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ORIGINAL ARTICLE

Regional Cerebral Oxygenation Changes Monitored with Near Infrared Spectroscopy Device During Spinal Neurosurgery in Prone Position and Postoperative Cognitive Dysfunction

Sniedze Murniece*, **, Indulis Vanags*, *, Biruta Mamaja*, ****
* Riga Stradins University, Doctoral studies, Riga, Latvia
** Riga Eastern Clinical University Hospital, Department of Anaesthesiology, Riga, Latvia
*** Pauls Stradins Clinical University Hospital, Department of Anaesthesiology, Riga, Latvia

Summary

Introduction. The adverse effects of hypoxia are well known, especially regarding the brain, and can lead to postoperative cognitive disturbances. On the other hand, the brain is still one of the least monitored organs intraoperatively. Near infrared spectroscopy devices are non-invasive continuous cerebral oxygenation monitoring devices that can also be used intraoperatively.

Prone position used during spinal neurosurgery is of particular importance regarding physiological changes that can occur in the human body and can lead to reduced blood and oxygen supply of the brain.

Aim of the Study. The aim of the study was to determine whether prone position used during spinal neurosurgery impacts cerebral oxygenation and patients' cognitive performance after the surgery.

Material and methods. 40 patients were included in the study (32 study group, 8 control group). Patients were scheduled for spinal neurosurgery in prone position. All patients received standard general anaesthesia. In the study group regional cerebral oxygen saturation ($rScO_2$) was continuously monitored using INVOS 4100 near infrared spectroscopy device. During the surgery every 5 minutes in study and control group medium non–invasive blood pressure, heart rate, peripheral oxygen saturation, exhaled CO_2 and cerebral oxygenation measurements were fixed. We also fixed intraoperative blood loss and duration of the operation. Cognitive function was assessed in both groups using Montreal - Cognitive Assessment (MoCA) scale before surgery and two days after the surgery.

Results. We didn't observe any significant changes in our calculated medium $rScO_2$ intraoperative values. During induction of anaesthesia when patients were lying supine $rScO_2$ above the right cerebral hemisphere was $rScO_2$ 72±9.7%, above the left cerebral hemisphere 71± 9.7%. Cerebral oxygen saturation in prone position was $rScO_2$ R 74±10.7% and $rScO_2$ L 74±10.1%. At the end of the surgery when patients were lying supine again $rScO_2$ R was 74±9.3% and $rScO_2$ L was 74±7.9%.

We didn't observe any differences in medium MoCA scores when comparing study and control group. MoCA score before surgery in the study group was 24.1±2.9 points and 24.6±4.1 points in the control group. MoCA performed 2 days after the surgery was 24.6 ±3.2 points in study group and 24.6±2.4 points in control group.

Conclusions. No significant changes were observed in medium MoCA scores between patients who intraoperatively received non-invasive cerebral oxygen saturation monitoring and patients who did not receive it.

Despite medium calculated MoCA scores, individually we observed postoperative cognitive function impairment for MoCA 1-2 points in 5 out of 8 patients in the control group, but in the study group only 1 patient out of 32 showed cognitive dysfunction.

Intraoperative regional cerebral oxygen saturation monitoring can help to obviate cerebral desaturation that can lead to postoperative cognitive decline.

Key words: cerebral oxygenation, prone position, cognitive dysfunction.

INTRODUCTION

Adequate oxygen delivery matching tissue and organ demand and metabolic needs is one of the main tasks during anaesthesia (17,11). The adverse effects of hypoxia are already proven and well known, especially regarding the brain (17). Brain is highly dependent on a continuous oxygen supply and it takes only 5 minutes until hypoxic damage occurs (2). Cognitive disturbances after surgery and anaesthesia may emerge and lately have become widely investigated as postoperative delirium or postoperative cognitive dysfunction may be associated with increased mortality, permanent disability (19) as well as predispose dementia (12). There are studies showing increased incidence and positive correlation between neurophysiological dysfunction, prolonged hospital stay length (14) and major organ morbidity and mortality (5) in patients that experience cerebral oxygen desaturation episodes during surgery. In the century where all range of monitoring devices are widely available, brain is still one of the least monitored organ intraoperatively (17).

