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Early Clinical Outcomes of Thoracoscopic Mitral Valvuloplasty: The First 90 Cases

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ABSTRACT

Background: We reported 90 cases of thoracoscopic mitral valvuloplasty in its early stages and sought to analyze early clinical outcomes.

Methods: Ninety consecutive patients, who underwent thoracoscopic mitral valvuloplasty at our institute between April 2020 and December 2021, were assessed for outcomes. Clinical data, including baseline characteristics, operative data, postoperative data, and early follow-up results, were collected. The early clinical outcomes were used to assess the reliability and efficiency of this technique.

Results: No in-hospital death occurred. One patient underwent a median sternotomy for bleeding. Intraoperative transesophageal echocardiography revealed no mitral regurgitation in 82 patients and mitral regurgitation of 0–2 cm^2 in six. The remaining two patients with mitral regurgitation >2 cm^2 experienced serious systolic anterior motion but underwent successful re-valvuloplasty during a second pump-up. the mean cardiopulmonary bypass time was 177.1±54.8 min and aortic clamping time, 114.0±44.9 min. Each patient received a prosthetic ring (CG Future™), and 64 patients received artificial chordae with an average of 2.7±1.5 (ranging from 1 to 6) pairs. The mean follow up was 8.8±7.0 (range, 1–22 months), while two patients were lost to follow up. Recurrent severe mitral regurgitation was observed in one patient three months after the operation, and mitral valve replacement was performed via median sternotomy. During follow up, one patient died of upper respiratory tract infection, and one suffered from low cardiac output.

Conclusions: Thoracoscopic mitral valvuloplasty is safe and effective and, once surgeons overcome the learning curve, can achieve excellent early clinical outcomes.

INTRODUCTION

Although various endoscopic techniques have been used in many other surgical departments during the last century, cardiac surgery has been one of the last domains to introduce endoscopic techniques. In 1996, Carpentier et al. [Carpentier 1996] completed the first case of minimally invasive (MI) mitral valvuloplasty under video-assisted surgery, which became the prologue for thoracoscopic valvular surgery. Thoracoscopic cardiac surgery has the same efficacy as other MI approaches (via an upper and lower incision on the sternum and via left and right anterolateral incisions [Saunders 2004; Doty 2000]), as well as less trauma, faster recovery, and better cosmetic results. Moreover, thoracoscopy can provide a high-resolution amplified image of the valve, which allows a systematic assessment of mitral leaflet morphology, as well as the subvalvular apparatus, and allows for superior restoration of valve structure and function. Despite its many advantages, thoracoscopic mitral valvuloplasty still is in the development stage, and few centers can carry out this technique independently due to its very narrow operating field and the use of long-shafted thoracoscopic instruments. Some surgeons may be unwilling to adopt this approach because of the initial learning curve involved [Murzi 2014; Modi 2008]. Therefore, it remains unclear whether thoracoscopic mitral valvuloplasty is worthy of widespread clinical use. Our study aimed to evaluate the reliability and efficiency of this newly introduced surgical procedure by analyzing the clinical data of 90 cases of total thoracoscopic mitral valvuloplasty performed in the early period.

PATIENTS AND METHODS

This single-center, retrospective, observational study collected data from consecutive patients. From April 2020 to December 2021, patients underwent thoracoscopic mitral valvuloplasty performed by an experienced surgeon in our department. There were 62 men and 28 women, aged 15–71 (49.7±12.9) years. All patients were diagnosed using routine transthoracic echocardiography (TTE). We suggest that patients with severe symptoms should be treated with medications (diuretics, β blockade, etc.) before surgery. The cases of mitral valve lesions consisted of 71 cases of degenerative valvular disease, 7 of congenital valvular cleft, 6 of infective endocarditis, 5 of rheumatic valvular diseases, and 1 of congenital leaflet thickness. Informed consent was obtained from all enrolled patients. The study was approved by the Ethics Committee of the Union Hospital. The baseline patient characteristics are presented in Table 1. (Table 1)

