Autonomic cardiovascular control – Applications in ICU

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Introduction

In the past decade, alteration of cardiovascular autonomic function has been identified as a powerful predictor of fatal outcome in cardiovascular patients. The following study was performed to assess the differences in the post-operative recovery of autonomic regulation after mitral valve (MV) and aortic valve (AV) surgery with a heart–lung machine. Besides the different kinds of surgical graftings, the previous investigations about the time coarse during the first postoperative 24 hours [1] and the preoperative autonomous status [2] should be considered in a future cardiovascular perioperative risk stratification.

Methods and Patients

Patients

A total of 60 consecutive male patients undergoing either isolated MV or isolated AV surgery and being in stable sinus rhythm were enrolled in this study [3]. Prolonged intubation time and/or prolonged need for inotropic support after surgery led to ex-post exclusion of the respective patient, so 43 patients remained for analysis. Of them, 26 underwent AV surgery and 17 MV surgery. In order to maintain the best possible uniformity of the cohorts, patients with concomitant cardiac diseases and/or additional procedures on the heart or great vessels were excluded from the study. The mean age of the AV patients and MV patients was 62±13 years and 59±12 years, respectively. Patients with concomitant coronary heart disease were excluded for the known effects of atherosclerosis. Perioperative medication and anaesthesia were standardized. All operations were carried out with cardiopulmonary bypass in mild hypothermia (32–34°C) and pulsatile perfusion mode, cold crystalloid cardioplegia was used for cardiac arrest after crossclamping the aorta. Surgical access to the AV was achieved by horizontal transection of the anterior aspect of the ascending aorta, while access to the MV was performed by opening the left atrium close to the interatrial groove. After declamping, most of the patients needed one countershock to terminate ventricular fibrillation.

After 10 min equilibrations to the environment, non-invasive blood pressure signals were collected from the radial artery by a tonometer (Colin Medical Instruments) at 1000 Hz. Data were channelled into a bedside laptop after A/D conversion and stored for analysis. Simultaneously, breathing excursions and a standard ECG were monitored. Data were sampled for a 30 min period the day before, 24 hours after and 7 days after surgery in the intensive care unit. Care was taken to perform the measurements at the same time of day in each patient. From the recorded data, the beat-to-beat intervals (BBIs) as well as the beat-to-beat systolic and diastolic values were extracted; premature beats, artefacts and noise were excluded.

Methods

The characterization of the cardiovascular regulatory behavior was performed by analyses of heart rate variability (HRV), systolic (SBPV) and diastolic blood pressure variability (DBPV) as well as puls pressure variability (PPV) [4,5]. Hereby, various approaches of time and frequency domain and non-linear dynamics were applied. Analysis of coupling phenomena between systolic blood pressure and heart rate regulation was performed by dual sequence method to characterize the spontaneous baroreceptor sensitivity (BRS). Statistical analysis was performed by the non-parametric Mann–Whitney U-test.

Results

The post-operative clinical course was comparable in both patient groups. The number of major post-operative complications was low without differences between groups. There were no major differences between the two groups pre-operatively. At 24 hours after surgery, both groups showed a depression of HRV and BRS parameters, which was more pronounced in the MV group. One week after surgery, however, marked differences were present: sdNN 15±5 (MV) versus 27±13 (AV), $p<0.001$; Shannon 1.11±0.28 (MV) versus 1.55±0.34 (AV), $p<0.001$ (fig. 1).

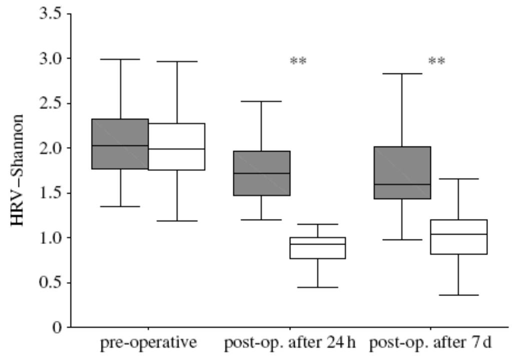

Fig. 1: HRV, the Shannon entropy of the histogram (**$p<0.001$; MV (open bars) versus AV (filled bars) surgery).

