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Cerebral Microemboli During Minimally Invasive and Conventional Mitral Valve Operations

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Background. **Intraoperative cerebral microembolism may cause postoperative neurologic damage. The aim of this study was to determine the frequency of cerebral microembolic signals (MES) during minimally invasive surgery (MIS) and conventional (conv.) mitral valve operations and to determine the association of MES with various stages of the operation.**

Methods. **Intraoperative computer-aided transcranial Doppler measurements were performed to detect cerebral microemboli in 21 patients undergoing MIS and in 14 patients undergoing conv. mitral valve operation. We calculated the mean embolic rate for three time periods: P1, start of the operation until aortic clamping; P2, aortic clamping until clamp removal; and P3, declamping until end of surgery.**

Results. **There was no significant difference in the total number of detected cerebral MES between both patient groups (MIS 1,014 ± 753, conv. 937 ± 519; NS). In both groups, the highest number of MES were detected during the third time period when the heart regained effective ejection (MIS 875 ± 746, conv. 680 ± 462; $p > 0.5$).**

Conclusions. **Transcranial Doppler was useful to detect cerebral microemboli in MIS and conv. mitral valve operation. We found no increased risk of cerebral microembolism during the minimally invasive method compared with the conventional technique.**

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Mitral valve operations have been performed through a median sternotomy or an anterior thoracotomy since the early days of cardiac surgery. During the last 3 years there has been a fast evolution of new surgical techniques for minimally invasive mitral valve repair and replacement procedures. A widespread minimally invasive access to the mitral valve is the Port-Access technique (Heartport Inc, Redwood City, CA) developed by Stevens and colleagues [1]. Mitral valve operations using the Port-Access system, which allows for closed chest cardiopulmonary bypass (CPB), endoaortic clamping, and video-assisted endoscopic surgery, have been performed successfully in many centers worldwide [2–7]. Nevertheless, the advantages and disadvantages are discussed controversially [8]. One complaint, among others, is an incomplete removal of air from the left heart and consequent systemic air bubble embolism. In recent studies an association between the number of intraoperative cerebral microembolic signals (MES) detected by transcranial Doppler and postoperative neurologic complications has been reported [9–11]. Braekken and colleagues [12] found that during aortic or mitral valve operations 85% of the MES were detected when the heart regained effective ejection. The aim of the present study was to determine the frequency of cerebral MES during minimally invasive surgery (MIS) in comparison with conventional mitral valve operations and to determine the association of MES to the various operative stages.

Material and Methods

Patient Selection

A total of 35 patients (14 men, 21 women) with nonischemic mitral valve disease were included prospectively in the study after they gave informed consent. Twenty-one patients underwent MIS and 14 had conv. mitral valve operation. Exclusion criteria were coronary artery disease; aneurysm and calcification of the ascending or descending aorta assessed by transesophageal echocardiography, peripheral artery disease, more than 50% stenosis or occlusion of a precerebral carotid, vertebral, or major intracranial artery assessed by Doppler examination, and history of stroke. All patients were operated at the Heartcenter Leipzig by one experienced surgeon.

Anesthesia

Intravenous anesthesia using sulfentanyl, disoprivan, and pancuronium was administered in all patients using a standard protocol. An arterial pressure line was placed in the right radial artery. After endotracheal intubation a Swan-Ganz catheter and a triple lumen central venous line were inserted through the right jugular vein.

Cardiopulmonary Bypass

In both groups a Stöckert S3 roller pump (Stökert, Munich, Germany), a membrane oxygenator (Maxima forte,

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Medtronic, Minneapolis, MN) and a 40-μm arterial blood filter (Medtronic) were used for CPB. In the MIS group vacuum-assisted venous drainage by applying negative pressure up to 50 mm Hg to the venous reservoir was used to enhance venous drainage. Systemic blood pressure was regulated pharmacologically to maintain mean arterial pressure above 50 mm Hg.

Moderate hypothermia (32°C) and the alphastat strategy were used during the period on bypass.