Surgical technique: The operation was performed with general anesthesia and single lumen endotracheal intubation. The patients were in supine position with the right hemithorax elevated by 15-25° and right arm was tucked at the side

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Table 1. Baseline characteristics

Variable	Data
Male/female	62/28
Age	49.7±12.9
BMI	22.0±4.0
Hypertension	16
Diabetes mellitus	6
Chronic obstructive pulmonary disease	3
Coronary atherosclerosis	2
Atrial fibrillation	20
New York Heart Association classes grade	
II	23
III	52
IV	15
Lesions	
Degenerative valvular disease	71
Congenital valvular cleft	7
Infective endocarditis	6
Rheumatic valvular disease	5
Congenital leaflet thickness	1
Echocardiography	
Left ventricular ejection fraction (%)	65.6±10.7
Pulmonary artery systolic pressure >60mmHg	6
Mitral regurgitation	
Moderate	14
Severe	76
Mitral stenosis	1
Tricuspid regurgitation (least moderate)	12
Involved regions	
Anterior leaflet (A1/A2/A3)	24(4/12/8)
Posterior leaflet (P1/P2/P3)	52(8/36/8)
Bivalvular leaflet	6
Commissure	8
Leaflets prolapse	66
Chordae rupture	
A1	4
A2	6
A3	4
P1	4
P2	36
P3	10

Table 2. Operative and postoperative data

Variable	Data
CPB time (min)	177.1±54.8
Aortic clamping time (min)	114.0±44.9
Operative time (min)	296.0±69.1
Artificial chordae implantation (pair/case)	2.7±1.5
MV coaptation length (mm)	8.1±1.6
MR (intraoperative TEE)	
0	82
0-2CM^2	6
>2CM^2	2
Repair technique	
Prosthetic annuloplasty	90
Artificial chordae	64
Rectangular resection	20
Commissuroplasty	8
Cleft suture	7
Triangular section	3
Edge to edge	1
Concomitant procedures	
Atrial fibrillation ablation	20
Left atrial appendage closure	12
Tricuspid valvuloplasty	12
Atrial septal defect repair	6
Mitral valve vegetation removal	6
Conversion to median sternotomy	1
Secondary clamping	2
SAM	2
Complication	
Postoperative acute renal failure	1
Postoperative pulmonary infection	1
Pleural effusion	2
Surgical incision infection	3
TTE before discharge	
Left atrium diameter (mm)	38.7±8.2
Left ventricular end diastole diameter (mm)	48.9±6.1
Left ventricular end systolic diameter (mm)	32.7±6.2
Left ventricular ejection fraction (%)	61.5±9.4
Mitral regurgitation	
Mild-Moderate	2
Mild	15
Slight	12