Cerebral homeostasis, including its oxygenation status, can be monitored using different devices, like, jugular bulb venous oximetry or microdialysis

catheters (10), but being highly invasive, they can not be used routinely, especially intraoperatively. In 1977 Jobsis already introduced to the world the near infrared light spectroscopy (NIRS) principle that can be used to measure oxygen saturation in the brain (8). NIRS cerebral oximetry devices have been known in clinical practice for about three decades. Previously used mainly in cardiac and vascular surgery and as a monitoring device in neurointensive care units at the beginning, now cerebral oximeters have gained their actuality in different medical fields, like, major abdominal, orthopedic surgery, neurosurgery as well as in patient monitoring during and after cardiac arrest and resuscitation or acute atrial fibrillation episodes. NIRS devices are non-invasive and provide continuous cerebral oxygen saturation ($rScO_2$) measurements. Two adhesive electrodes have been attached to patients' forehead – one above the right and one above the left cerebral hemisphere. Both electrodes include a light emitter that generates near infrared light. 650 – 940 nm length waves are capable to penetrate the skull and underlying cerebral tissue. Based on the fact that oxygenated and deoxygenated hemoglobin in cerebral blood absorbs near infrared light differently, it gives us information about oxygen saturation in the brain (13). The non-absorbed light returns back to the sensor incorporated in cerebral oximeters' electrodes and using special algorithms shows current brain oxygenation status. Normal cerebral oxygen saturation values are estimated to be between 60 – 80%, although it is more important to determine patients' individual baseline and keep numbers within 20% range, as 20% decline from baseline values are considered to be significant (7).
Spinal neurosurgery is a surgical field where one of the main anaesthetic and surgical management challenges is patient lying in prone position. Prone position, being non-physiological, causes multiple significant changes in the human body. Increased intrathoracic pressure decreases left ventricular compliance and filling, increased intraabdominal pressure directly compresses vena cava inferior – both of which reduce ventricular volume, stroke volume resulting in generalized hypotension (9). Arterial hypotension and decreased blood return to systemic circulation directly leads to changes in brain circulation with the following disturbances in its oxygen supply. Brain blood supply is also worsened by artificial hypotension that is often kept during spinal surgery with the purpose to diminish intraoperative bleeding.
The aim of the study was to determine whether prone position used during spinal neurosurgery impacts cerebral oxygenation and patients' cognitive performance after the surgery.

MATERIAL AND METHODS

40 patients were enrolled in our study – 32 patients in the study group, 8 - in the control group. Patients were scheduled for spinal neurosurgery (transpedicular fixation, microdiscectomy, removal of spinal tumours) in prone position. All patients received standard general anaesthesia - induction with fentanyl 0.1–0.2mg, propofol 1-2mg/kg, cisatracurium 0.2mg/kg; maintenance with fentanyl 0.03–0.06μg/kg/min, cisatracurium 0.06–0.1mg/kg/h, sevoflurane to MAC 0.7–1.0, FiO2 0.5. In the study group regional cerebral oxygen saturation ($rScO_2$) was continuously monitored using INVOS 4100 near infrared spectroscopy (NIRS) device. Two self-adhesive electrodes were attached to patients' forehead before induction of anaesthesia – one above the right, one above the left cerebral hemisphere. During the surgery every 5 minutes in study and control group medium non–invasive blood pressure (MAP), heart rate (HR), peripheral oxygen saturation (SpO_2) and exhaled CO2 ($EtCO_2$) measurements were fixed. We also fixed intraoperative blood loss and duration of the operation. Cognitive function was assessed in both groups using Montreal - Cognitive Assessment (MoCA) scale before surgery and two days after the surgery to avoid intraoperatively used drug interaction with the test performance. MoCA scores range between 0 and 30. A score 26 or over is considered to be normal.
Statistical analysis was performed using SPSS V.23.

RESULTS

The medium age in our study group was 56±15.8 years, in the control group 58±9.4 years (Table 1).

Table 1. Patients' characteristics

	Study group	Control group
Patients (n)	32	8
Medium age (years)	56±15.8	58±9.4
ASA * class I (n)	0	0
ASA *class II (n)	17	5
ASA *class III (n)	15	3
ASA *class IV (n)	0	0
Surgery performed:		
Microdiscectomy (n)	9	4
Treanspedicular fixation (n)	18	2
Spinal tumour evacuation (n)	4	2
Others (n)	1	

* ASA class – American association of anesthesiologists developed physical status classification system for assessing the fitness of patients before surgery

The average regional cerebral oxygen saturation $rScO_2$ during the whole surgery in our study group was 71±9.8 % above the right (R) cerebral hemisphere and 70±9.2 % above the left (L) cerebral hemisphere.
During induction of anaesthesia when patients were lying supine $rScO_2$ above the right cerebral hemisphere was $rScO_2$ 72±9.7%, above the left cerebral hemisphere 71±9.7%. At the end of surgery when patients were lying again supine $rScO_2$ R was 74±9.3% and $rScO_2$ L was 74±7.9%.

