Endovascular balloon versus transthoracic aortic clamping for minimally invasive mitral valve surgery: impact on cerebral microemboli

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Abstract

To evaluate micro embolic events occurrence during minimally invasive mitral valve procedures, comparing balloon endovascular aortic occlusion (Group I) and transthoracic aortic clamping technique (Group II), 36 patients (20 in Group I and 16 in Group II) undergoing minimally invasive mitral valve surgery were selected by CT scan and Doppler studies for absence of atherosclerotic disease at aortic, coronary or peripheral level. Assignment to one of the two groups was made on the basis of surgeon’s preference. Continuous automated intra-operative transcranial Doppler was used to monitor micro embolic events during five operative steps: cardiopulmonary bypass (CPB) setup, time interval from CPB start until aortic clamp positioning, first minute after clamp-on, first minute after clamp-off, first ten minutes after CPB weaning start. More embolic events were observed in Group II than in Group I (total 143.4 ± 30.6 per patient vs. 78.9 ± 28.6 per patient). A large amount of embolic events occurring mainly when the aortic clamp was positioned and released accounted for the observed differences. In a low risk population for embolic events occurrence, endovascular balloon aortic clamping determined less embolic signals than transthoracic aortic clamping.

1. Introduction

Mini-thoracotomic surgical methods to approach the mitral valve have been successfully tested in the last decade and have demonstrated to be reliable, reproducible and safe [1–3]. These methods require peripheral cannulation for cardiopulmonary bypass (CPB) setup and indirect handling of the ascending aorta for aortic cross-clamping. The Heartport system (Cardiovation, Ethicon Inc., St. Paul, MN) relies on a specifically designed trilumen catheter called the Endoclamp (Cardiovation) to achieve aortic clamping, cardiopulmonary bypass and aortic root venting and aortic root pressure monitoring [4]. Chitwood proposed a properly designed clamp that can be introduced through intercostal spaces and positioned, under video assistance, around the ascending aorta [5]. It works like a ‘lobster pincer’ since 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) requires positioning of a needle into the ascending aorta for cardiopulmonary delivery and aortic root venting. Aortic endovascular occlusion with the Endoclamp catheter (Cardiovation) has successfully been used in the context of severe disease of ascending aorta [6], and it should theoretically be less traumatic than transthoracic aortic clamping.

The aim of the study was to analyse, by intraoperative transcranial Doppler (TCD), the impact of endovascular aortic occlusion or transthoracic aortic clamping on cerebral microemboli occurrence during minimally invasive mitral valve surgery.

2. Patients and methods

2.1. Study population

Between September 2002 and April 2004, all patients undergoing minimally invasive mitral valve surgery (36 patients, 10 male, age 55.7 ± 6 years) underwent continuous automated intra-operative transcranial Doppler (TCD) monitoring of micro embolic events. Selection criteria were homogenous: coronary angiography, TOE, thoracic and abdominal CT scan and Doppler ultrasound tests were performed in all patients proposed for mitral valve surgery. Only patients with no calcified plaques or vessel stenosis >50% at any vascular level were selected for minimally invasive surgery. Patients with an ascending aortic diameter exceeding 35 mm or with ascending aortic calcifications or plaques or with an unsatisfactory TCD signal were excluded.

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Patients from this single pool were assigned to Group I (endovascular aortic occlusion) or Group II (transthoracic aortic clamping) depending on surgeon preference, not on preoperative characteristics. Operations were performed by surgeons experienced in minimally invasive mitral valve surgery after completion of the learning curve.

2.2. TCD monitoring technique and statistical analysis

The EmboDop machine (EmboDop, DWL, Germany) was used for intraoperative automatic online embolus detection and discrimination following machine set-up suggested by Brucher and Russell [7,8]. 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 operative procedure was divided into 5 phases.

1. cardiopulmonary bypass (CPB) setup: from CPB setup start to CPB start
2. CPB On: from CPB start to aortic clamping start
3. Clamp On: first minute after aortic clamp positioning start
4. Clamp Off: first minute after aortic clamp removal start
5. CPB Off: first ten minutes from CPB weaning start.

