Right mini-thoracotomy approach in patients undergoing redo mitral valve procedure

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Abstract

Aim A minimally invasive technique is an attractive option in cardiac surgery. In this study, we present our experience with minimally invasive cardiac surgery (MICS) via right mini-thoracotomy on patients undergoing mitral valve procedure as reoperation.

Methods From 2017 until 2019, 20 patients underwent reoperation of the mitral valve through a right-sided mini-thoracotomy. Cardiopulmonary bypass was established through cannulation of the femoral vessels. All patients requiring isolated re-operative mitral valve surgery with suitable femoral vessels for cannulation were included in the study. Patients requiring concomitant coronary artery bypass grafting (CABG) or with peripheral artery disease were excluded.

Results The mean age was 65 ± 12 years. The average log. EuroSCORE was $9 \pm 5\%$. Ten patients with severe mitral valve regurgitation (MR) underwent re-repair of the mitral valve. Seven of them were post mitral valve repair (MVR), one was post aortic valve replacement (AVR), one had tricuspid valve repair, and one other patient had CABG before. Ten patients underwent mitral valve replacement due to mixed mitral valve disease ($n = 9$) or mitral valve endocarditis ($n = 1$). Eight patients were post MVR and 2 had AVR before. The mean time to reoperation was 7.5 ± 8 years. In-hospital mortality was 5% ($n = 1$). The mean cross clamp time was 54 ± 26 min. Postoperative echocardiography revealed competent valve function in all cases with mean ejection fraction of $55 \pm 9\%$. The Kaplan-Meier 1- and 2-year survival was 95% .

Conclusion The MICS approach for mitral valve reoperation in selected patients seems to be safe and feasible. It is also a surgical option for high-risk patients.

Keywords Mitral valve · Minimally invasive surgery · Video-assisted redo valve procedures

Introduction

Redo cardiac surgery procedures are associated with increased operative risk and postoperative morbidity and mortality [1]. A minimally invasive approach where possible avoids the need for re-sternotomy and injuries related to re-entry. It also may result in less blood loss and requirement of blood transfusion as well as reduced postoperative morbidity. Advancement of technical settings like the minimally invasive cardiac surgery (MICS) approach without re-sternotomy could be an option to minimize injury to cardiac structures

and reduce the operative risk of redo cardiac procedures. Since Carpentier and colleagues introduced the MICS technique for mitral valve procedures using a video-assisted right mini-thoracotomy in 1996, this approach has become more and more popular worldwide [2–5]. Even though it is reported that this approach is associated with less blood transfusion and faster recovery in comparison with median sternotomy [6], only a few studies are published about redo mitral valve procedures via mini-thoracotomy [7–10]. We report on the in-hospital mortality and short-term outcomes of our single-center experience.

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Material and methods

Study design

From April 2017 until June 2019, 20 patients underwent reoperation of the mitral valve via right mini-thoracotomy at the

Siegburg Heart Center. During the same period, 19 patients underwent redo-sternotomy for mitral valve procedures.

The retrospective, observational study was approved by our local ethics committee.

Inclusion criteria

All patients requiring isolated re-operative mitral valve surgery with suitable femoral vessels for cannulation were included in the study. Routine ultrasound studies to assess the diameter of the femoral artery were performed on admission. All the patients underwent preoperative angiography to rule out coronary artery disease.

Exclusion criteria

A diameter of less than 7 mm for the common femoral artery was an exclusion criterion for the MICS approach. Patients with history of peripheral artery disease or type B aortic dissection were excluded from the study. Patients requiring concomitant coronary artery bypass grafting (CABG) were also excluded. All patients not suitable for the MICS were operated with redo-sternotomy. Any patient found to have pectus deformity on routine preoperative computed tomography (CT) of the chest was also excluded from the study.

Indication for reoperation

The indication for mitral valve procedure was mixed mitral valve disease in 45% ($n = 9$), severe mitral valve regurgitation (MR) in 50% ($n = 10$), and endocarditis in 5% ($n = 1$). The patients' preoperative characteristics are presented in Table 1.

Echocardiography

Pre-, intra-, and postoperative (before discharge) echocardiography was performed routinely in all patients. We used the jet size method (vena contracta) to grade the MR.