Similar kinetics was found for the other linear HRV parameters calculated in this study. Regarding the nonlinear parameters quantifying decreased complexity, there was a significant elevation present already 24 hours after surgery for both groups, which, again, was more pronounced for MV patients. These alterations were even more distinct after one week (forbidden words 48.5±5.7 (MV) versus 38.6±11.5 (AV), p<0.01; POLVAR10 0.33±0.20 (MV) versus 0.18±0.22 (AV), p<0.01). The BR was impacted in a similar way for both the number and the strength of regulations (number of bradycardic synchronous BR events 3.2±3.9 (MV) versus 11.2±12.1 (AV), p<0.01; average slope of bradycardic synchronous BR 5.2±2.6 (MV) versus 6.2±4.4 (AV), p<0.01; fig. 2 and 3).

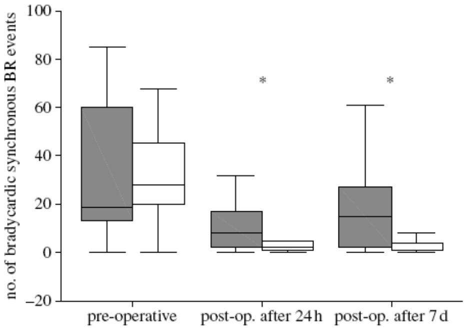

Fig 2. BRS, the number of bradycardic BR events (*p<0.01; MV (open bars) versus AV (filled bars) surgery)

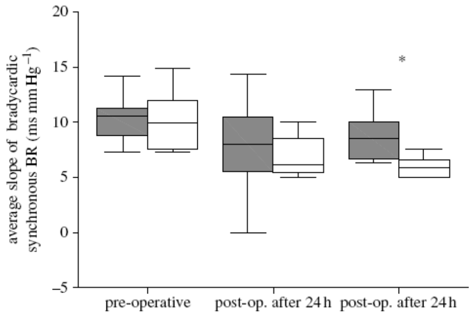

Fig 3. BRS, the average slope represents the strength of bradycardic regulations (*p<0.01; MV (open bars) versus AV (filled) surgery).

The tachycardic part of the BR, however, for both the aortic and the mitral patients failed to recover after one week.

Discussion

The last decade witnessed a strong increase in basic knowledge about the cardiovascular autonomic system. However, as far as alterations in the cardiac patient and in patients undergoing open-heart surgery are concerned, we are still at the very start. Meanwhile, it is well known that cardiac surgery leads to an early depression of autonomic function, and that there is potential for recovery after a certain time frame. The mechanisms for both phenomena are quite unclear, so the aim of the present study was to shed light on the precise role of direct surgical trauma. On purpose, the operative procedures carried out in these patients offer two entirely distinct entities of surgical trauma: while for AV replacement the heart is left more or less untouched and the valve is approached by an incision in the anterior aspect of the ascending aorta only, in MV operations both the caval veins are extensively dissected and the heart is opened by an incision right posterior to the interatrial groove, where an abundance of AV endings are supposed to be. In this study, both entities of surgical trauma are supported by distinct depressions of linear HRV parameters (e.g. sdNN) and BRS (e.g. average slope synchronous BR) as well as by clearly different elevations of the nonlinear HRV parameters (e.g. POLVAR10) for both groups. The similar depression in both groups observed at 24 hours may reflect the effects of standardized anaesthesia, general surgical trauma and perioperative treatment being comparable in all patients. Compared with the AV patients, the MV patients showed a more pronounced depression of the autonomic system already during the recordings 24 hours post-operatively, this effect being even more obvious after one week.

Analysing BR response, there was a surprising difference between bradycardic and tachycardic regulations. The parasympathetically mediated bradycardic response showed a steep decline 24 hours after surgery with a subsequent tendency to recover after one week.

Summarizing, we found evidence indicating that direct surgical trauma is likely to be one of the mechanisms leading to the depression of cardiovascular autonomic function. The diversity of results in earlier studies may be caused by the case mix of patients, comprising different initial conditions as well as different extents of trauma.

These investigations may attach the importance to biosignal analysis during perioperative monitoring in order to predict postoperative cardiovascular complications. For application in clinical routine, enlarged and prospective validated studies should be performed.

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