We didn't observe any significant changes in our calculated medium $rScO_2$ values when patients were lying in prone position. Cerebral oxygen saturation in prone position was $rScO_2$ R 74±10.7% and $rScO_2$ L 74±10.1% (Figure 1).

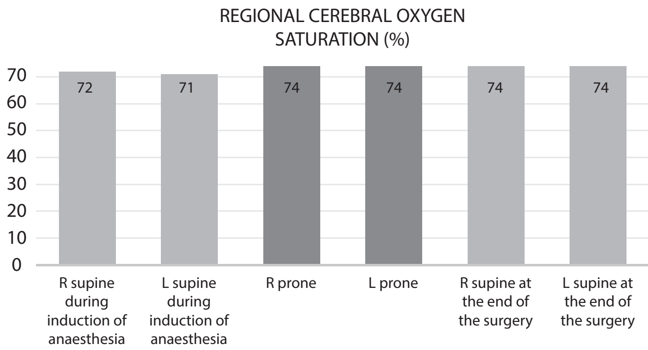

Fig. 1. Medium regional cerebral oxygen saturation $rScO_2$ (%) values above the right (R) cerebral hemisphere and above the left (L) cerebral hemisphere during induction of anaesthesia, in prone position and lying supine at the end of surgery

Despite our calculated mean $rScO_2$ values, 12 out of 32 study group patients individually showed a small to medium drop in $rScO_2$ values in prone position compared to position on spine. The maximum drop we observed in prone position was 34.1% from patients' individual baseline (Figure 2).

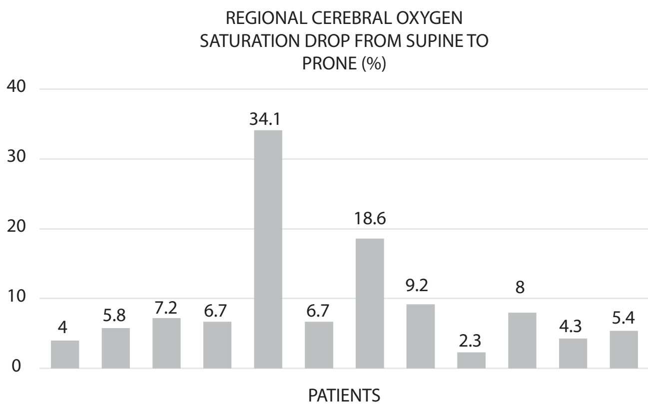

Fig. 2. $rScO_2$ drop in prone position compared to $rScO_2$ values lying supine

The average MAP in the study group was 86±12.7 mmHg which didn't differ much from the average MAP in the control group - 90±12.2 mmHg. In the study group we observed an 11% drop in medium non-invasive blood pressure (MAP) when lying in prone position – from MAP 90 mmHg lying supine to MAP 80 mmHg in prone position. In our control group we observed the same level MAP drop of 10% – from MAP 96mmHg lying supine to MAP 86 mmHg in prone position. We observed medium strong correlation between medium blood pressure and cerebral oxygen saturation values (r=0.31).

The average duration of operation was 110±39.1 min in the study group and 126±48.9 min in the control group. The medium blood loss was 301±335.4 ml – study group, 175±148.8 ml – control group. The average hemoglobin level was 13.56 mg/dl in the study group and 13.57 mg/dl in the control group. We didn't observe any correlation between blood loss, hemoglobin level and $rScO_2$ values (Table 2).

Table 2. Medium duration of operation, medium intraoperative blood loss, medium hemoglobin level in the study group and in the control group

	Study group	Control group
Medium duration of operation (min)	110±39.1	126±48.9
Medium intraoperative blood loss (ml)	301±335.4	175±148.8
Medium hemoglobin level (mg/dl)	13.56	13.57

We didn't observe any differences in medium MoCA scores when comparing the study and the control group. MoCA score before surgery in the study group was 24.1±2.9 points and 24.6±4.1 points in the control group. MoCA performed 2 days after the surgery was 24.6±3.2 points in the study group and 24.6±2.4 points in the control group (Figure 3).