Study endpoints

The primary endpoint was in-hospital mortality. The secondary endpoints were early postoperative morbidity and complications including stroke, reoperation for bleeding, acute renal failure requiring hemodialysis, pacemaker implantation, wound infection, respiratory failure, reoperation at the valve, and short-term survival.

Table 1 Preoperative patient demographics

Baseline characteristics	
Patient number	20
Age, mean $\pm$ SD (years)	65 $\pm$ 12
Systemic hypertension, n (%)	10 (50%)
Male, n (%)	10 (50%)
Mitral valve endocarditis, n (%)	1 (5%)
Mixed mitral valve disease, n (%)	9 (45%)
Severe mitral valve insufficiency, n (%)	10 (50%)
Diabetes mellitus, n (%)	4 (20%)
COPD, n (%)	2 (10%)
Chronic renal failure, n (%)	5 (25%)
CAD involvement, n (%)	4 (20%)
EuroSCORE log (mean $\pm$ SD %)	9 $\pm$ 5
NYHA class (mean $\pm$ SD)	3 $\pm$ 0.5
LVEF, mean $\pm$ SD (%)	52 $\pm$ 8
LVEDD, mean $\pm$ SD (cm)	54 $\pm$ 10
Previous cardiac surgery	
Mitral valve repair	15 (75%)
CABG	1 (5%)
Tricuspid valve repair	1 (5%)
Aortic valve replacement	3 (15%)

COPD, chronic obstructive pulmonary disease; *CAD*, coronary artery disease; *NYHA*, New York Heart Association; *LVEF*, left ventricular ejection fraction; *LVEDD*, left ventricular end-diastolic diameter; *CABG*, coronary artery bypass grafting

Surgical procedure

Minimally invasive approach

All operations were performed under general, intravenous anesthesia. The patients were intubated with a single-lumen endotracheal tube. The patient was placed in a supine position with elevation of the right side. A three-dimensional videoscope was inserted via a port site (Fig. 1). We followed the technique and the operative setting described by Seeburger et al. [11]. Carbon dioxide (CO₂) was also used to prevent air embolism. Cardiopulmonary bypass (CPB) was initiated using femoro-femoral cannulation. Depending on the patients' weight (> 80 kg), an additional right internal jugular vein cannula was established by the anesthesiologist. The right mini-thoracotomy was performed using a 4–7-cm incision in the fourth or fifth intercostal space (Fig. 1). Afterwards, a soft tissue retractor (Geister, Tuttlingen, Germany) and a rib retractor (Geister, Tuttlingen, Germany) were inserted. Two small incisions for ports were made for placing a videoscope (Aesculap, Tuttlingen, Germany) and a left atrial retractor. In cases of heavy pleural adhesions, the right lung was carefully mobilized from the thoracic wall. The ascending aorta was mobilized and cannulated with a vent/cardioplegia catheter.

Fig. 1 Minimally invasive cardiac surgery (MICS) mitral valve procedure through video-assisted right mini-thoracotomy. Black arrow: right mini-thoracotomy incision. Blue arrow: port site for the 3D videoscope. Red arrow: port site for the aortic clamp (Chitwood clamp)

The Chitwood clamp was used for clamping the ascending aorta through a skin incision usually lateral in the second right intercostal space. Mitral valve reconstruction (Fig. 2) or replacement was performed using endoscopic instruments (Geister, Tuttlingen, Germany). We also used an automatic suture device for the annular/subannular sutures (COR-KNOT, LSI solutions, Victor, NY, USA).

Mitral valve repair/replacement technique

The mitral valve was accessed through an incision in the interatrial groove. Ruptured chordae were replaced by neochordae using the loop technique with pledget-armed Gore-Tex CV-5 sutures (GoreInc., AZ, USA). Additionally, annuloplasty was applied to stabilize the repaired valve. In cases of mitral leaflet degeneration, the valve was replaced

Fig. 2 Visualization of mitral valve annuloplasty

by resection of the anterior leaflet including the corresponding chordae. The valve was excised 2–4 mm from the annulus. The posterior leaflet including the corresponding chordae was preserved to maintain the annulopapillary continuity and prevent left ventricular function deterioration. Transesophageal echocardiography (TEE) was performed in all patients before weaning from CPB to assess mitral valve function/- MR/-paravalvular leak and evaluate presentation of air. Deairing was performed via the vent catheter placed in the ascending aorta and with TEE guidance.