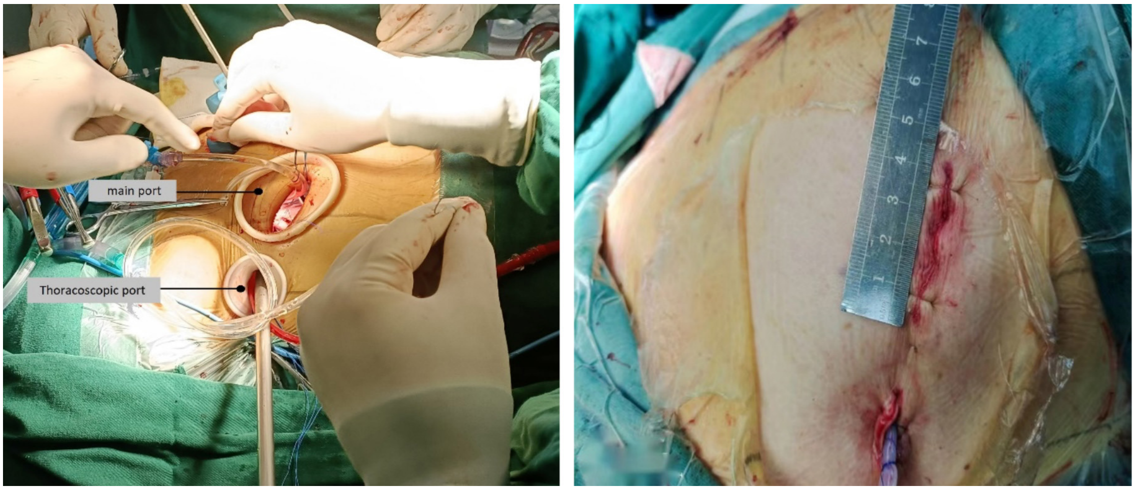

Figure 1. Two incisions in anterolateral thoracic wall. (A) The port accesses (I) main port, (II) thoracoscopic port. (B) The appearance of the incisions.

to improve access to the middle axillary line. A small pillow was place inferior to the scapula to open up the axillary space. Two incisions routinely were performed, roughly divided into a main port, a 3.0–3.5 cm incision in the fourth intercostal space lateral to the right midclavicular line, for facilitating manipulation of surgical instruments, and a thoracoscopic port, a 1.5 cm incision in the fourth intercostal space at the level of the right midaxillary line to inserting a camera, a left ventricle vent catheter, and an aortic cross-clamp (shown in Figure 1). (Figure 1) The right inguinal area was dissected to expose the femoral artery and vein, then intubate right femoral vein to inferior vena cava and the right femoral artery to ascending aorta under screening of transesophageal Doppler ultrasound to establish peripheral cardiopulmonary bypass. If the drainage was not satisfied, the right internal jugular vein could be intubated to the superior vena cava to strengthen the drainage. After cardiopulmonary bypass, cold cardioplegia was perfused anterogradely through the aortic root. When the anal temperature dropped to 32°C, blocking forceps were inserted through the main operating hole to block the ascending aorta, and intracardiac operation was performed under cardiac arrest. The mitral valve was exposed by means of traditional left atrium incision, which was parallel to the interatrial sulcus. Transesophageal echocardiography (TEE) was performed to evaluate valvular and ventricular function before and after surgery in all patients.

Follow up: All patients underwent TTE to evaluate their cardiac function and structure before discharge. Discharged patients were followed up by outpatient service postoperative examination or by telephone calls every three months after the operation. The data obtained included TTE, functional status, mental state, survival, and cardiac-related hospital readmissions. The details of the operative and postoperative data are presented in Table 2. (Table 2)

Statistical analysis: SPSS 22.0 software (SPSS Inc., Chicago, IL) was used for statistical analysis. Measurement data were expressed as mean ± standard deviation (x ± s), and categorical data were presented as percentages. The Student t test and variance analysis were used to compare continuous variables, and the chi-squared test and Fischer's exact test were used for analysis of categorical variables. Two-sided P-value was taken, and $P < 0.05$ was considered statistically significant.

RESULTS

Operation and postoperative data: All 90 thoracoscopic mitral valvuloplasty procedures were performed by an experienced surgeon. Repair techniques included edge-to-edge in one case, triangular resection in three, cleft suture in seven, commissuroplasty in eight, rectangular resection in 20, artificial chordae implantation in 64 (2.7±1.5 [range, 1–6]), and prosthetic ring annuloplasty (CG Future™) in all cases. Concomitant procedures included atrial fibrillation ablation in 20 cases, left atrial appendage closure in 12, tricuspid valvuloplasty in 12, atrial septal defect repair in six, and mitral valve vegetation removal in six. TEE revealed no mitral regurgitation (MR) in 82 patients and MR with an area of 0–2 cm^2 in six; the remaining two patients with MR >2 cm^2 successfully underwent re-valvuloplasty. The mean cardiopulmonary bypass (CPB) time was 177.1±54.8 min and aortic clamping time was 114.0±44.9 min; in the latest 10 cases these were 140.2±20.8 min and 77.9±15.5 min, respectively ($P < 0.05$). The same result appears for operative time (296.0±69.1 vs. 261.4±24.9 min, $P < 0.05$), mechanical ventilation length (25.3±6.2 vs. 17.6±8.9 h, $P < 0.05$), postoperative chest drainage in the first 24h (277.0±272.0 vs. 186.0±68.7 ml, $P < 0.05$), blood products use include red blood cells and fresh frozen plasma (1.8±1.9 vs. 0.9±1.7 U; 157.0±185.7 vs. 70.0±149.4 ml, respectively, $P < 0.05$), and postoperative hospital stay (10.7±8.1 vs. 7.9±2.1 d, $P < 0.05$), as presented in Table 3. (Table 3) Mitral valve valvuloplasty successfully was performed in all patients. No in-hospital death occurred. Intraoperative conversion to median sternotomy (MS) was performed in one case because of uncontrollable bleeding at the aortic root. Two patients with MR >2 cm^2, found during the operation, experienced serious systolic