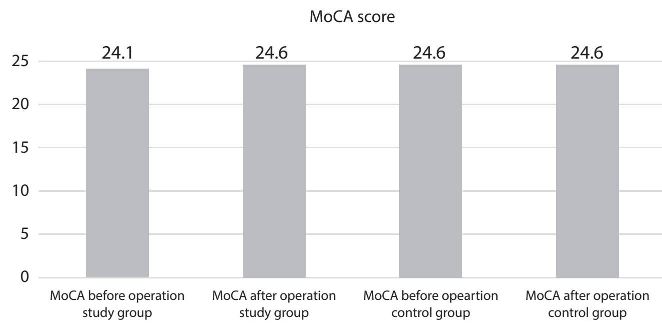

Fig.3. MoCA medium scores in the study group and in the control group before operation and 2 days after operation

In our study group only 1 patient out of 32 showed postoperative cognitive decline. His MoCA score went from MoCA 27 points before surgery to MoCA 23 points after the surgery reveling cognitive dysfunction. We didn't observe any significant changes in other patients' measurements that would differ from average in the study group or would correlate with lower postoperative MoCA score. Patients' intraoperative $rScO_2$ during induction of anaesthesia lying supine was R 75%, L 73%; $rScO_2$ in prone position was R 79%, L 71%; $rScO_2$

lying supine at the end of the surgery was R 73% and L 74%. The average blood loss during the surgery was 150 ml; the duration of operation was 120 min. Patients' hemoglobin level was 15.8 mg/dl.

In our control group 5 out of 8 patients showed a MoCA score decrease of 1 – 2 points after the surgery.

DISCUSSION

There is a limited number of studies published regarding regional cerebral oxygenation monitoring during specifically spinal neurosurgery in prone position. One of them is Deiner et al. (4). In his study he included 211 patients (≥ 68 years) in total. 142 patients underwent surgery lying supine and 63 patients had surgery in prone position. Throughout the whole surgery $rScO_2$ was monitored. They observed that patients undergoing surgery in prone position 2.3 times more often experience mild cerebral desaturation ($rScO_2 <$ 65%) than patients having surgery lying supine. In our study patients were significantly younger (medium age 56±15.8 years). We also compared $rScO_2$ values between periods when patients were lying supine at the induction of anaesthesia and at the end of the surgery with the period when patients were lying in prone position. We didn't observe any significant changes in our calculated mean $rScO_2$ values between supine and prone position although in our study it was the same group of patients where measurements were taken.

Our study results are consistent with Fuchs et al. (6) study. He measured how $rScO_2$ changes with different body positions in the same patient group. He included 48 patients (51.3 years) that underwent lumbar discectomy. Besides $rScO_2$ measurements in supine and prone position he also included lateral right, lateral left and sitting positions. In his patient group he didn't observe important changes in $rScO_2$ with different body positions.

Andersen et al. (1) performed a study investigating heads positions influence on $rScO_2$ during spinal neurosurgery in prone position. 48 patients (56.8 years) were included. As a conclusion neutral head position was strongly recommended as the rotation of the head to the left or right showed lower $rScO_2$ measurements. In our study special care was taken while positioning patients in prone position regarding neutral head position, excluding it as a cause for $rScO_2$ intraoperative changes.

Trafidlo group in 2015 (18) published the first study that monitored $rScO_2$ intraoperatively and measured cognitive function in patients undergoing spinal neurosurgery in prone position. In total 43 patients were included - 13 in the study group that received intraoperative $rScO_2$ monitoring using NIRS device and 30 patients in the control group that didn't receive $rScO_2$ intraoperative monitoring. Cognitive function was assesed using a battery of neurocognitive tests preoperatively and after the surgery. They found a significant difference in postoperative cognitive performance where more profound cognitive decline was observed in the control group that didn't receive intraoperative $rScO_2$ monitoring. They met the same study limitation with small patient groups as it is also in our study.

On a daily basis postoperative cognitive dysfunction mostly can not be detected if special neurophysiological tests are not used, although cognitive decline can have serious long term consequences (4) like risk of leaving the labor market prematurely or dependency on social services (16). On the other hand, the significance of NIRS intraoperative utility as a useful additional monitoring device has been described with persuasive results in many other studies, like, Casati et al. (3) who showed that avoiding intraoperative cerebral hypoxia leads to better cognitive performance or Slater et al. (15) which proved that cerebral oxygen desaturation predicts cognitive decline and leads to longer hospital stay.

CONCLUSIONS

No significant changes were observed in medium MoCA scores between patients who intraoperatively received non-invasive cerebral oxygen saturation monitoring and patients who did not receive it.

Despite the calculated medium MoCA scores, individually we observed postoperative cognitive function impairment for MoCA 1-2 points in 5 out of 8 patients in the control group, but in the study group only 1 patient out of 32 showed cognitive dysfunction.

Intraoperative regional cerebral oxygen saturation monitoring can help to obviate cerebral desaturation that can lead to postoperative cognitive decline.

Conflict of interest: None

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Address:
Sniedze Murniece
Department of Anaesthesiology,
Riga Eastern Clinical University Hospital,
Hipokrāta street 2,
Rīga, Latvia, LV-1038
e-mail: murniece.sniedze@gmail.com