Concomitant procedures

No concomitant procedures were performed in this group. Any patient who required a concomitant procedure was operated through a median redo-sternotomy.

Myocardial preservation

CPB was initiated and the heart was arrested with cold crystalloid cardioplegia that was applied antegrade via the aortic root. There were no cases of significant aortic valve insufficiency (AI $\geq$ grade 2). We utilized (HTK)-Bretschneider's solution (Custodiol®, Köhler-Chemie, Alsbach-Haenlien, Germany) to arrest the heart and applied it again after 90 min [12].

Follow-up

The mean follow-up of the study population was 1.3 ± 1 year. Clinical follow-up was done over the telephone and echocardiographic parameters were retrieved through records accessed from the cardiology follow-up clinic attendance.

Statistical analysis

Statistical analyses were performed with the (biometric analysis of sampling) BIAS 11.06 software (Frankfurt, Germany). Categorical variables are expressed as frequencies. Continuous variables are presented as mean $\pm$ standard deviation. Preoperative and postoperative left ventricular ejection fraction (LVEF) and left ventricular end-diastolic diameter (LVEDD) were compared using the paired *t* test.

Results

Demographic profile

Twenty patients underwent redo cardiac surgery for mitral valve repair/replacement via right mini-thoracotomy. The mean time to reoperation was 7.5 ± 8 years. The mean age was 65 ± 12 years and 50% were female. Two different

surgeons performed the procedures. During the same period, 19 patients underwent redo-sternotomy for mitral valve procedures.

Coronary artery disease

Four patients had a history of coronary artery disease. While three of the patients had stenting to one or more coronary arteries, one patient had CABG with mitral valve replacement. The patients underwent angiography and as there was no progression of disease, no further intervention on the coronary arteries was deemed necessary in these patients.

Surgical profile

Mitral valve repair was performed in 10 patients (50%). Ten patients underwent mitral valve replacement (50%). Conversion to full sternotomy was not required. The operative and perioperative results are presented in Table 2.

Table 2 Operative and perioperative results

Operative and perioperative data	
Surgical access	
Mini-thoracotomy right, <i>n</i> (%)	20 (100%)
Conversion to median sternotomy, <i>n</i> (%)	0
Mitral valve replacement, <i>n</i> (%)	10 (50%)
Mitral valve repair, <i>n</i> (%)	10 (50%)
Isolated ring implantation	1 (5%)
Leaflet plication and ring implantation	6 (30%)
Quadrangular excision and ring implantation	1 (5%)
Neochoord (loop) and ring implantation	2 (10%)
Cardiopulmonary bypass time, mean $\pm$ SD (min)	105 $\pm$ 40
Cross clamp time, mean $\pm$ SD (min)	54 $\pm$ 26
Intensive care unit stay, mean $\pm$ SD (days)	3 $\pm$ 2
Rethoracotomy for bleeding, <i>n</i> (%)	1 (5%)
Blood loss, mean $\pm$ SD (ml)	570 $\pm$ 360
RBC (red blood cell) concentrate, mean $\pm$ SD (unit)	3 $\pm$ 4
Ventilation time, mean $\pm$ SD (h)	28 $\pm$ 39
Neurologic event (stroke), <i>n</i> (%)	0
Wound infection, <i>n</i> (%)	0
Atrioventricular block, <i>n</i> (%)	0
LVEF, mean $\pm$ SD (%)	55 $\pm$ 9
LVEDD, mean $\pm$ SD (cm)	51 $\pm$ 6
MV max gradient, mean $\pm$ SD (mmHg)	12 $\pm$ 4
MV mean gradient, mean $\pm$ SD (mmHg)	5 $\pm$ 2
In-hospital mortality, <i>n</i> (%)	1 (5%)

LVEF, left ventricular ejection fraction; LVEDD, left ventricular end-diastolic diameter; MV, mitral valve

Cardiopulmonary data, myocardial preservation

The CPB time was 105 $\pm$ 40 min. The cross clamp time was 54 $\pm$ 26 min (Table 2). The heart was arrested with cold crystalloid cardioplegia (HTK-Bretschneider's solution, Custodiol®, Köhler-Chemie, Alsbach-Haenlien, Germany) that was given antegrade via the aortic root.

