Institutional report - Cardiac general

Multifrequency transcranial Doppler for intraoperative automatic detection and characterisation of cerebral microemboli during port-access mitral valve surgery

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Abstract

In 20 patients (6 male; age 56.5 ± 6.4 years; BSA 1.6 ± 0.1 m²) undergoing port-access mitral valve surgery, automated intraoperative transcranial Doppler was used to monitor absolute amount, side distribution, and type of embolic events during selected phases of the procedure to evaluate the impact of specific surgical manoeuvres on cerebral microembolism. The rate of events per minute was acquired for the following five operative periods: from cardiopulmonary bypass (CPB) set-up to CPB start, from CPB start to aortic clamping, first minute after aortic endoclamp inflation, first minute after aortic endoclamp deflation, and first ten minutes from CPB weaning start. Endoclamp navigation into the aortic arch, CPB start and CPB weaning determined the highest absolute count of embolic events. When embolic rate was normalised for length of selected operation periods CPB start (1.58 ± 1.9 events/min), endoclamp inflation (1.42 ± 1.7 events/min) and endoclamp deflation (3.1 ± 3.5 events/min), resulted as the most critical phases. No side prevalence was observed. In conclusion, brain embolism during port-access mitral valve procedures occurs predominantly at CPB start and during ascending aorta clamping and unclamping. Aortic arch navigation with catheters exposes to the risk of cerebral embolic events.

Keywords: Minimally invasive surgery; CPB complications; Embolism

1. Introduction

Port-access surgery was proposed in the late 1990s to approach the heart with a minimal chest trauma [1,2]. Serious concerns about risks of retrograde aortic perfusion and endo-clamping of the aorta raised by the first users [3], have been overcome by experience and it has been shown in large clinical series that the technique can be reliable and safe [4,5]. A theoretical risk of brain embolism related to retrograde aortic perfusion cannot be excluded even in patients carefully screened for absence of atherosclerotic disease of the thoracic and abdominal aorta. As blood coming from the descending aorta ends in the cul-de-sac formed by the endoclamp and the innominate artery, a possible preferential emboli distribution to the right side of the brain could be expected. This study was designed to assess quantity, quality and distribution of cerebral microembolism during port-access mitral valve surgery and to define the impact of any single manoeuvre on embolic events occurrence.

2. Materials and methods

Twenty patients (6 male; age 56.5 ± 6.4 years; BSA 1.6 ± 0.1 m²), undergoing port-access mitral valve surgery at our institution between September 2002 and April 2004, underwent continuous automated intra-operative transcranial Doppler (TCD).

The EmboDop machine (EmboDop, DWl, Germany) was used for automatic online embolus detection and discrimination. Technical characteristics and machine set-up have been described in detail by Brucher and Russell [6,7]. Left and right middle cerebral arteries were insonated the day before the operation using the TCD instrumentation to check quality of the signal. The probes were fixed on a frame that was stored for that single patient. This method allowed a faster acquisition of the signal at the time of operation.

The day of the operation patients were positioned in supine position, a 30° left tilt of the right chest was obtained by inflating a plastic bag under the right emithorax. After anaesthesia was induced, and before draping the patient, the headset was repositioned and quality of the Doppler signal checked, eventual repositioning of the transcranial probes was made at this time. A rigid plastic protection was placed around the head of the patients in order to allow trans-oesophageal (TOE) probe manipulation without interfering with the TCD frame. Probes were connected to the TCD instrumentation and machine set-up completed.

A Stokert S III (Stokert, Munich, Germany) roller pump, a Monolyth pro coating mimesys (Sorin Biomedical, Saluggia,
Italy) membrane oxigenator, a coating mimesys circuit (Sorin) and a 40-μm bubble trap were used for CPB. Venous drainage was achieved by a 17 Fr trans-jugular and a 25 Fr trans-femoral cannula. Venous drainage was enhanced by applying negative pressure up to $-30$ mmHg to venous reservoir. The level of blood in the venous reservoir was not allowed to fall below 500 ml during perfusion. Perioperative medication were injected in a central venous line not in the extracorporeal circuit inlet. Moderate hypothermia ($32^\circ C$) and the alpha-stat strategy were used while on CPB.

Antegrade warm blood cardioplegia was delivered through the endoclamp lumen into the aortic root. The procedure was completed under thorascopic video-assistance. CO$_2$ was continuously delivered at 3 to 5 l/min into operative field until the left atrium was de-aired and closed.

Absolute number, type (solid or gaseous as detected from the machine) and distribution (right or left side of the brain) of embolic events was recorded on line at the following 11 time intervals: trans-femoral venous guide wire insertion, venous cannula positioning, arterial guide wire insertion, arterial cannula positioning, endoclamp guide wire insertion, endoclamp positioning, CPB on, 0–1 min endoclamp on, 0–1 min endoclamp off, 0–1 min CPB off, 2–10 min CPB off. The normalised event rate per minute was acquired for the following five operative periods: from cardiopulmonary bypass (CPB) setup to CPB start, from CPB start to aortic clamping, first minute after aortic endoclamp inflation, first minute after aortic endoclamp deflation, and 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 patients due to involuntary displacement during the procedure. Every time interval includes all events recorded from the beginning of a single phase until the beginning of the following phase. Off-line analysis was carried out to discriminate emboli and artefacts. Results are given as mean ± standard deviation. Paired Student’s t-test or analysis of variance (ANOVA), with two factor interaction tests as appropriated, 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

A mitral valve replacement was performed in 9 cases, a mitral valve repair in 11 cases. Mean operation time was 175 ± 42 min, CPB time 95 ± 32 min, and endo-clamp time 68 ± 25 min. There were no deaths. No neurological deficits were observed.

