Non-Invasive Cerebral Autoregulation Monitoring During Cardiac Surgery

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Introduction. Post-operative cognitive dysfunction (POCD) is the most common clinical evidence of brain injury after the cardiac surgery with a cardiopulmonary bypass (CPB) [1, 2]. POCD after the cardiac surgery occurs in up to 40–60% of cases in the early postoperative period and their incidence still remains high after 6 weeks (~30%) and 1 year (~25%) [1]. Our hypothesis is that POCD can be related to a temporal cerebral hypoperfusion and consequently to the impaired cerebrovascular autoregulation (CA). The current clinical guidelines recommend that the mean arterial blood pressure (MAP) during the CPB should be kept 50–60 mmHg or higher [2], but the individualized MAP identification is needed during CPB. We propose to use the innovative ultrasonic real-time CA monitoring technology [3] for identification of the individual patient-specific MAP values during CPB in order to prevent brain injury and POCD.

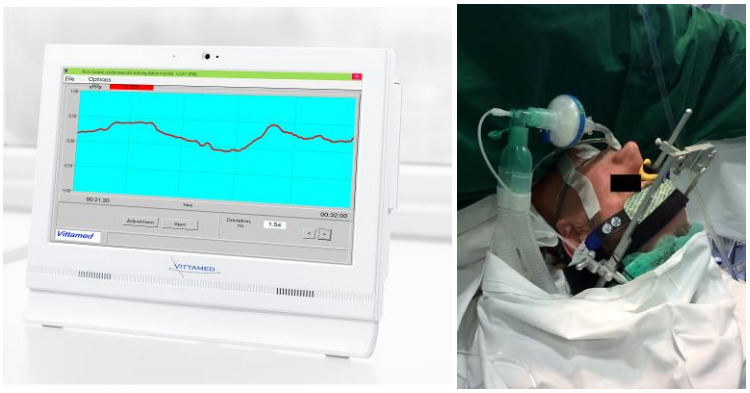
Methods. The prospective observational study commenced at the Hospital of Lithuanian University of Health Sciences in Kaunas. This ongoing study includes patients undergoing the elective coronary artery bypass grafting surgery without preoperative neurological disorders. The standard monitoring was used during the anaesthesia: ECG, invasive MAP, SpO_2, rSO_2, and temperature.

Additionally, the "Vittamed" non-invasive CA monitor [3] based on the intracranial blood volume (IBV) measurement was used for testing of our hypothesis on cardiac surgery patients (Fig. 1). The CA status was estimated continuously during CPB by calculating the pressure reactivity index vPRx(t) as a moving correlation coefficient between the slow waves of MAP(t) and IBV(t) [3].

The cognitive and neurological functions were evaluated by performing 5 memory and mental ability tests for each patient (MMSE, ADAS-Cog, Trail Making A B, WAIS-Digit Span and WAIS-Digit Symbol Substitution Test. The selected reliable change indices (RCI) were calculated for each patient in order to estimate changes of mental abilities according to each test [4]:

$$RCI = (X1 - X2 - (M2 - M1))/SED \quad , \qquad (1)$$

where, X1–test score before the surgery, X2–test score 10 days after the surgery, M1–test score mean of the group before the surgery, M2–test score mean of 10 days after the surgery, SED–a standard error of a difference.



a) b)

Fig. 1. The Vittamed 505 non-invasive CA monitor (a), the mechanical frame with ultrasonic transducers mounted on the patient's head during cardiac surgery with CPB (b).

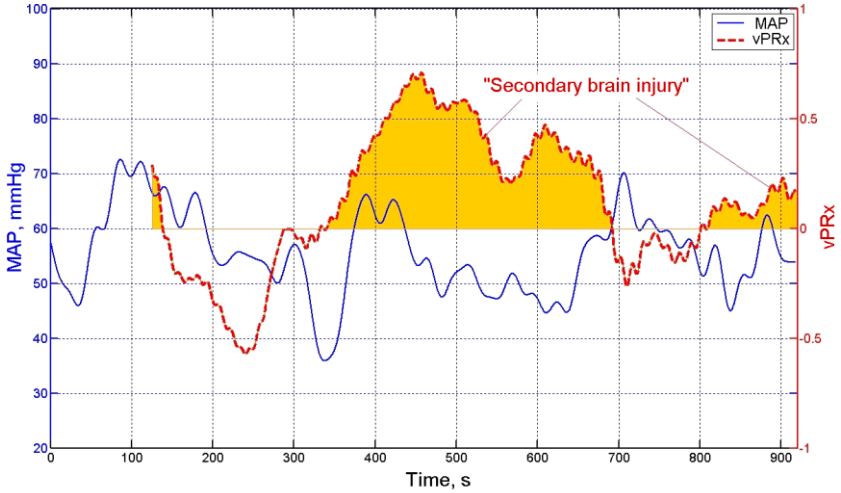


Fig. 2. The case of CA monitoring during the patient's cardiac surgery. The drop of MAP below the lowest patient-specific critical threshold causes the impairment of CA (vPRx>0) and a "secondary brain injury".