Surgery

The technique of Port-Access mitral valve surgery has been described in detail by others and our group [13]. After a right femoro-femoral CPB was established, the endoclamp was positioned under control of transesophageal echocardiography [14] and transcranial Doppler echography [15] in the ascending aorta just above the sinotubular junction. Following decompression of the heart the endoclamp was inflated and through an endoclamp-tipped catheter anterograde cold crystalloid cardioplegia (Bretschneider HTK, Köhler Chemie, Alsbad, Germany) delivered into the aortic root. Videoscopically guided and robotic-assisted surgery [16] was then performed using a 4- to 5-cm right lateral minithoracotomy in the fourth intercostal space. After deflation of the right lung allowed for exposure of the heart, the pericardium as well as the left atrium were opened and mitral valve replacement or repair was performed using specially designed instruments. As there is no direct access to the aorta and left ventricle, manual manipulation and puncture of the left ventricular apex are impossible. So as soon as the valve is replaced or repaired, the aortic root was reperfused with blood through the inflated endoclamp. This maneuver reduces cross-clamp time on the one hand and on the other hand enhances the removal of air by associated backbleeding into the left ventricle as a result from minor aortic insufficiency caused by left atrial retractor.

Then the patient was positioned on the left side, the left ventricle was cannulated through the mitral valve, and the left atrium was closed while the heart was already beating. To support the removal of air the surgical field was constantly flushed with CO_2 5 L/min. A temporary pacing wire was positioned in the pericardial sac, the endoclamp withdrawn, a chest tube inserted, and the thoracotomy was closed.

Conventionally operated patients underwent anesthetic induction followed by a standard median sternotomy. After cannulating the ascending aorta and the right atrium, CPB was initiated. The ascending aorta was clamped and antegrade cardioplegic solution was administered. The left atrium was opened anteriorly to the right superior pulmonary vein. The mitral valve was now repaired or replaced using standard techniques. After completion of the procedure the left atrium was closed by a continuous suture. Air was removed by inflation of the lungs and simultaneous reduction of venous drainage with the patient placed in the Trendelenburg position, cannulating the apex of the left ventricle, and by suction on the aortic vent. Cardiopulmonary bypass was discontinued and the sternotomy was closed.

Table 1. Patient Characteristics

	MIS (n = 21)	Conv. (n = 14)	*p*
Age (y)	54 (±13)	59 (±10)	NS
Sex (M/F)	9/12	5/9	NS
NYHA class (n)			
I	0	0	. . .
II	8	5	NS
III	13	9	NS
IV	0	0	. . .
Arterial hypertension (n)	11	8	NS
Pulm. hypertension (n)	15	11	NS
Diabetes (n)	7	5	NS
LVEF (%)	54 ± 15	56 ± 14	NS
Pathology of the mitral valve (n)			
MI > II °	16	10	NS
MS > II °	5	4	NS
TI (I-II) (n)	7	5	NS
Preoperative rhythm (n)			
Sinus	8	7	NS
Atrial fibrillation	13	7	NS
Pacemaker	1	0	NS

Conv. = conventional mitral valve surgery; LVEF = left ventricular ejection fraction; MI = mitral insufficiency; MIS = minimally invasive mitral valve surgery; MS = mitral stenosis; NYHA = New York Heart Association; TI = tricuspid regurgitation.

Transcranial Doppler

Continuous computer-aided transcranial Doppler examination of the left and right middle cerebral arteries (MCAs) was performed from the beginning of the operation until closure of the thorax using a Multi-Drop X4 machine (DWL, Sipplingen, Germany). Two-megahertz pulsed-wave probes—fixed by a spectacle frame—were positioned transtemporally in front of the ear above the right and left zygomatic arch. The MCAs were simultaneously sonicated to a depth of 53 and 48 mm, respectively (multirange principle). This procedure allows monitoring of blood flow velocity and detection of cerebral emboli in the MCAs. Using automated software (TCD-8 for Multi-Drop X4, version 8.00q) we discriminated during off-line analysis between emboli and artfact signals. We calculated the mean embolic rate for three time periods: P1, start of operation until aortic clamping (di-

Table 2. Perioperative and Postoperative Parameters

	MIS	conv.	*p*
Mitral valve repair	n = 14	n = 5	. . .
Mitral valve replacement	n = 7	n = 9	. . .
CPB (min)	108 ± 25	74 ± 30	< 0.001
Ischemic time (min)	51 ± 20	46 ± 21	NS
Intubation time (hours)	13 ± 7	14 ± 7	NS
ICU time (days)	2.5 ± 1.4	2.4 ± 1.3	NS
Hospitalization (days)	10 ± 3	10 ± 4	NS

conv. = conventional mitral valve surgery; CPB = cardiopulmonary bypass; ICU = intensive care unit; MIS = minimally invasive mitral valve surgery.