A total number of 1578 (mean 78.9 ± 28.6 per patient) events was recorded in the whole population. Mean absolute rate of embolic events per surgical manoeuvre is reported in Fig. 1. Venous side manoeuvres were not immune from embolic events, bursts of embolic events could be observed during navigation of the aortic arch with the endoclamp, at CPB start and during CPB weaning.

To allow comparison of various operative phases, rate of events was normalised by dividing number of events by phase duration in minutes. Normalised rate of events was expressed as events per minute ratio, it is reported in Fig. 2. A significantly higher rate of events per minute could be observed at CPB start and at balloon inflation and deflation.

![Rate of embolic events according to operation phase](image)

![Normalized global embolic event rate](image)

![Embolic event distribution: right vs. left](image)
Normalised rate of left versus right embolic events expressed as events per minute ratio is reported in Fig. 3.

Normalised rate of solid versus gaseous embolic events expressed as events per minute ratio is reported in Fig. 4. No side prevalence was observed, gaseous emboli were significantly more than solid one during CPB setup (0.32 ± 0.26 vs. 0.11 ± 0.09 events/min, P < 0.01) and during CPB weaning (0.29 ± 0.28 vs. 0.07 ± 0.14, P < 0.01) phases.

4. Discussion

The main objective of this study was to analyse total amount, type, side prevalence and temporal distribution of embolic events during all steps of port-access procedures. Any correlation between embolic events and clinical findings or neuropsychological behaviour was excluded from the objectives of the study.

Our results are similar to those obtained by Lund who compared embolic potential of on-pump and off-pump coronary artery bypass surgery [8]. A higher rate of embolic events was documented by Sylivris in a population of patients undergoing coronary artery bypass surgery in which no neuropsychological decline was documented [9]. No definitive conclusion can be drawn since the methodology was completely different and could account for differences observed. It has been demonstrated that open heart surgery and vacuum-assisted venous drainage are associated with increased gaseous embolism [10].

Comparison of the embolic potential of port-access minimally invasive surgery versus conventional surgery was reported by Schneider and colleagues [11], who were not able to find any difference between the two techniques in terms of brain embolic potential, the embolic burden of any single surgical manoeuvre was not analysed.

Interesting conclusions can be drawn by analysing the temporal clustering of events throughout the procedure (Fig. 1). The pre-CBP phase is characterised by set-up of the peripheral extracorporeal circulation. This phase is relatively safe but not absolutely immune from embolism. Maneuuvres on the venous side can be provocative of brain embolism, these events were recorded when the venous guide wire and the venous cannula reached the right atrium, we speculate that they can be attributed to manipulation of the interatrial septum or unintentional compres-

sion of the aortic root. The majority of these ‘venous phase’ events were of gaseous type and were recorded in 3 patients only, this suggests a cause related to the technique used, not to the procedure per se.

Arterial guide wire positioning and femoral artery cannulation were relatively safe. A step increase in the number of embolic events was observed when the endoclamp guide wire and the endoclamp catheter were positioned into the aortic root. Normalised rates (Fig. 3) showed no side prevalence. A higher rate of gaseous type events was observed in the CPB setup and CPB Off phases (Fig. 4).

The time interval from CPB start to aortic clamping represents a critical phase for embolism occurrence in extracorporeal circulation. The number of events observed in our population (1.6 ± 1.5 events/min) is lower than that reported in literature for standard antegrade aortic perfusion [8]. When normalised for duration of sampling period, CPB start is significantly at risk for embolic events occurrence as is endoclamp inflation and deflation. Embolic events are usually reported in conventional cardiac surgery during aortic clamp positioning and removal [8,12]. Our experience confirms that aortic clamping and unclamping can represent a traumatic event even if an endoaortic balloon is used.

The vast majority of events occurred after unclamping the aorta and during weaning from CPB. It can reasonably be assumed that the main source of emboli is the heart itself. Since CO₂ was administered during the whole procedure, most of these emboli were probably made of small CO₂ bubbles, which dramatically limits their ‘offensive’ potential. When normalised for sampling period duration, however, CPB weaning showed to be less at risk than previous operative steps.

Automatic detection, counting and discrimination between gaseous and solid emboli have been validated in vitro and in vivo by Brucher and Russell [6,7]. They emphasised 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 of 40 μm and solid emboli of 450 μm can overload the instrumentation. These limitations could have affected our results.

In conclusion, CPB start and ascending aorta indirect manipulation, by inflating and deflating the endoclamp, represent the most critical phases for brain embolism during port-access mitral valve surgery. In our experience no side prevalence could be documented for brain microemboli distribution. Gaseous type microemboli occurs more frequently during CPB set-up and during CPB weaning. Aortic arch navigation with the endoclamp and, surprisingly, venous cannulation, can determine cerebral microembolism.

References