The RCI change below -1.645 was considered as a reliable criterion indicating the deteriorated mental abilities [5]. However, for POCD detection, these RCI scores from each used to create a compound test score ($Z_{combined}$) by summing up all scores for each test and dividing by the standard deviation of

this summation [6]. POCD was identified if the patient had two or more scores of single tests ≤ -2, or a $Z_{combined}$ score ≤ -2 [6].

Results. The preliminary clinical study of CA monitoring was performed on 17 cardiac surgery patients. All patients were ASA III class, NYHA III class; their average age was 63 years. The mean duration of CPB was 88.67 min., the mean MAP during CPB was 65.75 mmHg.

It was found that the deterioration of CA lasting up to a few minutes typically appears when MAP temporarily drops below the lowest individual MAP threshold (50…60 mmHg) and at the beginning/finishing moments of CPB. The case of CA monitoring on the patient during the cardiac surgery with CPB showing the temporarily impaired CA status is presented in Fig. 2.

For one patient from the group two cognitive function tests and $Z_{combined}$ score (-6.67 < -2) showed the detected POCD. Some single tests also showed deteriorated mental abilities for other four patients (RCI < -1.645). These patients were suffering from longer cerebrovascular autoregulation impairment (LCAI) events when vPRx(t)>0 lasted for more than 400-500 sec. The performed tests for the remaining 12 patients did not reveal declined mental abilities.

The calculated critical threshold of duration of LCAI events showing association with the deteriorated mental ability was 280 secs (χ^2 = 7.97, p = 0.006). The critical threshold duration of LCAI events showing the association with POCD was 410 secs (χ^2 = 4.96, p = 0.026). The correlation coefficient between the LCAI duration of LCAI and deterioration of mental ability was r = 0.754 (Fig. 3).

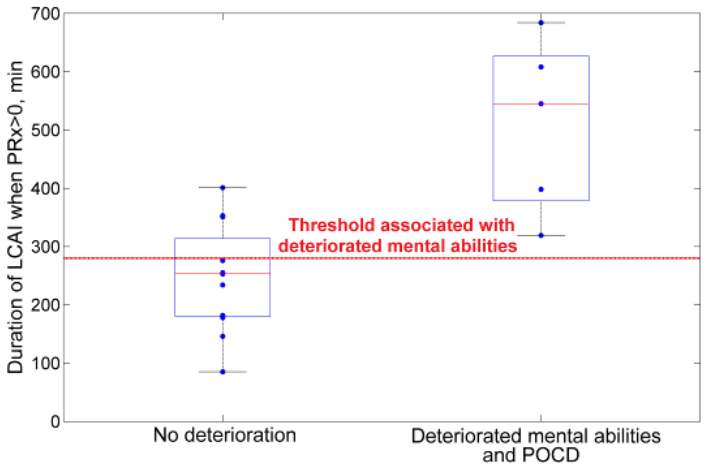


Fig. 3. The association between the LCAI event duration (when vPRx(t)>0) and deterioration of mental abilities. The correlation coefficient between LCAI duration and deterioration of mental abilities was r = 0.739 (p < 0.001).

Conclusions. The preliminary study shows that the LCAI event duration (when vPRx(t) continuously exceeds the zero value) during the cardiac surgery with CPB is associated with deteriorated mental abilities and the risk of appearance of POCD. The „Vittamed" non-invasive CA monitor can be used for the individual patient-specific MAP management during the CPB in order to prevent brain injuries and cognitive dysfunctions. However, further clinical studies are needed in order to validate and optimize the applicability of the presented method.

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The results of the ongoing preliminary study of non-invasive cerebral autoregulation (CA) monitoring during the cardiac surgery with the cardiopulmonary bypass (CPB) are presented. It is shown that the CA impairment events during CPB may be consequence of the temporarily dropped mean arterial blood pressure (MAP) below the lowest individual MAP threshold; and the duration of CA impairment events is associated with the deteriorated mental abilities. The „Vittamed" non-invasive CA monitor can be used for individual patient-specific MAP management during the CPB in order to prevent brain injuries and cognitive dysfunctions.