two-stage, femoral venous drains, for easier performance of tricuspid valvuloplasty and adequate emptying of the left atrium. Without direct vision, our technique requires video guidance only, and delicate manipulation habits from the minimally procedure proceed to the two-incision totally thoracoscopic approach. An aortic cross-clamp, carbon dioxide insufflation tube, and camera are inserted in the second incision altogether, which is 1.5 cm long. The aortic cross-clamp and the carbon dioxide insufflation tube are observed by the camera. Movement of the camera is extensive without being interruptive. During the period of aortic clamping, attention should be paid because of sharing the port with the aortic cross-clamp while holding the camera. The 3-cm incision is long enough for introduction of a prosthetic valve, permitting handling and manipulation of two instruments. In our experience, gentler manipulation in the minimally invasive method made our technique easier, but tying knots in our two-incision totally thoracoscopic approach was challenging. There are three important points to note in the two-incision totally thoracoscopic approach as follows: 1) the teflon pledgets should be carefully checked to avoid twisting before tying; 2) all of the knots should be tied on one side of the suturing; and 3) two slip knots are initially necessary with the second knot tightly tied on the first knot.
pressing on the first knot, and then a square knot should be performed.

Robotically assisted MVR is currently thought to be the most minimally invasive approach, but it requires a 3-cm incision used for introducing a prosthetic valve, as well as 3-4 cm working ports. In our two-incision totally thoracoscopic approach, the longest incision is only 3 cm, and only one working port is necessary. Moreover, our study showed that the median cardiopulmonary bypass and cross-clamp times in the two-incision totally thoracoscopic approach were acceptable, which are comparable with robotic cases. In our study, the mean postoperative mechanical ventilation time and mean volume of total blood drainage in the two-incision totally thoracoscopic group were less than those in the sternotomy group. This enabled patients in the two-incision totally thoracoscopic group to recover earlier and less blood products were dispensed.

In our experience, due to long-time single lung ventilation, part of the lung is still expanded incompletely after inflation, especially the right lower lobe. To achieve fully expanded lungs, the right lung should be inflated under a camera, which could help confirm adequate inflation. For some cases of postoperative atelectasis, administering direct suction to the trachea, chest physiotherapy, and positive end-expiratory pressure are both useful treatments. All of the patients were re-evaluated by echocardiography, chest X-ray, and an electrocardiogram 3 months after the operation. No deaths, perivalvular leakage, infectious endocarditis, atelectasis of the lungs, or moderate tricuspid regurgitation were found.

Limitations: Because of the lack of feeling of depth and direct vision, our two-incision totally thoracoscopic approach requires surgeons to have special training in endoscopy in addition to the basic techniques of conventional cardiac surgery. Therefore, a period of systematic learning is necessary. Additionally, our study was a retrospective, single-center series, and the non-randomized design may have affected the results with some unmeasured confounders. A longer time of follow-up and further study are needed.

Conclusions

In conclusion, our two-incision totally thoracoscopic approach for MVR shows promising outcomes during the perioperative period, and the early follow-up results are encouraging. We believe that the two-incision totally thoracoscopic approach is safe and reproducible, and with short-term training, operators could master this technique.

Disclosures

Conflict of interest statement: None declared

References

1. Wang YC, Tsai FC, Chu JJ, Lin PJ. Midterms of outcome of rheumatic mitral repair versus replacement. Int Heart J 2008; 49: S65-76.

2. 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. (Review)

3. Cheng DC, Martin J, Lal A, et al. Minimally invasive versus conventional open mitral valve surgery: a meta-analysis and systematic review. Innovations (Phila) 2011; 6: 84-103.

4. Glauber M, Miceli A. State of the art for approaching the mitral valve: sternotomy, minimally invasive or total endoscopic robotic? Eur J Cardiothorac Surg 2015; 48: 639-41.

5. Suri RM, Burkart HM, Rehfelt DH, et al. Robotic mitral valve repair for all categories of leaflet prolapse: improving patient appeal and advancing standard of care. Mayo Clin Proc 2011; 86: 838-44.

6. Mihaljevic T, Jarrett CM, Gillinov AM, et al. Robotic repair of posterior mitral valve prolapse versus conventional approaches: potential realized. J Thorac Cardiovasc Surg 2011; 141: 72-80.