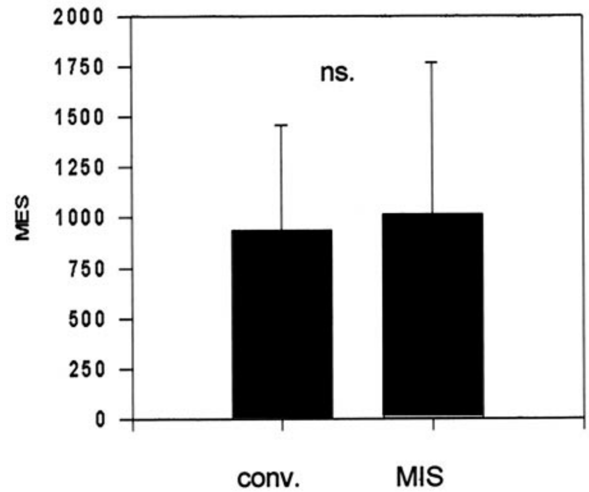

Fig 1. Total rate of microembolic signals (MES) *given as mean ± standard deviation.* (conv. = *conventional mitral valve surgery;* MIS = *minimally invasive mitral valve surgery.)*

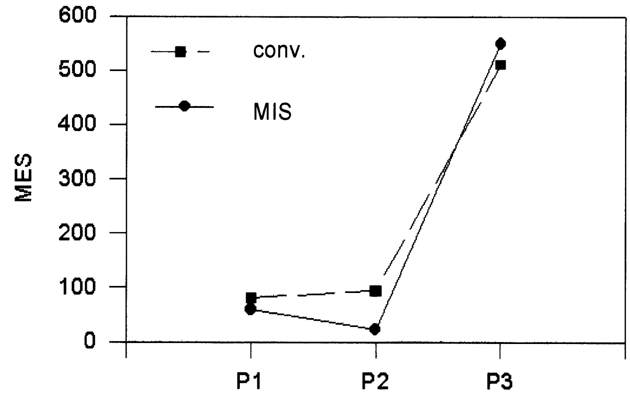

Fig 2. Median rate of microembolic signals (MES) *detected during the three time periods. Note the significantly increased number of MES in both groups during the third time period.* (conv. = *conventional mitral valve surgery;* MIS = *minimally invasive mitral valve surgery.)*

rect/endoaortic); P2, aortic clamping until clamp removal; and P3, declamping until end of procedure.

Results are given as mean ± standard deviation. For comparison of group mean values after testing for control distribution, the *t* test was applied.

Results

Demographics and patient characteristics are summarized in Table 1. The mean duration of CPB was 108 ± 25 minutes (MIS) and 74 ± 30 minutes (conv.); $p < 0.001$ Cross-clamp-, intubation-, ICU- and hospitalization time were not significantly different within the two MIS and conv. groups (Table 2).

The total rates of detected cerebral microemboli were as follows: MIS 1014 ± 753 versus conv. 937 ± 519 (Fig 1). MES detected during the three time periods (P1, P2, P3) are shown on Table 3. Figure 2 reveals that the majority of all MES in both groups occurred during the third time period when the heart regained effective ejection.

Table 3. Microembolic Signals During the Three Time Periods

	Mean	SD	Median	Min	Max
P1					
MIS	84	79	60	7	314
conv.	114	99	82	11	340
P2					
MIS	67	88	23	3	313
conv.	142	174	94	0	683
P3					
MIS	875	746	549	105	2,785
conv.	680	462	511	252	1,840
Σ					
MIS	1,014	753	643	211	3,004
conv.	937	519	781	322	2,202

conv. = conventional mitral valve surgery; MIS = minimally invasive mitral valve surgery.

