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Measurement of the cerebral saturation for assessment of safety of epidural anaesthesia during abdominal surgery

Tomasz Składzień[1], Janusz Andres[2], Artur Pasternak[3], Jerzy Wordliczek[1]

[1]Department of Intensive Interdisciplinary Care, Jagiellonian University Medical College, Kraków, Poland
[2]Department of Anesthesiology and Intensive Care, Jagiellonian University Medical College, Kraków, Poland
[3]Department of Anatomy, Jagiellonian University Medical College, Kraków, Poland

Corresponding author: Tomasz Składzień, MD, PhD
Department of Intensive Interdisciplinary Care, Jagiellonian University Medical College
ul. Jaworskiego 5/12, 31-519 Kraków, Poland
Phone: + 48 506 602 250; E-mail: t.skladzien@interia.pl

Abstract: Background: Near Infrared Spectroscopy (NIRS) is considered a reliable assessment method of a balance between cerebral oxygen demand and supply. One of forms of anaesthesia applied during extensive abdominal surgical procedures is the epidural anaesthesia. Its application in addition to the general anaesthesia is a commonly accepted form of anaesthesia in patients undergoing abdominal surgery.
The aim of this study was to verify the hypothesis that epidural blocks may have effects on cerebral saturation in patients undergoing abdominal surgery under general anaesthesia.
Methods: Cerebral saturation was monitored intrasurgically. Reduction of cerebral oxymetry by over 25% in relation to the baseline, or cerebral oxymetry value below 50% was considered clinically significant.
Results: One hundred and one (101) subsequent and non-randomised patients, age between 35 and 84 years (mean 64 ± 10) qualified for major abdominal surgeries were enrolled. In 14 (13.9%) patients of 101 enrolled a clinically significant reduction of cerebral saturation was observed. In 50 (49.5%) of the enrolled patients, the epidural anaesthesia was applied along the general anaesthesia. A clinically significant reduction of cerebral saturation was observed in 9 of them. No statistically significant association was found between the application of epidural anaesthesia and development of cerebral desaturation.
Conclusion: The application of epidural anaesthesia caused no clinically significant reduction of cerebral saturation during the general anaesthesia in course of major abdominal surgical procedures.

Key words: NIRS, cerebral saturation, epidural anaesthesia.

Introduction

Near Infrared Spectroscopy (NIRS) is used for monitoring of efficiency of microcirculation of a tested organ. A NIRS control of regional blood flow in the cerebral cortex has become practically available due to development of devices, approved for marketing by the Food and Drug Administration (FDA). NIRS is considered a reliable assessment method of a balance between cerebral oxygen demand and supply [1].

NIRS is commonly used for optimisation of the general anaesthesia during surgical procedures on open heart [2, 3], in patients with head trauma [4], and also during procedures of the carotid artery endarterectomy [5]. The usability of NIRS has been confirmed [6, 7] in clinical situations associated with an increased risk of cerebral ischemia. NIRS value is affected by the stroke volume of the heart.

In the available literature there are few studies regarding the measurement of cerebral saturation in patients undergoing abdominal surgical procedures. In one of a study on a group of 122 patients aged over 65 years and subject to abdominal surgery under general anaesthesia, a reduction of cerebral saturation was found in approximately 20% of patients [8].

One of forms of anaesthesia applied during extensive abdominal surgical procedures is the epidural anaesthesia. Its application in addition to the general anaesthesia is a commonly accepted form of anaesthesia in patients undergoing abdominal surgery [9–11]. The neuraxial blockade may result in reduced arterial blood pressure that may be accompanied by reduced heart rate and compromised myocardial contractility. Those effects are usually proportional to the level of anaesthesia. Vascular tonus depends mostly on sympathetic fibres originating from Th5 to L1, responsible for tonus of smooth muscles of arteries and veins. Pharmacological block of those nerves leads to relaxation of blood vessels and increased venous capacity, and reduced venous return to the heart, and in some cases relaxation of arteries may cause a reduction of the vascular resistance.

There are multiple theories explaining the cause of postoperative cognitive dysfunctions. There is a possibility that it results from intra-operative microembol. A lot of data confirm that regional anesthesia decreases the hypercoagulable tendency in the postoperative period and helps maintain normal coagulation and platelet function, probably due to modulation of the neuroendocrine response to tissue injury. It is confirmed that homeostasis of the neuroendocrine system and the immune responses are better preserved after regional anesthesia than after general anesthesia [12]. Epidural anesthesia and analgesia have the potential to reduce or eliminate the perioperative physiologic stress responses to surgery and thereby decrease surgical complications and improve outcomes [13–15].

The aim of this study was to verify the hypothesis that epidural blocks may have effects on cerebral saturation in patients undergoing abdominal surgery under general anaesthesia.