7. Ward AF, Loutnet DF, Neuburger PJ, Grossi EA. Outcomes of peripheral perfusion with balloon aortic clamping for totally endoscopic robotic mitral valve repair. J Thorac Cardiovasc Surg 2014; 148: 2769-72.

8. Senay S, Gullu AU, Kocygiet M, et al. Robotic Mitral Valve Replacement for Severe Rheumatic Mitral Disease. Innovations (Phila) 2014; 9: 292-6.

9. Ma ZS, Dong MF, Yin QY, Feng ZY, Wang LX. Totally thoracoscopic repair of ventricular septal defect: a short-term clinical observation on safety and feasibility. J Thorac Cardiovasc Surg 2011; 142: 850-4.

10. Wang F, Li M, Xu X, et al. Totally thoracoscopic surgical closure of atrial septal defect in small children. Ann Thorac Surg 2011; 92: 200-3.

11. Mandal K, Alwair H, Nifong WL, Chitwood WR Jr. Robotically assisted minimally invasive mitral valve surgery. J Thorac Dis 2013; 5: S694-703. (Review)

12. Sliwa K, Carrington M, Mayosi BM, Zigiriadis E, Mvungi R, Stewart S. Incidence and characteristics of newly diagnosed rheumatic heart disease in urban African adults: insights from the heart of Soweto study. Eur J Heart J 2010; 31: 719-27.

13. Chikwe J, Goldstone AB, Passage J, et al. A propensity score-adjusted retrospective comparison of early and mid-term results of mitral valve repair versus replacement in octogenarians. Eur Heart J 2011; 32: 618-26.

14. Jeng B, Vahanian A. Epidemiology of acquired valvular heart disease. Can J Cardiol 2014; 30: 962-70. (Review)

15. Rankin JS, Burrichter CA, Walton-Shirley MK, et al. Trends in mitral valve surgery: a single practice experience. J Heart Valve Dis 2009; 18: 359-66.

16. Yankah CA, Siniawski H, Detschesd C, Stein J, Hetzer R. Rheumatic mitral valve repair: 22-year clinical results. J Heart Valve Dis 2011; 20: 527-64.

17. 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: 1039-46.

18. Chitwood WR Jr, Elbeery JR, Chapman WH, Moran JM, Lust RL, Wooden WA, et al. Videoassisted minimally invasive mitral valve surgery: the “micro-mitral” operation. J Thorac Cardiovasc Surg 1997; 113: 413-4.

19. Chitwood WR Jr, Elbeery JR, Moran JM. Minimally invasive mitral valve repair using transthoracic aortic occlusion. Ann Thorac Surg 1997; 63: 1477-9.

20. Felger JE, Chitwood WR Jr, Nifong LW, Holbert D. Evolution of mitral valve surgery: toward a totally endoscopic approach. Ann Thorac Surg 2001; 72: 1203-8.

21. Colangelo N, Torracca L, Lapenna E, Moriggia S, Crescenzi G, Alfieri O. Vacuum-assisted in extrathoracic cardiopulmonary bypass management during minimally invasive cardiac surgery. Perfusion 2006; 21: 361-5.

22. Kitamura T, Suklis SG, Edwards J. Redo mitral valve operation via minithoracotomy—“no touch” technique. Int Heart J 2011; 52: 107-9.
23. Casselman FP, Van Slycke S, Dom H, Lambrechts DL, Vermeulen Y, Vanermen H. Endoscopic mitral valve repair: feasible, reproducible, and durable. J Thorac Cardiovasc Surg 2003; 125: 273-82.

24. Senay S, Gullu AU, Kocyigit M, et al. Robotic mitral valve replacement for severe rheumatic mitral disease: peroperative technique, outcomes, and early results. Innovations (Phila) 2014; 9: 292-6.

25. Gao C, Yang M, Xiao C, et al. Robotically assisted mitral valve replacement. J Thorac Cardiovasc Surg 2012; 143: S64-7.

26. Li G, Qiao Y, Zou C, et al. Totally thoracoscopic surgical treatment for atrial septal defect: mid-term follow-up results in 45 consecutive patients. Heart Lung Circ 2015; 22: 88-91.