The time period included between aortic clamp inflation and aortic clamp deflation (myocardial ischemic time) was excluded from our evaluation because, in our experience, this period is traditionally affected by a huge number of artefacts determined by surgery. Moreover, during this period Doppler probe position had to be rechecked in 8 of 20 in Group I and in 6 of 16 patients in Group II due to involuntary displacement during the procedure. Offline analysis was carried out to discriminate emboli and artefacts.

2.3. Surgical technique

After draping the patient heparin was administered and CPB set up started: to allow a good drainage during CPB a 17 Fr cannula was percutaneously advanced into the right atrium via the right jugular vein and connected to the pump circuit. Right femoral vessels were exposed at the right groin and 5/0 polypropylene purse-string sutures were placed on the ventral aspect of both the femoral vein and artery. Under TOE guidance the venous and arterial cannula were positioned. In Group I only, the endoclamp was positioned at this point in the ascending aorta under video-assistance in Group II, and by closing the clamp around the ascending aorta under video-assistance in Group II. A 30° left tilt of the patient’s chest was achieved by inflating a plastic bag below the right hemithorax. The right lung was deflated and a right lateral minithoracotomy was performed in the fourth intercostal space. To guide the successive surgical steps, voice-activated video-assistance was used. Pericardium was opened and trans-thoracic stay sutures applied in order to expose the ascending aorta and the interatrial groove. In Group II patients, a needle for cardioplegia delivery and aortic root venting was inserted between two pledgetted 4/0 polypropylene purse-string sutures on the ventral portion of the ascending aorta, and the transthoracic clamp was positioned under video-assistance. Note that, in order to allow comparison, clamp positioning, inside (Group I) or around (Group II) ascending aorta, was realized in the same CPB setup phase in the two groups. CPB was then cannucated and aortic clamping achieved, by inflating the Endoclamp under TOE and TCD guidance in Group I, and by closing the clamp around ascending aorta under video-assistance in Group II.

Antegrade warm blood cardioplegia was delivered through the endoclamp lumen in Group I, and directly into the aortic root in Group II. A left atriotomy was performed in the interatrial groove and the video-assisted mitral procedure completed. Pacing wires were placed on the right ventricle before de-airing manoeuvres. CO₂ was continuously delivered at 3–5 l/min into operative field until the left atrium was de-aired and closed. The same three-steps de-airing procedure was used for both groups: left atrium was de-aired before tying the left atriotomy suture by inflating the lungs and reducing venous return. Patient was then placed head-up, the aorta still clamped, and lungs inflated while return was reduced and aortic root suction activated. The patient was then placed in the Trendelenburg position and aortic clamp was removed. Aortic venting continued during the 15 min reperfusion period, through the Endoclamp lumen in Group I, and through the aortic root in Group II. CPB was discontinued and the chest closed.

2.4. Statistical analysis

Results are given as mean ± standard deviation. Paired Student’s t-test or analysis of variance (ANOVA) with two factor interaction tests as appropriate were applied to evaluate differences between event type or distribution at every time interval. Statistical analysis was performed by NCSS-PASS 2004 statistical package.

3. Results

Patients characteristics and operative time are reported in Table 1. Note that duration of phases selected for TCD monitoring data acquisition was recorded online during CPB setup and CPB On phases, it was fixed by design of the study for the other three phases. No death occurrences were observed in either group. Due to the limited number of cases an analysis of the neurological outcome was not considered as a part of the study.

At TCD monitoring 1578 (78.9 ± 28.6 per patient) embolic events were recorded in Group I and 2295 (143.4 ± 30.6 per patient) in Group II. In order to allow between group comparison, rate of embolic events was normalized for
duration in minutes of the five operative phases selected for TCD sampling. Normalized global event rate is reported in Fig. 1. Between phases comparison: in both groups normalized embolic event rate was higher in CPB On phase, Clamp On and Clamp Off phases compared to CPB setup and CPB Off phases ($P<0.001$, not reported in Fig. 1 to enhance clarity). Between groups comparison: in Group II a significantly higher rate of embolic events was observed during Clamp On and Clamp Off phases in respect to Group I. Solid microemboli were significantly more represented in Group II than in Group I during both Clamp On and Clamp Off phases (Fig. 2). Predominance of gaseous embolic events could be demonstrated in Group II in the Clamp Off phase only (Fig. 3). No side prevalence in the brain distribution of microemboli could be demonstrated. No differences could be demonstrated in the CPB Off phase.

