Video-Assisted Minimally Invasive Mitral Valve Surgery

External Aortic Clamp Versus Endoclamp Techniques

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Objective: Video-assisted minimally invasive mitral valve surgery can be performed through different approaches. The aim of the study was to report our early results and compare the external transthoracic aortic clamping with the endoaortic balloon occlusion techniques according to our experience.

Methods: Between January 2000 and March 2010, 138 patients (103 women, aged 58.4 ± 10.2 years) underwent video-assisted mitral valve surgery through a right thoracotomy. Cardiopulmonary bypass was instituted by femoral arterial and bicaval cannulation with active venous drainage and normothermia; cardioplegic arrest achieved with intermittent blood cardioplegia. In group A (93 patients, 68 women, aged 58.8 ± 7.8 years, 72 MV replacement, 21 MV repair), aortic clamping was achieved using the external transthoracic aortic clamp. In group B (45 patients, 35 women, aged 58.1 ± 11.4 years, 33 MV replacement, 12 MV repair), aortic clamping was achieved with endoaortic balloon occlusion.

Results: Intraoperative procedure-associated problems were experienced in one patient (0.7%) in group A (one conversion to sternotomy for pleural adhesions and bad exposure). At a mean follow-up of 36 ± 18 months, 135 patients (97.8%) were in New York Heart Association class I to II, with satisfactory echocardiographic follow-up. In group A, two patients had noncardiac-related deaths. No perioperative deaths were observed in both groups. There were four (2.8%) transient ischemic attacks and one (0.7%) peripheral ischemic event (group A) during the early postoperative period. Mitral valve repair patients had a 5-year freedom from reoperation of 100% in both groups. There was no significant difference between the two groups regarding preoperative variables, such as age, sex, New York Heart Association class, and left ventricular ejection fraction ($P > 0.05$). Postoperative levels of myocardial cytonecrosis enzymes (MB fraction, creatine kinase, and troponine I) as well as operative time, extracorporeal circulation, and aortic cross-clamping times or ventilation and intensive care unit times were not significantly different between the two groups ($P > 0.05$). More microembolic events were observed in group A than in group B (total 143.4 ± 30.6 per patient vs 78.9 ± 28.6 per patient) by means of continuous automated intraoperative transcranial Doppler evaluations ($P < 0.05$) applied to part of population.

Conclusions: Both techniques proved safe and comparable with low risk of morbidity and mortality. Patients undergoing endoclamp technique resulted to be less subject to embolism.

Key Words: Mitral valve, Minimally invasive surgery, Aortic endoclamping, External aortic cross-clamping.

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Due to excellent results, minimally invasive mitral valve surgery (MIMVS) evolved and became the preferred method of mitral valve repair (MVP) and mitral valve replacement (MVR) in several specialized centers worldwide. MIMVS refers to a collection of new techniques and operation-specific technologies such as modified perfusion methods and visualization techniques that are directed toward minimizing surgical trauma. The belief that this approach leads to less pain, shorter hospital stays, faster return to normal activities, superior cosmesis, and potential cost savings has driven this development.[1,2] However, some surgeons still express concern that restricted exposure, limited operating space, and longer instruments may lead to inferior results both in ability to repair the valve and long-term outcomes.[3]

The aim of this study was to review our collective early results and to examine the safety, efficacy, and early outcomes of MIMVS through a 5-cm right minithoracotomy. The external transthoracic aortic clamp (ETAC) was compared with the transfemoral endoaortic balloon occlusion (EABO) techniques by dividing the population into two groups. A review of literature concerning MIMVS has been reported.

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METHODS

Patients

We prospectively collected pre-, intra-, and postoperative data on all patients who had video-assisted mitral valve surgery at S. Camillo Hospital between January 2000 and March 2010. Absolute contraindications to this approach included severe peripheral vascular disease, a history of a prior right-sided thoracotomy/irradiation, concomitant coronary artery disease requiring surgical revascularization, or concomitant aortic valvular disease requiring replacement.