Material and Method

After obtaining approval from the Bioethics Committee — decision no KBET/104/B/2012 of 26.04.2012 and written informed consent from the study participants, 101 non-randomised individuals were recruited to take part in this study. Patient's age was between 35 and 84 years (mean 64 ± 10).

Surgical procedures involved: resection of the intestine, hemihepatectomy, gastrectomy, Whipple's procedure.

During surgery the following were routinely monitored: ECG, noninvasively arterial blood pressure every 5 minutes, capnography and peripheral saturation (pulse oxymetry). Additionally, the cerebral oxymetry saturation was monitored continuously, using a non-invasive method. The mean arterial pressure was calculated with the formula stating that it equals the diastolic blood pressure + 1/3 of the difference between the systolic and diastolic pressures.

Standard general anesthesia was then induced with 0.1 mg kg-1 IV midazolam, 2 μg kg-1 IV fentanyl and 0.3 mg kg-1 IV ethomidate or 2 mg kg-1 IV propofol. After administration of 0.5 mg kg-1 atracurium or 0.1 mg kg-1 IV vecuronium, tracheal intubation was performed and mechanical ventilation was started using a 40% oxygen-air mixture (tidal volume, 7 mL kg-1; respiratory rate, 12 breaths per minute; inspiratory-to-expiratory time, 1/2, with a 10% inspiratory pause). Mechanical ventilation was adjusted to maintain an etCO2 partial pressure ranging between 32 and 36 mm Hg. General Anesthesia was maintained with sevoflurane by adjusting the end tidal concentrations between 1% and 4% to maintain heart rate and mean arterial blood pressure within 15% of baseline values. Supplemental IV boluses of fentanyl (1 μg kg-1) were administered if required to maintain cardiovascular stability, and muscle relaxation was maintained with 5 mg boluses of atracurium or 1 mg boluses of vecuronium at the discretion of the attending anesthesiologists and according to the surgeon's needs.

The cerebral saturation was monitored intraoperatively with near infrared spectroscopy (INVOS 4100; Somanetics Inc, Troy, MI). Data acquired from the device were automatically and continuously recorded in 10-second intervals throughout the anaesthesia. A lead for the cerebral saturation monitoring was placed according to the manufacturer's directions, on degreased skin on the patient's forehead, on the right side, some 1 cm over the eyebrow. The baseline value was determined before induction of anaesthesia (with no oxygen therapy at the time), approximately 3 minutes after placement of the lead, and at constant cerebral saturation for approximately 1 minute. The following criteria were accepted as significant reduction of the cerebral oxygenation (saturation) value:

- reduction of the cerebral oxymetry by over 25% in relation to the baseline;
- the absolute value of cerebral oxymetry below 50%.

The area under the curve (AUC) was calculated in order to determine the level and duration of the cerebral saturation reduction below the value deemed as clinically significant. The AUC value was calculated as a product of the lowest percent value of cerebral saturation and its duration, expressed in minute-percent [min%].

Considering the primary condition, a catheter for epidural anaesthesia was localised on various levels of the spine, e.g. in case of gastrectomy it was localised between Th7 and Th9 and was blocking 8 segments, in case of anterior resection of the rectum it was localised between Th9 and Th10 and was blocking 8 segments, and in case of the Whipple's precedure it was localised between Th7 and Th9, and blocking 8 segments. 0.25% Bupivacaine was administered in bolus via the epidural catheter, in volume calculated using the modified Bromage formula [16] — 0.8 ml + 0.05 ml per each 5 cm of body height over 150 cm for block of a single segment of the spinal cord.

Interventions aimed at correction of the reduced cerebral saturation in patient operated on involved: changed position of the head (improved position for better blood perfusion), increase of the etCO2 value, increase of the arterial pressure by intravenous administration of a bolus of 250 ml of infusion fluid, or by pharmacological intervention with intravenous Ephedrine hydrochloride at the dose of 5–10 mg, or increase of the heart rate by intravenous administration of 0.5–1 mg of Atropine. In case of observed cerebral desaturation, the decision regarding type of intervention was made independently by an anaesthesiologist responsible for the patient's anaesthesia.

Upon the day preceding the actual surgery, and again at 5 days after the surgery, the Mini Mental State Examination test was completed, with a view to assessing the changes in the patients' cognitive function.

The general anaesthesia of the study group of patients was performed using a typical method deemed the safest for the individual patient. The patients were not pre-medicated before the surgery.

Due to lack of published literature to evaluate the incidence of rSO2 decreased in patient without age limit, we could not perform sample size calculations for this pilot study. A sample size of 45 patients was adapted to the exploratory study referencing the literature that rSO2 decrease in older patients undergoing prolonged major abdominal surgery [17].

