

## CEREBRAL OXIMETRY DURING CARDIOPULMONARY BYPASS

The cerebral oximeter has been recently introduced to monitor regional cerebral oxygenation during cardiopulmonary bypass (CPB). The device is based on near infrared cerebral spectroscopy (NIRS) which can provide non-invasive and continuous monitoring of cerebral oxygen supply-demand balance during CPB including deep hypothermic circulatory arrest (DHCA). The regional cerebral oxygen saturation measured by NIRS is closely related to the oxygen saturation monitored by the invasive jugular bulb technique which represents the mixed venous oxygen saturation of the whole brain. However, it is different from the values achieved by the traditional cerebral venous monitoring of the whole body.

Although the brain is only about 2% of the body weight, its oxygen consumption amounts up to 20% of the whole body oxygen consumption. The cerebral blood flow (CBF) is about 12% of the cardiac output, and is regulated by the MAP-ICP gradient, by MAP-CBF autoregulation, and by the cerebral blood flow-metabolic coupling, as well as by the  $PO_2$  and  $PCO_2$  values and the degree of hemodilution.

Perioperative cerebral hypoxemia during CPB can result in a spectrum of manifestations. Stroke and encephalopathy are reported in 1-3% and 10-15% of patients respectively, while delirium and postoperative cognitive dysfunction (PGCD) is more common affecting 15-40% of patients.

The two main causes of cerebral hypoxemia during CPB are cerebral embolization and cerebral hypoperfusion. 30-50% of postoperative strokes result from cerebral macroembolization, mostly arising from atherosclerosis of the ascending aorta. Recent data show that as many as 27-43% of patients experience regional or global cerebral oxygen desaturation during CPB, indicating cerebral oxygen supply-demand mismatch.

Cerebral hypoperfusion is not limited to bypass cardiac surgery, but may also occur during “off-pump” cardiac surgery, secondary to displacement of the heart which may lead to systemic hypotension associated with paradoxical increase of the central venous pressure. In addition, cerebral hypoperfusion can occur during one lung ventilation, and during carotid endarterectomy. Also, it has been observed during surgery in the head up or sitting position. Elderly patients are more prone than younger patients to develop cerebral desaturation because of the reduced physiologic reserve that accompany aging.

During CPB, the cerebral oxygen supply-demand mismatch can result from decreased pump flow and MAP, or secondary to severe hemodilution. The CBF-MAP autoregulation support the common practice of maintaining the MAP at 50-70 mmHg during CPB. However, elderly arteriosclerotic and hypertensive patients can have the autoregulation curve shifted to the left which requires a higher MAP. Thus, the MAP must be optimized within the individual's autoregulatory range. The introduction of NIRS which monitors continuously and noninvasively the regional cerebral oxygen saturation opens up the possibility that MAP during CPB can be individualized, and should be maintained  $>70$  mmHg in high-risk patients. NIRS may also help to optimize the red cell transfusion trigger during CPB. There is evidence that hyperglycemia during hypoxemia

worsens the impact of ischemia through increased glycolysis and intracellular acidosis. Using cerebral oximetry reduces the potential exposure of the brain to hypoxia and enhance management, which decrease the incidence of postoperative cognitive dysfunction and shorten PACU as well as hospital stay.

Hypothermia during cardiopulmonary bypass (CPB) can decrease the cerebral oxygen demand according to the Q10 principle (i.e. every decrease of 10°C can decrease the oxygen requirements by about 50%). Using the alpha-stat strategy of carbon dioxide management during moderate hypothermia can maintain the cerebral autoregulation and the cerebral oxygen supply-demand balance, while avoiding luxury perfusion. In contrast, the pH-stat management is recommended during deep hypothermic circulatory arrest (DHCA) in order to ensure homogenous cooling of all areas of the brain, associated with maximal depression of cerebral metabolism which allows safe circulatory arrest up to 30-40 minutes. NIRS can provide a continuous monitoring of cerebral oxygen supply-demand balance during deep hypothermia including circulatory arrest.

Experimentally, hypothermia reduces the extent

of neuronal ischemic injury. However, rapid rewarming and/or postoperative hyperthermia are associated with risk of neurological complications. Slow rewarming to 34°C rather than 37°C resulted in improvement of neurocognitive outcome after CABG surgery. During rewarming, the use of alpha-stat is thought to be beneficial as it decreases cerebral blood flow and the risk of cerebral edema.

In conclusion, NIRS can be used as a noninvasive and continuous monitor of the balance between cerebral oxygen supply and consumption. An algorithm was proposed based on optimizing factors that can affect the cerebral oxygen supply-demand balance. These factors are adequate positioning of the vascular cannulae, and optimizing perfusion pressure, cardiac output, PaO<sub>2</sub>, PaCO<sub>2</sub> and Hb concentration, as well as decreasing the cerebral metabolic rate.

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