

Neuromonitoring during cardiac surgery

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Introduction

Neurologic complications present commonly following cardiac surgery, with an impact on patients' quality of life.^{1, 2} Several mechanisms are implicated, including cerebral embolism, cerebral hypoperfusion and inflammation. All of these mechanisms cause an imbalance between oxygen delivery and oxygen consumption in the brain. Neuromonitoring during cardiac surgery might help to prevent injurious events or to detect them in the early hours in order to employ strategies to minimise secondary cerebral damage.

Monitoring cerebral oxygenation

Neuromonitoring includes the monitoring of oxygenation, perfusion and function of the brain. Near infrared spectroscopy (NIRS) can be used to measure the cerebral tissue oxygen saturation of the bifrontal cortical regions. This method is non-invasive and works by the emission of near infrared light and the measurement of the absorption characteristics of oxy- and deoxyhaemoglobin. Cerebral desaturation in this context is defined as a decrease in saturation values below 70% of baseline or as absolute values below 55%.³ As soon as cerebral desaturation is detected, intervention is recommended. This includes checking of the patient's head position to ensure that it is not rotated, increasing the PaCO₂ to above 40 mmHg, increasing the mean arterial pressure to above 60 mmHg, increasing the pump flow to 2.5 l/m²/min, raising the haematocrit above 20%, lowering the central venous pressure below 10 mmHg, increasing the inspiratory oxygen concentration, and deepening anaesthesia.³

In a retrospective study of 2 279 patients, Goldman et al showed that improved cerebral oxygen delivery monitored by using cerebral oximetry was associated with a reduced incidence of permanent strokes following cardiac surgery.⁴ However, a limitation of this study is the retrospective design. To overcome this disadvantage, Murkin et al performed a prospective randomised trial to study the impact of monitoring regional oxygen saturation (rSO₂) and improving cerebral oxygenation by applying the already mentioned interventions on outcome. Indeed, they showed less major organ morbidity and mortality compared to a control group with blinded measurements of rSO₂.³ However, this study was not powered to assess stroke rate, the outcome of paramount interest in this context. A detailed analysis of cognitive outcome following cardiac surgery showed recently that intra-operative cerebral desaturation was associated with a worse

cognitive outcome. However this study failed to minimise the amount and duration of cerebral desaturation by interventions according to cerebral oximetry.⁵ Even though it is not known yet whether cerebral oximetry during cardiac surgery can improve cerebral outcome, it can certainly be helpful to detect severe events like malposition of the aortic cannula.⁶

Transcranial Doppler

Transcranial Doppler (TCD) presents a non-invasive technique to monitor not only cerebral blood flow velocity but also to detect cerebral emboli. Routinely, the middle cerebral artery is monitored via a temporal bone window. The measured blood flow velocity is dependent on three parameters: blood flow, diameter of the middle cerebral artery, and blood viscosity. The angle of incidence to the direction of flow in the vessel of interest impacts the measured blood flow velocity and must be kept constant during the whole assessment period. This explains one of the major limitations of this technique, since minor changes in probe position may result in significant signal alterations.

A unique contribution of TCD is the detection of high intensity transient signals (HITS). These present signals of short duration (< 300 ms) with a high intensity that spread within the bloodstream and signify embolic events. It has been shown that the number of emboli measured by TCD during cardiac surgery was correlated with the incidence of cognitive deficits eight weeks later. In other words, the likelihood for cognitive deficits increases with a higher number of cerebral emboli.⁷

TCD cannot distinguish between solid and gaseous emboli. But a study showing a correlation between aortic atheromatous disease assessed with transoesophageal echocardiography (TOE) and the amount of HITS analysed by TCD suggest that significant aortic atheromatous disease might be the source for cerebral emboli.⁸ Aortic surgery requiring deep hypothermic circulatory arrest with or without selective cerebral perfusion is associated with the highest risk for postoperative neurologic deficits. In these patients, cerebral malperfusion can occur not only due to a cannula malposition but also due to an inefficient selective cerebral perfusion.

In this context, Estrera et al have shown benefit for TCD monitoring when applied during the repair of aortic dissection. Based on the

findings of TCD, the position of the aortic cannula was changed during cardiopulmonary bypass (CPB) in 28% of the patients. Furthermore, they used TCD to confirm a reversal of blood flow in the middle cerebral artery during retrograde cerebral perfusion. Interestingly, almost 80% of the study population required modifications in retrograde cerebral perfusion flow to identify this reversal. By doing so, neurologic outcome was improved in patients monitored with TCD compared to patients without TCD monitoring.⁹ However, this is just a small non-randomised study which shows the potential benefits for using TCD. A limitation of this technique is that it requires a skilled technician for the monitoring and the likelihood of obtaining false results by minor changes of probe position as mentioned before.

Electroencephalography

Electroencephalography (EEG) assesses the electrical functional activity of the brain. It is commonly used to avoid awareness but can also identify cerebral ischaemia and can localise the area of injury. In addition, EEG can detect seizures, which may be subclinical in manifestation or obscured by neuromuscular blockade. EEG is able to confirm adequate cooling and metabolic depression before commencement of deep hypothermic circulatory arrest. However, it requires a skilled technician or physician for correct interpretation of the findings and it identifies cerebral ischaemia relatively late.

Epi-aortic echocardiography

Finally, epi-aortic echocardiography is an important tool with which to avoid or minimise cerebral injury during cardiac surgery. Even though this technique does not monitor the brain directly, it can be considered as a neuromonitoring technique in the broader sense. Epi-aortic ultrasound scanning of the aorta has been shown to be sensitive in detecting aortic atheromatous disease or plaques, the potential source for cerebral emboli during cardiac surgery. For the performance of a detailed epi-aortic ultrasonographic examination, please refer to the guidelines of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists.¹⁰ The use of epi-aortic echocardiography does not only result in surgical modification, but has been shown to reduce the incidence of cognitive deficits after coronary artery bypass operations.¹¹

Conclusion

In summary, neuromonitoring is important to prevent cerebral injury during cardiac surgery. It can help to detect cerebral hypoperfusion and cerebral emboli, which are the main contributors to early adverse cerebral outcome after cardiac surgery. Consequently, secondary injurious events can be avoided by the employment of specific interventions. However, all the available neuromonitoring techniques have certain limitations, which might be overcome by a multimodal monitoring approach.

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