4. Discussion

The potential theoretical risk of neurological damage intrinsic to the Port-Access technique has been extensively studied. Schneider [9] found no increase in the risk of cerebral microembolism during minimally invasive Port-Access mitral valve surgery compared to conventional surgery. In a prospective randomized study comparing Port-Access technique and conventional mitral valve surgery, Dogan [10] documented no significant differences, between the two techniques, in markers of cerebral damage dosage and in neuropsychological tests.

A meticulous comparison of Port-Access and transthoracic clamp techniques has been made by Reichenspurner [11] 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 minimally invasive mitral valve surgery. No differences were observed in terms of clinical evidence of cerebrovascular accidents.

A TCD analysis comparing embolic potential of aortic endo-clamping versus mechanical cross-clamping has never been reported, however, in the context of minimally invasive mitral valve surgery. On the one hand, aortic manipulation has been claimed as a major cause of cerebral microembolism during cardiac surgery. Sylivris [12] studied by TCD cerebral microemboli occurrence during on-pump coronary artery surgery. He demonstrated that aortic manipulation with cross clamp is associated with a step increase in the number of cerebral embolic events per minute. Lund [13], in a study performed with the same TCD machine used in our study, compared the embolic stress of on-pump and off-pump coronary artery surgery, he found a significant reduction of brain embolism with off-pump coronary artery surgery and emphasized that most of embolic events occur in the first few seconds after aortic clamping and declamping. Abu-Omar and colleagues [14] analyzed the number and nature of intraoperative microemboli comparing off-pump, on-

![Fig. 1. Global event rate per operation phase. Total number of events was normalized by dividing it for duration of the phase during which they occurred. TtC = transthoracic clamp group. EC = endoclamp group.](image1)

![Fig. 2. Solid embolic events occurrence per operation phase. Refer to text for definition of time intervals. TtC = transthoracic clamp group. EC = endoclamp group.](image2)

![Fig. 3. Gaseous embolic events occurrence per operation phase. Refer to text for definition of time intervals. TtC = transthoracic clamp group. EC = endoclamp group.](image3)
pump and open cardiac procedure. They observed the largest proportion of microemboli in concomitance with cannulation, decannulation and application and removal of crossclamp and sideclamp.

On the other hand, endoclamping has been successfully used in the context of severe atherosclerotic ascending aorta [6] and is hopefully less traumatic than a mechanical clamp. This could be true also for ‘normal’ ascending aorta.

Our objective was limited and focused to address the embolic stress, to not compare the neurological outcome of the two techniques. Our study shows that aortic manipulation, in the context of minimally invasive mitral valve surgery, is associated with a significant increase in brain embolic event rate even in a very low risk group of patients as the one we studied after a strict selection. This happens with both endoaortic balloon occlusion and transthoracic aortic cross-clamping. In our low risk population, however, the embolic potential of the transthoracic aortic clamping technique was higher compared to the endovascular aortic occlusion technique.

4.1. Study limitations

Automatic detection, counting and discrimination between gaseous and solid emboli have been validated in vitro and in vivo by Brucher and Russell [7,8]. They emphasized the limits of the technique: multiple gas bubbles can be detected as a single event, gas emboli < 2 to 3 µm and solid emboli < 80 µm may cause such a small increase in Doppler energy that they do not exceed the detection threshold of the instrumentation, gaseous emboli > 40 µm and solid emboli > 450 µm can overload the instrumentation. These limitations could have affected our results.

Middle cerebral arteries express only a sample of total brain embolic load, therefore we could have missed many events.

Even if inclusion criteria were homogeneous and defined a single group of patients that were assigned to one of the two techniques, patients were not randomized and a control group was absent.

Preoperative screening of our patients was very careful and selection criteria were restrictive in order to exclude patients with detectable atherosclerotic plaques into ascending aorta. Soft, non-calcified aortic plaques, which are not easy to detect, have a higher probability of embolization than calcified plaques [15]. Patients enrolled in the endoclamp group could have been ‘less prone to embolism’ by chance.

References