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Oximetry of the brain

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Background. Devices allowing direct assessment of brain tissue oxygenation have showed promising results in clinical studies. However, estimation of brain oximetry still has some challenges. The aim of our study was to estimate the feasibility to monitor cerebral oximetry for neurosurgery patients in the Operating Room and in the Neurosurgery Intensive Care Unit, possible basic disturbances for the study and early results.

Materials and methods. The prospective trial took place in a tertiary university setting – the Neurosurgery Department of the Lithuanian University of Health Sciences Hospital (Kaunas Clinics). The monitoring was performed with an INVOS® Cerebral / Somatic Oximeter, which is based on near-infrared spectroscopy. The monitoring places were the Operating Room, later the Neurosurgery Intensive Care Unit and for some patients the regular Neurosurgery Ward. All patients had acute open or closed traumatic brain injury and had undergone neurosurgery.

Results. 52 patients were included in the study, while 36 operations were performed after traumatic brain injury with successful monitoring. Preoperatively GCS ranged from 3 to 15 (average 10.2 ± 4.6), all patients had no hypotension ranged from 214 mmHg to 112 mmHg (average 148.0 ± 26.6), the mean arterial pressure ranged from 155 mmHg to 61 mmHg (average 106.0 ± 21.8), only two patients had hypoxia with SpO_2 of 86% and 76%, other values averaged 96.7% ± 4.3% . Hemoglobin preoperatively ranged from 162 g/l to 82 g/l (average 133.7 ± 17.9). The values of cerebral oxygenation preoperatively in the Operating Room were 42–96% (average 74.8 ± 10.8), and one patient with cerebral oxygenation of 15% bilaterally before surgery died in 24 hours after the surgery (normal values vary from 58 to 82%). The values varied from to 15–95% in the period of the operation. The biggest difference of cerebral oxygenation between brain hemispheres was registered as 42% and 68% before the intubation, 60% (±8.8) and 76% (±4.0) during the operation, 64% (±4.9) and 80% (±5.3) in the Intensive Care Unit. 13 patients died, 17 were discharged with GCS of 13–15 and 6 patients with GCS of 8–12.

Conclusions. Monitoring of regional cerebral oximetry for neurosurgery patients can be performed, despite of its limitations: surgery or application of the Mayfield holder in the frontal region of the head, intraoperative transcranial Doppler monitoring

Key words: cerebral oximetry, near-infrared spectroscopy, traumatic brain injury, neurosurgery

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INTRODUCTION

Cerebral ischemia is a well-recognized contributor to high morbidity and mortality after traumatic brain injury (TBI) (1). Devices allowing direct assessment of brain tissue oxygenation have showed promising results in clinical studies and its use was implemented in the Brain Trauma Foundation Guidelines for the treatment of TBI patients in 2007 (2). Results of several studies suggest that a "brain tissue oxygen-directed" therapy guided by these monitors may contribute to reduced mortality and improved outcome of TBI patients.

Measurement of cerebral oxygenation is widely used to assess the balance between cerebral metabolic supply and demand although standard bedside methods of measuring cerebral oxygenation have significant limitations. Near-infrared spectroscopy (NIRS) is a noninvasive bedside technology that offers the potential for cerebral monitoring over multiple regions of interest. The technique of NIRS is based on the principle of light attenuation by the chromophores oxyhaemoglobin, deoxyhaemoglobin and cytochrome oxidase. Changes in the detected light levels can therefore represent changes in concentrations of these chromophores. The clinical availability of non-invasive NIRS-based cerebral oximetry devices represents a potentially important development for the detection of cerebral ischaemia (3).

We used the INVOS cerebral oximeter in our research. The INVOS device is an inexpensive, non-invasive oximeter. It has been shown to be effective in identifying changes in cerebral oxygenation induced by hypoxemia (4) and in detection of clinically relevant levels of desaturation (5), and it has furthermore been validated in numerous clinical settings such as carotid endarterectomy (6). Additionally, while the INVOS device is commonly used, questions remain regarding the validity of its data in some situations. In dead or injuried non-metabolizing brain, for example, oxygen saturation values can be near normal due to the absence of metabolic activity (7).

MATERIALS AND METHODS

The prospective trial took place in a tertiary university setting – the Neurosurgery Department of the Lithuanian University of Health Sciences Hospital (Kaunas Clinics). The monitoring was performed with an INVOS® Cerebral / Somatic Oximeter, which is based on near-infrared spectroscopy (NIRS). The monitoring places were the Operating Room, later the Neurosurgery Intensive Care Unit and for some patients – the regular Neurosurgery Ward. All patients had acute open or closed traumatic brain injury and had undergone neurosurgery. All patients were monitored in the Operating Room, also in the Neurosurgery Intensive Care Unit and / or in the Traumatic Brain Injury Department.

52 patients were included in the study. 16 of these included patients were excluded from further data analysis due to registration limitations. Records of 36 patients were analysed (10 or 27.8% women and 26 or 72.2% men). Age of the patients ranged from 16 to 88 years (average 53.9 ± 17.5).

RESULTS

16 patients were withdrawn from the data analysis due to the following problems: the site of surgery, which involved the frontal region of the head (9); application of the Mayfield holder in the frontal region of the head (5); intraoperative transcranial Doppler registration (2).