Table 3. Learning curve

Variable	All patients	Latest 10 cases	*P*-value
CPB time (min)	177.1±54.8	140.2±20.8	<0.05
Aortic clamping time (min)	114.0±44.9	77.9±15.5	<0.05
Mechanical ventilation length (h)	25.3±27.9	17.6±8.9	<0.05
Postoperative chest drainage in the first 24 hours (mL)	277.0±272.0	186.0±68.7	<0.05
Chest drainage tube removal time (d)	3.5±1.6	3.0±0.9	<0.05
Blood transfusion			
Red blood cells	1.8±1.9	0.9±1.7	<0.05
Fresh frozen plasma	157.0±185.7	70.0±149.4	<0.05
Postoperative hospital stay (d)	10.7±8.1	7.9±2.1	<0.05

anterior motion (SAM), and re-valvuloplasty successfully was performed during a second pump-up. One patient underwent tracheostomy two weeks after surgery because of postoperative pulmonary infection, requiring long-term mechanical ventilation. Two patients underwent bedside TTE, due to increasing chest tightness, and massive right pleural effusion and closed right thoracic drainage were performed. One patient received continuous renal replacement therapy (CRRT) for postoperative acute renal failure. After the corresponding postoperative treatment, all 90 patients were discharged after meeting discharge criteria.

Follow up: The mean follow up was 8.8±7.0 (range, 1–22 months), excluding two patients who were lost to follow up. During the follow-up period, recurrent severe MR was observed in one patient 3 months after surgery, and mitral valve replacement was performed via MS. Moderate regurgitation occurred in five cases, mild regurgitation occurred in 29 cases, and mitral regurgitation below slight was observed in 55 cases at the latest follow up. All patients' subjective symptoms improved significantly, with the New York Heart Association (NYHA) functional classification changing from a preoperative mean of 2.91 to 1.04. They were satisfied with how quickly they could return to their normal lives after surgery as well as the cosmetic results of the procedure. During follow up, one patient died of upper respiratory tract infection, and one suffered from low cardiac output postoperatively.

DISCUSSION

Mitral regurgitation (MR) is among the most common diseases in China. The main causes are degenerative (with valve prolapse), ischemic (i.e., due to consequences of coronary disease), or rheumatic disease. Surgery is the only treatment proven to improve symptoms and prevent heart failure [Enriquez-Sarano 2009]. Surgical procedures include mitral valvuloplasty and replacement. It is widely accepted that valve repair is the preferred treatment when feasible. Compared with valve replacement, valve repair has lower operative mortality. Furthermore, better preservation of both early and late ventricular function results in improved long-term survival, and fewer valve-related complications (endocarditis and thromboembolism), anticoagulation-related bleeding events, and late prosthetic dysfunction occur [Vassileva 2011].