Because this was our standard approach, Institutional Review Board approval was not needed, but standard informed consent regarding surgical approach and expected outcomes was obtained by either the operating surgeon or team.

Surgical Technique

Each operation was performed through a 5-cm working incision made in the right infrathoracic groove and carried through the fourth intercostal space. Rib spreading was limited by using small thoracic and soft tissue retractors. Each patient had double-lumen endotracheal intubation followed by a transesophageal echocardiography study. To minimize intracardiac air retention, the pleural cavity was flooded continuously with CO_2.

Vacuum-assisted femoral–femoral cardiopulmonary bypass was used with upper-body venous return augmented through a 15F to 17F right internal jugular cannula positioned in the superior vena cava. As primary procedures, aortic occlusion was accomplished by either transthoracic clamping (ETAC) (Cygnet R; Novare Surgical Systems Inc., Cupertino, CA USA) or EABO (Edwards Lifesciences, Irvine, CA USA) according to surgeon preference. Normothermic antegrade blood cardioplegic solution, administered at 15-minute intervals, was used for myocardial protection. When necessary, in case of alarm of pressure monitoring delivery system, and according to the surgeon preference, the retrograde cardioplegic solution was administered through a transthoracic coronary sinus catheter (resulting in 50% per each group). Long-shafted instruments were used to perform each operation (Heartport system; Edwards Lifesciences).

Operative visualization was through a 5-mm endoscope, passed through an anterior axillary line fourth intercostal space trocar. A left atriotomy (Waterston's interatrial groove) was made, and MVPs were done using standard Carpentier techniques. Posterior and bileaflet prolapsing valves were repaired in this series. MVR was performed with interrupted pledgetted 2-0 Ticron (Tyco Healthcare, Mansfield, MA USA) mattress sutures using mechanical valves. Cardiac deairing was performed by flushing the left atrium across the atrial suture line and aortic root venting. Echocardiography ensured intracardiac air removal and was used to monitor valve and ventricular function.

The EmboDop machine (EmboDop; DWL, Germany) was used for intraoperative automatic online embolus detection and discrimination after machine set-up as suggested by Brucher and Russell.[4,5] Both left and right middle cerebral artery Doppler signals were acquired by two separate probes that were fixed in optimal position on a wearable frame. The emboli detection was achieved in part of population, as previously described.[4,5]

Statistical Analysis

Descriptive statistics were reported using means ± standard deviations. Comparisons of data between groups were carried out using a two-sided *t* test for continuous data and Fisher exact test for categorical data. All analyses were performed using SPSS version 11 for Windows software program (Chicago, IL USA).

RESULTS

A total of 138 patients had a minimally invasive mitral valve procedure at S. Camillo Hospital. MVR was performed in 105 patients (76.08%) and MVP in 33 patients (23.9%). Preoperative patient characteristics and echocardiographic data are shown in Table 1. Patients having ETAC had same risk profile compared with patients having EABO, as patients having MVR compared with patients having MVP, with a greater proportion having mitral rheumatic stenotic or mixed disease.

Mean aortic occlusion and cardiopulmonary bypass times were 68.5 ± 27.1 minutes and 94.8 ± 34.6 minutes for EABO procedures and 67.2 ± 25.4 minutes and 92.3 ± 35.7 minutes for ETAC patients, respectively (Table 2). There were neither concomitant procedures nor redo operations in this series.

The ETAC was used in 93 patients (67.3%) (group A: 93 patients, 68 women, aged 58.8 ± 7.8 years, 72 MVR, 21 MVP), and EABO in 45 patients (32.6%) (group B: 45 patients, 35 women, aged 58.1 ± 11.4 years, 33 MVR, 12 MVP).