The following statistical methods were used for the analysis: Pearson's linear correlation coefficient, chi-squared, variance analysis. The value of $p < 0.05$ was considered statistically significant. All calculations were completed suing the Statgraphics Plus 1.4 software, available for non-commercial use.

Results

One hundred and one (101) subsequent and non-randomised patients, age between 35 and 84 years (mean 64 ± 10) qualified for abdominal surgeries were enrolled. Anthropometric data of enrolled patients are presented in the Table 1.

Table 1. Mean age, gender, mean ASA index and BMI of patients with or without epidural anaesthesia.

	Patients with epidural anaesthesia (n = 50)	Patients with no epidural anaesthesia (n = 51)	Statistical significance (p)
Mean age [years]	61 (± 10)	66 (± 11)	0.026
Gender [m. — male; f. — female]	31 m. 19 f.	31 m. 20 f.	0.9
ASA index	I — 3 II — 39 III — 8	I — 4 II — 28 III — 19	0.034
BMI	26.46 (± 4.11)	27.9 (± 4.54)	0.12

ASA — ASA [American Society of Anesthesiologists] Physical Status Classification System
BMI — Body Mass Index

There are more patients ASA III in group without epidural anaesthesia because of anticoagulant therapy.

Continuous monitoring of the cerebral saturation for optimisation of the general anaesthesia demonstrated clinically significant reduction of the cerebral saturation in 14 (13.9%) patients. The mean are under the curve (AUC) of desaturation in those 14 patients was 6.39 ± 7.16 min%.

In 50 (49.5%) of the enrolled patients, the epidural anaesthesia was applied along the general anaesthesia. A clinically significant reduction of cerebral saturation was observed in 9 of them. No statistically significant association was found between the application of epidural anaesthesia and development of cerebral desaturation ($p = 0.3661$).

The mean AUC value in the sub-group of patients with the applied epidural anaesthesia was 5.28 ± 6.89 min%, and in the sub-group in which the epidural anaesthesia was not used it was 8.4 ± 7.99 min% ($p = 0.25$).

In patients with epidural anaesthesia the mean value of cerebral saturation was 66.61 ± 6.98%, and in the sub-group of patients with no epidural anaesthesia the value was 67.88 ± 7.81%. No statistically significant difference was found between the mean value of cerebral saturation during a surgical procedure with or without the epidural anaesthesia (p = 0.39).

The effect of Bupivacaine administered to the epidural space on the absolute value of the cerebral saturation was assessed. Within 20 minutes after administration of Bupivacaine, the mean absolute cerebral saturation value was reduced from 68.62 ± 9.25% to 65.14 ± 9.99%. The change was statistically significant (p = 0.001).

A correlation was also studied between the value of cerebral saturation before induction of anaesthesia and the value in 20 minutes after administration of Bupivacaine into the epidural space. The mean absolute saturation value reduced from 66.26 ± 7.04% to 65.14 ± 9.99%. That results was also statistically significant (p = 0.001).

In 9 patients with epidural anesthesia, cognitive dysfunctions occurred in the postoperative period. There were cognitive dysfunctions in 15 patients in the group without epidural anesthesia. There was no influence of the use of epidural anesthesia on the occurrence of cognitive disorders in the postoperative period (p = 0.18).

The summary of study results for patients with or without the epidural anaesthesia is presented in the Table 2.

Table 2. The summary of study results for patients with or without the epidural anaesthesia.

	Patients with epidural anaesthesia (n = 50)	Patients with no epidural anaesthesia (n = 51)	Statistical significance (p)
The number of patients with a clinically significant reduction of cerebral saturation	9	5	0.3661
Mean AUC in patients who had a clinically significant reduction of the cerebral saturation [min%]	5.28 ± 6.89	8.4 ± 7.99	0.25
The number of patients with post-surgical complications other than cognitive dysfunctions	11	10	0.77
The number of patients with cognitive dysfunctions in the post-surgical period	9	15	0.18
Mean baseline cerebral saturation [%]	66.26 ± 7.04	65.9 ± 6.42	0.75
Mean cerebral saturation [%]	66.61 ± 6.98	67.88 ± 7.81	0.39
Mean number of hospitalisation days	12 ± 11	12 ± 9	0.55
Mean number of days in the ICU	17 ± 14	13 ± 5	0.71
Number of deaths	3	1	0.3

Discussion

The effect of a medicinal procedure on a patient's condition after discharge from a hospital is of growing importance. That is especially associated with possibility of recovery to the pre-surgical condition. The literature articles assessing the applicability of NIRS in patients subject to abdominal surgical procedures [9, 17] focused only on patients over the age of 65. A relatively common (14 patients — 13.9%) occurrence of reduced cerebral saturation, requiring a therapeutic intervention was observed. Optimised treatment applied at the moment of reduced cerebral saturation allowed to achive duration of desaturation, to the mean value of 6.39 min%. Casati *et al.* in their study on patients subject to abdominal surgery demonstrated the mean AUC of 80 min% in the group of patients with no medicinal intervention [9]. Monitoring of the cerebral saturation allows prevention of prolonged desaturation.