At present, MS is still the most common approach for cardiac surgery in China because it provides good exposure of the valve and subvalvular apparatus. However, it also has drawbacks, including inevitable blood loss and necessary transfusion, unbearable postoperative pain, and long recovery time [Shibata 2015]. The use of thoracoscopy in mitral repair has promoted the development of minimally invasive valve surgery. However, the technical difficulty of this technology and the long training cycle of surgeons limit the popularity of thoracoscopic mitral valvuloplasty. In addition, some previous studies have shown that the CPB and aortic clamping times were prolonged at the beginning of this procedure [Bergsland 2011], which makes its safety and effectiveness questionable. In our series, although we observed a certain extension of the CPB time (177.1±54.8 min) and aortic clamping time (114.0±44.9 min), there was no corresponding increase in mechanical ventilation length (25.3±6.2 h), postoperative hospital stay (10.7±8.1 d), ICU stay (49.6±31.1 h), demand for blood transfusion (1.8±1.9 U; 157.0±185.7 ml), and no serious postoperative adverse events. While ensuring the safety and feasibility of the operation, the use of thoracoscopy promotes functional recovery, aesthetic surgical incision, and reduction of complications related to sternotomy.

The concept of annuloplasty with a prosthetic ring was introduced in 1968, while exploration of reconstructive valve surgery technology also had begun. Currently, prosthetic ring annuloplasty is one of the major steps of valve reconstruction and is mandatory in almost all cases of MR [Carpentier 1983; Carpentier 2010]. Other procedures involve directly suturing the mitral ring to reduce the annulus diameter. The prosthetic ring restores the normal systolic size and shape of the mitral annulus without impairing leaflet motion, which is the premise for better leaflet coaptation. Stabilizing the annular structure and eliminating the risk of further deformation guarantees good long-term results. In this study, prosthetic annuloplasty was performed in all patients. All the implanted prosthetic rings were those of Colvin-Galloway Future (CG Future™), with an average size of 30.2±1.7 (range, 27–32).

The anteroposterior diameter of the CG Future™ ring has been slightly increased, and a semi-rigid structure is adopted to fix the rear ring, retain the mobility of the front ring, and better fit the prevalent degenerative lesions [Carpentier 1995]. Its saddle-like shape conforms to the contour of the valve annulus; especially, the bulge of the aorto-mitral curtain—to which the anterior leaflets are attached in systole—is preserved.

Gore-tex (expanded polytetrafluoroethylene) sutures have been used to replace chordae since 1985 [David 2004]. Mitral valvuloplasty with artificial chordae always has good long-term results and is an effective method to treat complex MR, such as anterior valve prolapse and Barlow's disease. Because rectangular or triangular resection of the leaflets is avoided, leaflet coaptation can be increased. However, there are highly technical requirements for artificial chordae implantation, and the primary difficulty lies in determining the required length of the artificial chordae. Adjusting and fixing the artificial chordae length between the apex of the papillary muscle and the edge of the leaflet are key to the success of artificial chordae implantation. In this study, artificial chordae implanting was one of the most commonly used techniques, accounting for 71%, with an average number of 2.7±1.5 (1 to 6) pairs. The average mitral valve coaptation length was 8.1±1.6 mm. Artificial chordae were constructed by a single insertion. Under thoracoscopy, it is easier to observe the length of the adjacent normal chordae as a reference and to adjust and fix the length of the artificial chordae using a slip knot. This effectively solves the problem of Gore-tex sutures being easy to slide and difficult to knot.

Systolic anterior motion (SAM) of the MV refers to the paradoxical movement of the anterior leaflet and/or chordae toward the interventricular septum during systole [Carpentier 1991], which can lead to two adverse outcomes: left ventricular outflow tract obstruction (LVOTO) and MR. SAM after valve reconstruction is the result of redundant posterior valve tissue and/or the use of improperly small prosthetic rings. In this study, the TEE found that two cases of MR >2cm^2 involved serious SAM. Exposure of the posterior leaflet was not as good as that of the anterior leaflet during thoracoscopy. Therefore, it was difficult to systematically measure the height of each segment of the posterior leaflet. To resolve regurgitation, one patient underwent oval excision of partial posterior leaflets, and the other was replaced with a larger prosthetic ring during a second pump-up. Re-valvuloplasty successfully was performed in both cases.