TABLE 1. Demographic, Preoperative Clinical, Laboratory, and Echocardiographic Characteristics

Parameter	ETAC (n = 93)	EABO (n = 45)	*P*
Median age (yr)	58.8 ± 7.8	58.1 ± 11.4	ns
BSA (m^2)	1.6 ± 0.1	1.7 ± 0.1	ns
Female gender	68 (73.1)	35 (77.7)	ns
Prior cardiac surgery	None	None	—
Diabetes	10 (10.7)	5 (11.1)	ns
Hypertension	42 (45.1)	19 (42.2)	ns
Pulmonary hypertension	33 (35.4)	14 (31.1)	ns
Preoperative AF	30 (32.2)	15 (33.3)	ns
NYHA class III/IV	37 (39.7)	18 (40)	ns
Echocardiographic findings			
MR	21 (22.5)	12 (26.6)	ns
MSR	72 (77.4)	33 (76.7)	ns
EF (%)	60 ± 9.5	58 ± 8.6	ns
INR	1.65 ± 0.77	1.62 ± 0.83	ns
Hct	33.8 ± 5.85	34.3 ± 5.29	ns
Total bilirubin (mmol/L)	2.02 ± 1.57	2.16 ± 1.42	ns
Creatinine (mg/dL)	1.39 ± 0.89	1.29 ± 0.64	ns

Values are presented as mean ± standard deviation or n (%) unless otherwise indicated.

ns indicates not significant; BSA, body surface area; NYHA, New York Heart Association; Hct, hematocrit; INR, international normalized ratio; EF, ejection fraction; MR, mitral regurgitation; MSR, mitral stenosis and regurgitation.

TABLE 2. Procedural Details and Outcome

Parameter	ETAC (n = 93)	EABO (n = 45)	*P*
VR type mechanical	100	100	ns
Mitral valve repair rate	22.5	26.6	ns
CPB time (min)	92.3 ± 35.7	94.8 ± 34.6	ns
AO time (min)	67.2 ± 25.4	68.5 ± 27.1	ns
Hypothermic fibrillation	—	—	—
Additional procedures	—	—	—
Conversion to sternotomy	1 (1.07)	—	—
Reoperation for bleeding	6 (6.4)	3 (6.6)	ns
Aortic dissection	—	—	—
Transfusion	38 (40.8)	18 (40)	ns
Mean ventilator time (H)	7.2 ± 1.5	7.1 ± 1.8	ns
New-onset AF	22 (23.6)	11 (24.4)	ns
Permanent stroke	—	—	—
TIA	4 (2.8)	—	—
Microembolic events (total per patient)	143.4 ± 30.6	78.9 ± 28.6	$P < 0.05$
Infection	—	—	—
Acute renal failure	—	—	—
MB fraction (ng/mL)	85 ± 10.5	88 ± 15.5	ns
Creatine kinase (UI/L)	165 ± 12.5	175 ± 15.1	ns
Troponine I (ng/mL)	1.15 ± 0.5	1.25 ± 0.5	ns
Mean hospital length of stay (d)	6 ± 1.5	5.5 ± 1.5	ns
Early mortality	—	—	—
Peripheral ischemia	1 (1.07)	—	—
Post-MR freedom from reoperation	100	100	ns

Values are presented as %, n (%), or mean ± standard deviation unless otherwise indicated.

ns indicates not significant; VR, valve replacement; AO, aortic occlusion.

Hypothermic fibrillation was used in none of the procedures. Compared with ETAC, the operative times were longer with EABO, but not significantly, and the rate of valve repair was similar (Table 2). The incidence of stroke was zero for both groups. There were no aortic dissections in both groups. There was no significant higher rate of conversion to sternotomy and longer hospital stay with ETAC.

Among patients having an MVP, repair techniques included a posterior annuloplasty by usage of a flexible partial ring (GoreTex) in all 33 patients with a mean ring size of 32 mm (range: 30–34 mm), Carpentier-type leaflet resection and sliding plasty always in all 33 patients, and GoreTex neochordae placement in two patients (6.06%). The intraoperative transesophageal echocardiogram demonstrated that 100% of patients having MVP for mitral regurgitation (MR) left the operating room with no more than trivial residual MR. In patients having MVR, due to a rheumatic disease, a mechanical valve was placed in all patients.