Morbidity and mortality (postoperative complications)

One patient (5%) had to undergo rethoracotomy because of postoperative bleeding. There were no neurologic events (stroke). None of the patients required permanent pacemaker implantation. In-hospital mortality was 5% (*n* = 1). This patient had a log. EuroSCORE of 10% and developed right heart failure, requiring veno-arterial extracorporeal membrane oxygenation (ECMO) therapy but died of multiorgan failure on the 13th postoperative day. No pneumothoraces were seen in any of the patients postoperatively. One patient with chronic renal failure developed acute renal failure with the need of hemodialysis postoperatively. The average transfused red blood cell (RBC) concentrate units were 3 $\pm$ 4. Two patients (10%) developed pneumonia and recovered after antibiotic treatment. There was no case of reoperation at the mitral valve within the hospital stay (13 $\pm$ 4 days mean). There was no wound infection. One patient developed a hematoma in the groin (after femoral cannulation) at the 10th postoperative day. He underwent wound revision, the hematoma was removed, and the wound was closed without difficulty.

Postoperative echocardiography and follow-up

Postoperative echocardiography data before discharge showed mean LVEF of 55 $\pm$ 9%. We observed competent mitral valve prostheses function in all 10 cases. There was only one patient with mild MR after repair. The other 9 patients who underwent mitral valve repair showed no MR postoperatively. The difference between preoperative and postoperative LVEF was not significant (*p* = 0.15). Similar results were observed regarding preoperative and postoperative LVEDD (*p* = 0.36).

At the latest follow-up, 80% of the patients were in New York Heart Association (NYHA) class I and 20% in NYHA class II. The Kaplan-Meier survival was 95% at 1 year and at 2 years (Fig. 3).

At last follow-up, there was no residual MR greater than grade 1. There were no paravalvular leaks. The mean mitral valve gradient was 4 $\pm$ 0.7 mmHg.

Fig. 3 Kaplan-Meier survival curve

Discussion

Redo cardiac surgery is associated with higher risk for morbidity and mortality [13]. As minimally invasive mitral valve surgery is performed in many cardiac surgery centers, reoperative surgery for mitral valve is becoming an important indication. A feasible alternative to redo-sternotomy mitral valve surgery is MICS-redo mitral valve procedure that potentially reduces adverse events like injury of cardiac and vascular structures [10]. Losenno and colleagues carried out a retrospective study where they compared 40 patients undergoing redo mitral valve procedure using MICS and compared them with 92 patients who received redo-sternotomy mitral valve surgery [14]. They observed a reduced blood product utilization (63% vs. 79%, $p = 0.04$) and length of hospital stay (8 vs. 12 days, $p = 0.02$) in the MICS-redo group in comparison with the redo-sternotomy group. Hiraoka and coworkers report of a series of 10 patients who underwent MICS-redo mitral valve procedure [15]. They observed an in-hospital mortality of 0%, no reoperation for bleeding, and an intensive care unit stay of 1.8 ± 0.6 days mean. In this study, we report our experience from 2017 onwards at the Siegburg Heart Center. Prior to this period, we have performed over 500 minimally invasive mitral valve procedures and thus have gained significant experience with this technique. During our learning curve, there were few areas where we improved and altered our techniques. One of them is the peripheral cannulation technique of the femoral artery and vein (open and percutaneous technique). We also progressed from 2D visualization of the mitral valve to 3D visualization, which helped us to have a better view of the valve pathology intraoperatively. In the course of time, we also applied the loop technique for neo-chordae implantation with pledget-armed Gore-Tex CV-5 sutures (Gore Inc., AZ, USA) that simplified the procedure. Furthermore, we moved on and used an automatic suture