Seeburger et al. [Seeburger 2008] performed minimally invasive MV repair for MR in 1,339 consecutive patients, and predischarge TTE showed mild or less MR in 96.9% of the patients. Casselman et al. [Casselman 2003] analyzed 187 patients, who underwent thoracoscopic MV repair, and found that the freedom from MV reoperation was 99.5% ± 0.5% at 30 days, 97.1% ± 1.4% at 1 year, and 93.3% ± 2.6% at four years. In our series, the TTE before discharge found mild-to-moderate MR in two patients (2.2%). At the recent follow up, moderate- and above-moderate regurgitation occurred in five cases. Only one patient (1%) underwent mitral valve replacement. Our early MR recurrence and reoperation rates were comparable with the rates reported in previous studies, indicating that a minimally invasive approach can achieve good early clinical outcomes.

Since the right thoracic approach was performed during the operation, the right lung collapsed; therefore, the postoperative complications were more related to the thoracic organs, including pneumonia in one case and right pleural effusion in two. Therefore, the postoperative respiratory management of patients should be strengthened. For patients with COPD, extubation was encouraged as early as possible and expectoration to promote recruitment of the lungs. Early studies reported that the incidence of perioperative neurological complications and aortic dissection due to arterial intubation was significantly higher than in conventional MS [Casselman 2003]. No perioperative aortic dissections or strokes were reported in any of the 90 enrolled patients. This is mainly due to preoperative vascular assessment and improved intraoperative cannulation.

Studies have shown that the learning curve for mitral valve varies between 75 and 125 cases per surgeon [Holzhey 2013]. We retrospectively analyzed the clinical data of 90 patients who underwent thoracoscopic mitral valvuloplasty. The mean time of CPB time and aortic clamping in the first 10 cases was 207±38.1 and 149±32.7 min, respectively, while in the latest 10 cases, they were decreased to 140.2±20.8 min and 77.9±15.5 min, respectively. Similar changes were observed in the mechanical ventilation length, postoperative chest drainage in the first 24h, demand for blood transfusion, and length of postoperative hospital stay. This indicates a learning curve for thoracoscopic mitral valvuloplasty. Although there are variations among surgeons, a considerable number of MIS-MV operations are required to overcome the learning curve. Therefore, thoracoscopic surgery is best performed at high-volume centers. Moreover, overcoming the learning curve depends not only on the surgeon but also on the entire cardiac surgery team.

The indications for MR repair have been expanded to include patients with early symptoms of MR and even those who are asymptomatic, assuming that the chance of successful repair is >90%, according to the latest American College of Cardiology/American Heart Association guidelines after surgery [Carpentier 1995]. Patients with severe symptoms before surgery continue to have increased mortality despite symptom relief, whereas in those with few or no symptoms, life expectancy can be restored [Enriquez-Sarano 2009]. This signal emphasizes the importance of early detection, assessment, and treatment of asymptomatic patients with MR. Considering that its prevalence increases with age, we call for routine echocardiography in elderly patients undergoing physical examinations.

Minimally invasive cardiac surgery is a current trend in modern surgery. Thoracoscopic mitral valvuloplasty now is routinely performed for MR at our institution. The main reasons for not using these procedures included severe pleural adhesions from a previous right-sided thoracic surgery and peripheral vascular disease. Despite a massive reduction in rheumatic heart disease, MR remains a serious public health issue in China. According to data from the National Bureau of

Statistics in 2019, there are 170 million people over the age of 60, and the prevalence of MR in this population is 6.4%–9.3% [Liu 2021]. As the population ages in China, more underlying diseases are associated with a high risk of surgery. Therefore, a minimally invasive surgical approach is urgently needed. At our institution, we performed thoracoscopic mitral valve valvuloplasty via a two-port approach, which resulted in less tissue damage and less intraoperative bleeding. Most patients were highly satisfied with the mild postoperative pain and aesthetically pleasing scar and returned to normal life faster during outpatient follow up after surgery.

As a single-institution, retrospective study, this study has unavoidable limitations, including a small-volume observational study design without a control group. Therefore, prospective, multicenter studies are needed to further enhance the persuasiveness of our results.

CONCLUSION

Thoracoscopic mitral valvuloplasty can achieve excellent early clinical outcome. Because of less trauma and good cosmetic effects, this minimally invasive technique is easily accepted by patients and is worthy of clinical promotion.

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