One patient of ETAC group had intraoperative conversion to sternotomy (MVR), the reasons being pleural adhesions and bad exposure type.

Postoperative and Midterm Outcomes

There were no operative mortalities in both ETAC and EABO patients. Reoperation for bleeding was required in nine patients (6.5%), with the same video-assisted approach used in all patients without the need for conversion to sternotomy. There were four (2.8%) transient ischemic attacks and one (0.7%) peripheral ischemic event, which were due to surgical mistake (group A) during the early postoperative period. Mean hospital stay was 5.7 days (range: 5–8 days) with nonsignificant difference for both groups. Overall complications are shown in Table 2.

There was no significant difference between the two groups regarding preoperative variables, such as age, sex, New York Heart Association class, and left ventricular ejection fraction ($P > 0.05$). Postoperative levels (first 36 hours) of myocardial cytonecrosis enzymes (MB fraction, creatine kinase, and troponine I) as well as operative time, extracorporeal circulation, and aortic cross-clamping times or ventilation and intensive care unit times were not significantly different between the two groups ($P > 0.05$; Table 2). More microembolic events were observed in group A than in group B (total 143.4 ± 30.6 per patient vs 78.9 ± 28.6 per patient) by means of continuous automated intraoperative transcranial Doppler (TCD) evaluations ($P < 0.05$) applied to part of population (Table 2).[4]

At a mean follow-up of 36 ± 18 months, 135 patients (97.8%) were in New York Heart Association class I to II, with satisfactory echocardiographic follow-up. In group A, two patients had noncardiac-related deaths. MVP patients had a 5-year freedom from reoperation of 100% in both groups.

DISCUSSION

The, well accepted, Heartport system (Edwards Lifesciences) relies on a specifically designed trilumen catheter called the Endoclamp (Edwards Lifesciences) to achieve aortic clamping, cardioplegia delivery or aortic root venting, and aortic root pressure monitoring. Aortic endovascular occlusion with the Endoclamp catheter (Edwards Lifesciences) has successfully been used in the context of severe disease of ascending aorta, and it is less traumatic than transthoracic aortic clamping. Chitwood and coworkers[4] previously proposed a properly designed clamp that can be introduced through intercostal spaces and positioned, under video assistance, around the ascending aorta. It works like a "lobster pincer" because only one of the two branches is actuated by the handle while the other is straight. The Chitwood clamp (Scanlan International Inc., St. Paul, MN USA) requires positioning of a needle into the ascending aorta for cardioplegia delivery and aortic root venting. A further improvement of this kind of aortic clamping has been the Cygnet device (Cygnet R; Novare Surgical Systems Inc.), which has a flexible handle thus providing more visibility and surgical space during ETAC procedures even if crossing the same thoracic incision necessary for MIMVS.

This series comprises our total experience of minimally invasive video-assisted mitral valve surgery from January 2000 to March 2010. The absence of in-hospital mortality results lower than the reported operative mortality rates in The Society of Thoracic Surgeons Fall 2007 report.[6–10]

Critics of MIMVS suggest that MVP may be performed less frequently and that the repair may be less durable than

that obtained through a sternotomy. The greater degree of difficulty presented by limited operating space, long instruments, and video assistance are cited as reasons for this opinion.[7] Overall, 23.9% of our patients had a repair; however, of those preoperatively judged and having a repair for MR, our successful repair rate was 100%. This is supported, in terms of MIMVS repair rate, by the series reported by Seeburger et al[7] (1536 patients, 87.2%), Aybek et al[11] (241 patients, 83%), Casselman et al[8] (306 patients, 74%), and Grossi et al[9] (561 patients, 66.8%), using the right minithoracotomy approach; and Mihaljevic et al[12] (474 patients, 88%), using the lower hemisternotomy; or Suri et al[13] (1411 patients, 83%), using a median sternotomy. This clearly demonstrates that this technique is reproducible with repair rates comparable to both conventional surgery and other minimally invasive approaches with over 97% of patients leaving the operating room with no more than trivial residual regurgitation. Thus, the early results of repair are clearly not compromised by this less-invasive approach. In terms of durability, our results over 5 years are consistent with published sternotomy repair data of other authors.[13] However, further data and studies are necessary to make our MVP results as MIMVS consistent.