Comment

Cerebral ischemia caused by cerebral emboli (air bubbles, atheromatous plaques) and hypoperfusion of the brain are important factors in the etiology of neurologic dysfunction after CPB. As shown by many researchers, transcranial Doppler echography can effectively monitor cerebral emboli. The application of intraoperative transcranial Doppler has revealed that MES occur in virtually all patients undergoing CPB. Cerebral MIS are known to occur during specific surgical interventions. As described by Barbut and colleagues [17] we have also seen cerebral microemboli during cannulation of the ascending aorta, cross-clamping, manipulation of the cross-clamp, clamp removal, and manipulation of the heart. In some patients we found a large proportion of unexplained MES during CPB. These emboli likely represent air bubbles that are not eliminated by the arterial line filter [18]. Perfusionist interventions (injection of drugs into the venous reservoir) and suction of air from the right atrium may cause these events.

In minimally invasive mitral valve operations we detected MES in context with positioning of the endoaortic clamp and migration of the clamp—caused by loss of balloon pressure—up to the brachiocephalic trunk during CPB. A decrease in blood flow velocity and simultaneously an appearance of embolic signals in the right MCA were noted (Fig 3A). Immediate repositioning of the endoclamp was followed by an increase of blood flow velocity in the right MCA to a normal level and no more cerebral embolic signals were detected.

Most microembolic events in both patient groups occurred after declamping during the third time period. As seen by transesophageal echocardiography there was no doubt that these MES were air bubbles remaining in the cavities of the heart and pulmonary veins. Despite the different surgical approaches and air removal procedures we observed no significant differences in the embolic stress rates within the two groups.

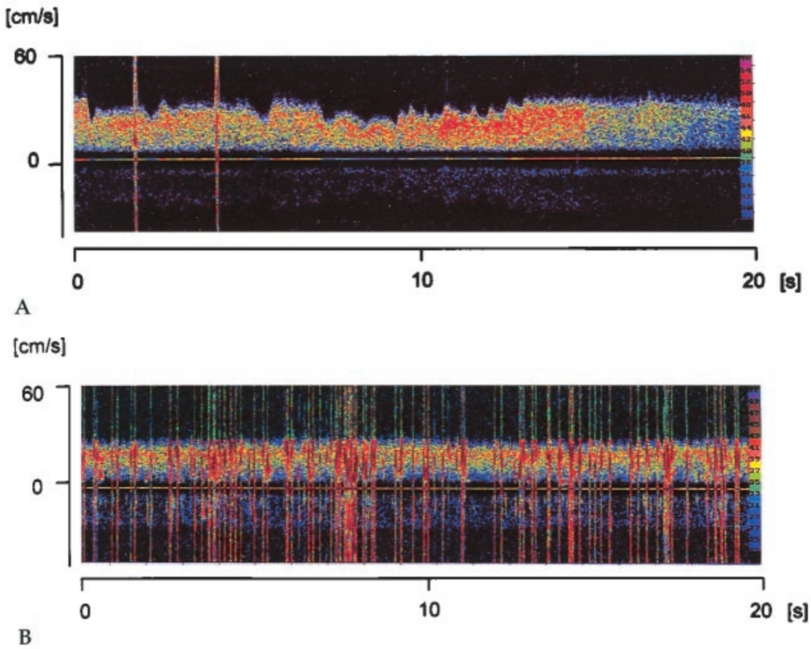

Fig 3. (A) Doppler pattern of the right middle cerebral artery: increased flow velocity during migration of the endoclamp up to the brachiocephalic trunk and two concomitant microembolic signals (MES). (B) "Shower" of MES during the third time period: air bubbles reaching the cerebral circulation after declamping. Patient operated using the conventional technique.

Several studies have demonstrated a correlation between the rate of cerebral MES during CPB and postoperative neurologic damage. The clinical consequences of cerebral MES, however, may be dependent not only on the number but also on the composition (gaseous or solid) and size of emboli entering the brain during CPB. In the near future a software should to be developed to differentiate between solid and gaseous emboli and to determine their size.

It has demonstrated that once given appropriate feedback, surgeons are able to modify their technique to minimize the occurrence of cerebral MES. Transcranial Doppler measurements to control endoclamp position and to detect MES may help to minimize the possible risk of intraoperatively induced neurologic dysfunction and is routinely used during minimally invasive mitral valve operation at our center.

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