The performed 36 operations after traumatic brain injuries with successful monitoring were as follows: 15 osteoplastic craniotomies and subdural and / or epidural haematoma evacuation, 12 decompressive craniotomies and subdural and / or epidural haematoma evacuations, 5 burr holes for subdural or epidural haematoma evacuations, 4 eliminations of the impressive bone fracture. Preoperatively GCS ranged from 3 to 15 (average 10.2 ± 4.6), all patients had no hypotension ranged from 214 mmHg to 112 mmHg (average 148.0 ± 26.6), the mean arterial pressure ranged from 155 mmHg to 61 mmHg (average 106.0 ± 21.8), only two patients had hypoxia with SpO_2 of 86% and 76%, other values averaged 96.7% ± 4.3%. Hemoglobin preoperatively ranged from 162 g/l to 82 g/l (average 133.7 ± 17.9). The values of cerebral oxygenation preoperatively in the Operating Room were 42–96% (average 74.8 ± 10.8), and one patient with cerebral oxygenation of 15% bilaterally before surgery died in 24 hours after the surgery (normal values vary from 58 to 82%). The values varied from 15 to 95% in the period of the operation. The biggest difference of cerebral oxygenation between brain hemispheres was registered as 42% and 68% before the intubation, 60% (±8.8) and 76% (±4.0) during the operation, 64% (±4.9) and 80% (±5.3) in the Intensive Care Unit. 13 patients died, 17 were discharged with GCS of 13–15 and 6 patients with GCS of 8–12.

DISCUSSION

According to our study results, TBI was well controlled perioperatively: there were no signs of hypotension, average mean arterial pressure, saturation, cerebral oximetry were in normal ranges, except few cases of abnormal values. Cerebral oximetry as a method has its place in monitoring patients with TBI in the Operating Room as well as in the Intensive Care Unit and in the regular Neurosurgery Ward. At the moment we observed not only benefits but also limitations of this monitoring method.

Despite of the growing number of users, the diagnostic value of NIRS still remains unclear, especially in case of acute brain injury and long-term neuromonitoring, necessary during intensive therapy of these patients.

To evaluate quality and sensitivity of NIRS measurements compared to invasive ICP-, CPP- and regional brain tissue pO_2 ($PbtO_2$) monitoring, 31 patients, suffering from severe brain injury due to subarachnoid hemorrhage or severe head injury, were studied. NIRS measurements were only possible in 80% (using the INVOS oximeter) and in 46% (using the CRITIKON monitor), while good data quality was obtained in 100% from ICP, CPP and $PbtO_2$. Major reasons for the failure of NIRS measurements were as follows: a wet chamber between a sensor and the skin, galea hematoma or subdural air after craniotomy. Different tests were performed to compare the sensitivity of regular oxygen saturation (NIRS) with the sensitivity of invasively determined $PbtO_2$. Only induced hyperoxia ($FiO_2 = 1.0$) revealed a significant correlation between both parameters ($r = 0.67$, $p < 0.01$). Lower or no correlation was found after changing $paCO_2$ and administration of mannitol. The high failure rate and the limited sensitivity affect the clinical use of near-infrared spectroscopy as a suitable part of neuromonitoring after acute brain injury at the present time (8).

On the other hand, cerebral ischemia may not be adequately detected with monitoring of CPP alone (9). A recent report noted that low $PbtO_2$ values may be present in 10% of the time with CPP values 60 mmHg (9). Cerebral ischemia may be secondary to impaired autoregulation, local hyperemia or vasospasm, focal tissue compression from edematous change, or hematoma formation. That is why cerebral oximetry could be very useful as a part of multimodal neuromonitoring.

Several studies have suggested that the utilization of PbtO2 monitor may be of use in patients with TBI (9–13). Overall, these studies state that the increased mortality is associated with the increased duration of time with $PbtO_2$ levels below 15 mmHg; however, it remains unclear if the treatment of PbtO2 levels over a certain threshold results in improved survival or functional recovery (2).

Further studies are needed to find out what are cerebral oximetry predictive values.

CONCLUSIONS

Monitoring of regional cerebral oximetry for neurosurgery patients can be performed despite its limitations: surgery involving the frontal region of the head, application of the Mayfield holder in the frontal region of the head, intraoperative transcranial Doppler monitoring.

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SMEGENŲ OKSIMETRIJA

Santrauka

Smegenų išemija, patyrus galvos smegenų traumą (GST), yra reikšmingas veiksnys, lemiantis didelį sergamumą ir mirštamumą ar ilgalaikę negalią. Studijos rezultatų duomenimis, į tikslinę smegenų audinio oksigenoterapiją nukreiptas gydymas gali sumažinti mirštamumą ir pagerinti pacientų, patyrusių GST, būklę. Smegenų audinio oksigenacijos tyrimas plačiai naudojamas siekiant įvertinti smegenų metabolijos poreikį ir aprūpinimą, tačiau smegenų audinio stebėsena neinvaziniu būdu vis dar yra iššūkis.

Mūsų studijos tikslas – įvertinti galimybę stebėti neurochirurginių pacientų, patyrusių GST, smegenų oksigenaciją operacinėje, intensyvios terapijos skyriuje, ir apžvelgti ankstyvuosius rezultatus. Prospektyvinis tyrimas buvo atliktas Lietuvos sveikatos mokslų universiteto ligoninės Kauno klinikų Neurochirurgijos anesteziologijos skyriuje. Stebėjimui panaudotas INVOS® Cerebral / Somatic oksimetras, kurio veikimo principas pagrįstas infraraudoniesiems spinduliams artimu spektru. Stebėseną mūsų studijoje ribojo kaktinės galvos srities chirurgija, uždėtas Mayfieldo laikiklis kaktinėje srityje, intraoperacinis transkranijinis Dopplerio tyrimas. Nepaisant apribojimų, vietinę smegenų oksimetriją galima atlikti ir neurochirurgijos pacientams.

Raktažodžiai: smegenų oksimetrija, infraraudoniesiems spinduliams artimas spektras, galvos smegenų trauma, neurochirurgija