In a multivariate logistic regression model of 409,904 valve procedures performed between 1994 and 2003 and cataloged in The Society of Thoracic Surgeons database, another important preoperative variable influencing operative mortality was a reoperation (odds ratio: 1.61, $P < 0.001$).[14]

However, our presented data do not report the outcome of redo-operations. Literature findings suggest that, in terms of early outcomes, this should be the technique of choice for reoperative mitral valve surgery in patients who do not need a concomitant aortic valve replacement or coronary revascularization. This is concordant with data demonstrating equivalent or lower mortality rates and less morbidity for a right minithoracotomy approach versus a reoperative sternotomy.[15–17] However, data on mid- and long-term outcomes are needed.

Patients with atrial fibrillation (AF) frequently present with more severe symptoms with increased cardiac morbidity in the form of a prior myocardial infarction, cardiomegaly, tricuspid valve regurgitation, and pulmonary hypertension. Prior nonsurgical and surgical series have identified AF as a marker of severe cardiac disease and a specific risk factor for decreased long-term survival.[18–25] The influence on both short-term outcomes and operative mortality has been less clear in literature. Both Lim et al[21] and Chua et al[26] demonstrated no difference in operative mortality for patients with AF versus those who are in sinus rhythm having MVP.[21,26] However, differences in baseline characteristics between patients with AF and without AF may have confounded these results. Our data show that preoperative AF is not an independent predictor of operative mortality after MIMVS.

Aortic dissection associated with a minimally invasive approach may occur either at the site of aortic occlusion, be it endoaortic or transthoracic, or from the femoral cannulation site through retrograde malperfusion. However we had no aortic dissection cases.

In the first Port Access International Registry report, the incidence of aortic dissection was 1.3% in the first half of the study compared with 0.2% in the second half, a difference attributable to experience, better techniques, and improved technology particularly in the balloon design.[10] Grossi et al,[9] Casselman et al,[8] and Onnasch et al[27] reported dissection rates of 0.3% (2/714), 0.7% (2/306), and 1.4% (3/209) with EABO, and the latter also reported a significantly higher incidence of neurologic complications with EABO compared with the transthoracic clamp.

These concerns led the authors to abandon EABO for primary mitral valve procedures.[27] Although operative times are longer with EABO, a finding that has been mirrored by other smaller studies,[28,29] this does not have a negative influence on the valve repair rate. These studies also demonstrated fewer technical difficulties and complications, less blood loss, and lower costs using the transthoracic clamp. Our data also show a similar postoperative stay and complications if EABO and ETAC were compared. However, EABO technology resulted to be more expensive.

Conversion to median sternotomy generally occurs infrequently during the right minithoracotomy approach and others have reported this in 0.3%,[7] 1.1%,[9] and 2.0%[8] of patients. We had only one case in our series belonging to ETAC group.

A reduction in postoperative hemorrhage, transfusion requirements, and need for reexploration for bleeding have been suggested as potential advantages of minimally invasive valve surgery because of a reduction in surgical trauma. This benefit is important given the significant morbidity and mortality associated with transfusions and reexploration.[30] Our data show that 45.5% of patients needed transfusion of blood or blood products (ETAC 40.8%, EABO 40%). Reexploration for bleeding occurred in 5.7% of patients similarly in the two groups; other similar studies have reported this in 4.9%,[9] 5.1%,[7] and 8.5% of patients.[8] The Society of Thoracic Surgery database between 1994 and 2003 reported this in 5.5% of all valvar procedures.[14] However, a recently reported meta-analysis of MIMVS did suggest a significantly reduced need for reoperation for bleeding compared with median sternotomy.[31] In the majority of cases, the source of bleeding was from the chest wall and, in all cases, reexploration was accomplished safely through the original minithoracotomy incision without the need for conversion to sternotomy. From a technical aspect, we believe that a 30-degree videoscope could be useful adjuncts for assessing chest wall hemostasis.