device for the annular/subannular sutures (COR-KNOT, LSI solutions, Victor, NY, USA) that reduced the cardiopulmonary and cross clamp time. In our series, 20 patients underwent a minimally invasive video-assisted mitral valve procedure through a right mini-thoracotomy. The use of a three-dimensional videoscope generates an excellent view of the mitral valve. The cross clamp time in our cohort is 54 ± 26 min that is comparable with other published data for minimally invasive redo procedures for mitral valve surgery [9, 16]. There was no conversion to full sternotomy in our series. This could be due to the excellent visualization of the structures on the one hand and avoidance of injury to cardiac structures on the other. Only one patient underwent reoperation because of diffuse bleeding. In our series, the mean blood loss was 570 ± 360 ml that is acceptable for redo mitral valve surgery. The mean usage of RBCs was 3 ± 4 units that is in keeping with expected blood transfusion rates for redo cardiac surgery procedures. Losenno et al. observed reduced blood product utilization (63%) in their series of 40 patients who underwent MICS-redo mitral valve procedure [14]. This supports our findings. Other centers also report less bleeding complications with this approach [9, 10, 16]. The intensive care unit stay was 3 ± 4 days mean in our patient cohort that is comparable with the results (2 days mean) of Losenno and colleagues [14]. We did not observe neurologic complications in our series. However, there are published data about a higher incidence of stroke up to 5% due to retrograde arterial cannulation and perfusion [14, 17, 18]. The in-hospital mortality rate is 5% in our study and comparable with that of other centers, ranging between 4 and 6.6% [9, 14, 19–22]. The average log. EuroSCORE was calculated with $9 \pm 5\%$ in our study population. Even though it is a high-risk population, the early outcome is favorable. Therefore, the performance of the MICS approach via mini-thoracotomy for redo mitral valve procedures seems to be safe. Postoperative echocardiography data

before discharge showed mean LVEF of $55 \pm 9\%$ and competent mitral valve, respectively, no paravalvular leak. One important issue in MICS-redo mitral valve surgery is the myocardial protection that has to be highlighted. The heart was arrested with cold crystalloid cardioplegia that was given antegrade via the aortic root in our series. This was possible as the aorta could be clamped with the Chitwood clamp. If the aorta cannot be clamped due to heavy adhesions of the aorta, there is also an option to perform the procedure under ventricular fibrillation without clamping the aorta as Hiraoka et al. already described in their study [15]. However, the neurologic events could be higher with this method due to potential embolism [23, 24]. Hiraoka et al. report a neurologic event rate of 10% [15] that is higher than in our cohort (0%). Another alternative is the endoclip technique that could also lead to potential neurologic events due to dislocation of the balloon. In our series, the ascending aorta was mobilized sufficiently and could be clamped so that we always used antegrade cardioplegia. Some of the disadvantages of minimally invasive redo mitral valve procedures need to be mentioned in this context. The cannulation of the femoral artery and vein can lead to complications such as retroperitoneal hematoma or retrograde dissection of the aorta. Especially in patients with atherosclerotic disease, the cannulation of the femoral artery can be difficult and cause dissection or rupture of the arterial wall. We therefore perform and recommend ultrasound of the femoral artery preoperatively. Patients with peripheral artery disease or atherosclerotic femoral artery were excluded from the MICS approach. Furthermore, injury of the lymph vascular system and persistent lymph fistula in the groin are potential complications after femoral cannulation. Another point is the difficult deairing of the heart which needs careful TEE guidance. CO₂ application is mandatory to reduce the risk of air embolism as exposure of the left ventricle is poor. Sometimes pacemaker leads have to be introduced via the internal jugular vein into the right ventricular in case of difficult placing of epicardial pacing wire. The MICS-redo procedure for the mitral valve remains challenging and demands high experience of the surgeon in this field.

Conclusion

Our results of MIC, video-assisted mitral valve reoperation through a right mini-thoracotomy approach demonstrate a good early outcome with low morbidity and mortality. The video-assisted right anterolateral mini-thoracotomy for redo mitral valve operation offers an excellent operative view and reduces the injury to cardiac structures. However, for making statements concerning the durability of repair, longer follow-up times are necessary.

Limitations of the study

Our study was retrospective in nature with only a short follow-up period. Thus, while the early results are satisfactory, we are unable to comment on the durability of the repair in the longer term. Also, there was no control arm in our study, and therefore the results could not be compared against the more commonly performed redo-sternotomy technique. A small sample size is another limitation of our study.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Statement of human rights/ethical approval This retrospective study complies with the principles of the Declaration of Helsinki and was approved by the institutional ethics committee. All procedures being performed were part of the routine care.

Informed consent Not applicable.

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