Abdominal surgical procedures, particularly those localised in the area of the diaphragm, weakening respiratory and abdominal muscles additionally increase the risk of respiratory complications, leading to reduced tidal volume, weakening of the cough reflex and atelectasis in the post-surgical period [13]. Studies demonstrated that compared to intravenous opioids, the epidural anaesthesia offers a non-inferior control of post-surgical pain, with a lower incidence of adverse effects [13, 18, 19]. Epidural anaesthesia is associated with a lower risk of cardiac events in cardiologically unstable patients [20]. A post-surgical improvement of the respiratory function was also demonstrated for epidural anaesthesia [21, 22].

Safety of the epidural anaesthesia was confirmed in relation to abdominal surgical procedures. However, a reduced cerebral saturation was observed in approx. 20 minutes after administration of drugs into the epidural space. That indicates an existing effect of the central block on perfusion of the brain and should lead to a more detailed control of patients at the moment of making decision concerning its introduction. Monitoring of the cerebral saturation during a central block allowed optimisation of therapy by intrasurgical correction of saturation disorders. Lee *et al.* [23] compared the general anaesthesia with the central one (spinal), monitoring the level of cerebral saturation in patients subject to transurethral prostatectomy. They concluded that the spinal anaesthesia, particularly combined with sedation, favour development of cerebral desaturation. That was especially evident in elderly patients.

A prospective randomized trial of total knee replacements in patients found no significant difference in cognitive tests at 1 week and 6 months postoperatively between epidural and general anesthesia groups [24]. Other prospective randomized trial by Hole *et al.* [25] found significant improvement in postoperative mental status and PaO2 values in patients undergoing total hip replacements with epidural anesthesia. Epidural anesthesia may also affect on cognitive disorders in a different way. Hodgson *et al.* [26] found that epidural anesthesia significantly reduced the MAC of sevoflurane (>50%) needed by 44 patients undergoing elective surgery. Moraca *et al.* [27] maintain that minimizes the amount of general anesthetic, allows better pain control with less sedation, and increases postoperative PaO2, all of which may contribute to improved postoperative cognition. In our data there was no evidence for influence of epidural anesthesia on cognitive dysfunction. However, it is proofed that epidural anesthesia cause reduction in cerebral vascular accidents [28].

Some limitations associated with the measurement of the cerebral saturation should be mentioned. It involves only frontal lobes. Therefore it is impossible to monitor any possible ischemic lesions in other parts of the brain. Additionally, one of the main problems encountered with interpretation of results of the cerebral saturation measurement is a possibility of "interference" from extracerebral tissues. The technology used by the manufacturer of INVOS should deal with the problem by application of 2 analysing optodes and a special algorithm. However, the problem of at most 4 cm-deep penetration into the structure over which a sensor is attached remains unsolved. The problem of penetration depth is associated mostly with interpretation of a result in patients with atrophic lesions of cortical structures that is in elderly patients. A trend of changes appears more important than the absolute value itself when measuring the cerebral saturation.

Absence of randomisation is the principal limitation of the study. A very short period of hospitalisation made the assessment of the effect of the surgical procedure on incidence of distant post-surgical complications impossible.

It is notable, that majority of studies with cerebral oxymetry test the cerebral flow with two electrodes localised on the right and on the left side of the forehead, approximately 1 cm over the eyebrow. In this study, considering no direct effect of the surgery on flow in the vessels carrying blood to the brain, a decision was made to employ a single lead.

Measurement of the cerebral saturation as an indirect method of assessment of cerebral flow may facilitate the assessment of a correlation between the arterial pressure and the cerebral flow.

Increasing number of articles indicate existence of a correlation between intra-surgical cerebral saturation disorders and the unfavourable post-surgical prognosis [2, 8, 29]. However, no study has been designed and presented that would clearly confirm the efficacy of NIRS.

Monitoring of the cerebral saturation allows initiation of a therapy for hypoxia of cerebral tissues in case when the systemic pressure and the peripheral arterial saturation remain normal. Cerebral saturation monitoring allows evaluation of metabolism of the cerebral tissue, providing information regarding the cerebral blood flow and blood saturation.

Although an individualised care of the patient during the surgical procedure becomes more complex and expensive, it allows avoiding post-surgical complications.

Conclusions

Reduction of the cerebral saturation during abdominal surgeries was a relatively common phenomenon 13.9% of patients. The application of epidural anaesthesia caused no clinically significant reduction of cerebral saturation during the general anaesthesia in course of abdominal surgical procedures.

Conflict of interest

None declared.

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