The aim of a previous study[4] was to analyze, by intraoperative TCD, the impact of endovascular aortic occlusion or transthoracic aortic clamping on cerebral microemboli occurrence during MIMVS.

The potential theoretical risk of neurologic damage intrinsic to the Port-Access technique has been extensively studied. Schneider et al[32] found no increase in the risk of cerebral microembolism during minimally invasive Port-Access mitral valve surgery compared with conventional surgery. In a prospective randomized study comparing Port-

Access technique and conventional mitral valve surgery, Dogan et al[33] documented no significant differences, between the two techniques, in markers of cerebral damage dosage and in neuropsychologic tests.

A meticulous comparison of Port-Access and transthoracic clamp techniques has been made by Reichenspurner et al[29] who recently reported excellent results with both methods and recommended a careful patient selection and use of the transthoracic clamp for first time and of the Port-Access technique for redo MIMVS. No differences were observed in terms of clinical evidence of cerebrovascular accidents.

Our TCD analysis comparing embolic potential of aortic endo-clamping versus mechanical cross-clamping resulted to favor EABO group (a total of 143.4 ± 30.6 emboli per patient in group A vs 78.9 ± 28.6 emboli per patient in group B).[4] These results may even support the transient ischemic attack events reported in ETAC group (Table 2). Therefore, the involved four ETAC MVR patients had a preoperative history of moderate carotid disease. Thereafter, only EABO population underwent a total body computed tomography scan to evaluate the aortic wall and dimensions before surgery.

In summary, video-assisted MIMVS is safe and associated with a high rate of repair, low perioperative morbidity, and excellent early echocardiographic results. When compared with the EABO, the ETAC technique, by the adoption of Cygnet aortic clamping device, had a similar outcome. Both techniques proved safe and comparable with low risk of morbidity and mortality.

Limitations

The aim of the study has been to compare EABO and ETAC approaches retrospectively despite the small cohort of patients. The EABO technique has been used only at the beginning of our experience. Actually, we use the ETAC technique even due to the lower costs of the latter.[34] In terms of "learning curve" in minimally invasive surgery, we adopted such techniques mainly for "routine" rheumatic MVR. By enlarging our indications, we would comprise more redo operations and planned MVPs. This will lead to a bigger volume of patients with different clinical scenarios to be analyzed further. The reported article described only the results of an "elegible" population of patients in terms of "initial" experience in minimally invasive surgery. Further studies with bigger populations are necessary, thus leading to a more robust statistical analysis.

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CLINICAL PERSPECTIVE

This report describes a single institution case series of 138 patients who underwent video assisted mitral valve surgery through a right thoracotomy. Ninety-three patients had aortic clamping using an external transthoracic aortic clamp; 45 patients underwent endoaortic balloon occlusion. Both techniques proved safe in comparable with low risk of morbidity and mortality. There were no strokes in either group. The authors did note a slightly higher incidence of micro-embolic events in the external transthoracic aortic clamp group. These were evaluated by means of continuous intraoperative transcranial doppler evaluations.

While this is an interesting contribution, there are several shortcomings that limit the conclusions that can be drawn from this case series. The two groups were not randomized and thus were subject to selection bias. Moreover, the difference in number of emboli between groups was relatively small and of questionable clinical significance. Both techniques of aortic clamping have their advantages and disadvantages. The external transthoracic aortic clamp technique is simpler and less expensive and has had excellent results in much larger series with few reported complications. The intraaortic balloon occlusion technique is particularly helpful in the redo situation and also has shown to be safe in experienced hands. The use of intraaortic balloon occlusion has been associated in some centers with a small but definable incidence of aortic dissection. Further clinical experience will continue to define the utility of these two techniques.