

Comparison of spinal and cerebral oxygen saturation with near-infrared spectroscopy method during spinal surgery in prone position

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ABSTRACT

Objectives: To assess spinal and cerebral oxygenation with near-infrared spectroscopy method during spinal surgery in prone position.

Methods: This prospective study included 64 patients, who were prepared for posterior spinal instrumentation and laminectomy surgeries. Group 1: 31 patients who had posterior spinal instrumentation; Group 2: 33 patients who had at least two levels of disk operation (Laminectomy). The following were recorded for all patients before and after anesthesia induction in supine position, after induction in prone position, during operation (beginning, middle and end of surgery) in prone position and before waking up in supine position: cerebral oxygen saturation (NIRSs) measurements, spinal oxygen saturation (NIRSp) measurements, peripheral oxygen saturation (SpO₂), heart rate (HR), invasively monitored systolic arterial pressure (SAP), diastolic arterial pressure (DAP), mean arterial pressure (MAP) values.

Results: There was no significant difference between two groups in terms of the variables of age, weight, anesthesia and surgery duration ($p > 0.05$). MAP values were significantly different in both groups before induction, during operation and postoperative periods ($p < 0.05$). NIRSs were significantly lower at mid-operation and at the end of operation ($p < 0.05$). NIRSp values had no significant difference in any period ($p > 0.05$). We found no significant difference between groups in HR, SAP, DAP, MAP, NIRSs and NIRSp parameters ($p > 0.05$) compared at different times.

Conclusions: MAP dropped depending on induction and prone position. Cerebral oxygenation significantly decreased at the time of mid-operation and at the end of operation but spinal oxygenation had no significant decrease. Compared to laminectomy, posterior stabilization surgery did not pose an additional risk to the patients in terms of spinal and oxygen saturation.

Keywords: prone position, spinal surgery, cerebral oxygenation, near-infrared spectroscopy

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To prevent the possible complications, it is important to recognize symptoms such as ischemia and hypoxia at an early stage which might develop during

spinal surgery due to surgical intervention or pre-existing trauma. Spinal surgeries are mostly performed in prone position. Spinal surgery presents a complex



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situation where surgery trauma, general anesthesia and prone position generate hemodynamic and respiratory effects. It is important to follow the changes in cerebral and spinal perfusion and oxygenation. Compared to discectomy and laminectomy, posterior stabilization surgeries pose more risk in terms of cerebral and spinal oxygen saturation due to more compression and bleeding risk.

In near-infrared spectroscopy (NIRS) method, infrared light is used to penetrate the tissue, and the optic values of oxyhemoglobin and deoxyhemoglobin in capillary bed are used to calculate the oxygen saturation in tissue [1]. It is a noninvasive method. It enables the measurement of cerebral tissue oxygen saturation with the help of the sensors placed on frontal region. Possibility of measurement mistakes prevents getting the real values for cerebral oxygen saturation and limits its use [2, 3]. Many factors such as the arterial and venous vascular density of the region where sensor is applied, arterio-venous shunts, hemodilution, edema, and patient's bilirubin level might prevent finding the real oxygenation value not only in cerebral tissue but in all measured tissues [2]. However, it is advantageous in terms of the real-time monitoring of oxygenation and its trend follow-up [4, 5]. It has also been reported that, in the light of the insufficiency of standard monitoring methods in following the changes in tissue oxygenation, NIRS monitoring of spinal cord will be a useful warning system for reducing ischemic spinal cord damages, which might occur due to spinal cord surgery [6-9].

In this study, our purpose was to find out whether patients' spinal and cerebral oxygenation values varied before induction, during operation and after operation, and to assess the relation between tissue oxygenation changes and hemodynamic changes in two different survey groups which had posterior spinal instrumentation and at least two levels of disk operation (laminectomy).

METHODS

The study started after getting the Local Ethics Council Approval from the Medical School of Celal Bayar University (26/02/2014, No: 20478486-100) and CBU BAP support (project no. 2014-076).

The study was prospective and included 64

patients who were prepared by the Neurosurgery Clinic for posterior spinal instrumentation and laminectomy, ASA I, II and III (American Society of Anesthesiologists classification) between May 2014 and May 2016. The patients aged between 18 and 70 years, were included in the study after their informed consents were received. Those who did not consent to take part in the study, pregnant patients, those with pre-diagnosed vascular operation and diseases (abdominal aorta surgery, etc.) or a history of cardiac surgery or any intracranial pathology were excluded. The patients, who were included in the study for their spinal surgeries were divided into two groups based on the surgery they underwent; Group 1: 31 cases who had posterior spinal instrumentation (Group 1, n = 31) and Group 2: 33 cases who had at least two levels of disk operation (Laminectomy) (Group 2, n = 33).

All patients were monitored for heart rate (HR), invasive arterial blood pressure, peripheral oxygen saturation (SpO₂), and end-tidal CO₂ (EtCO₂) after being taken into the operating room. In addition, Group 1 cases were monitored for central venous pressure (CVP). For monitoring tissue oxygenation, NIRS (NONIN-Somanetics, Nonin Medical Inc. Minnesota, MN) probes were placed on frontal region and on the distal of spinal segment to be operated.

Pre-oxygenation was performed for all cases with 100% oxygen. Then, the same general anesthesia induction and anesthesia maintenance were applied to both groups. General anesthesia induction was performed with: fentanyl 1-2 µg/kg, propofol 2-3 mg/kg, rocuronium 0.9 mg/kg. After endotracheal intubation, mechanic ventilation parameters were set to keep the tidal volume at 7 ml/kg and end-tidal CO₂ value at 30-40 mmHg. Anesthesia maintenance was provided with sevoflurane 1-2%, 40/60% O₂/N₂O mix and remifentanyl infusion. After the patient was put in prone position, endotracheal tube location was verified; eyeballs, nose and other possible pressure locations were checked; and proper position preventing abdominal pressure was confirmed.

Cerebral oxygen saturation (NIRSs) was measured with the NIRS device (NONIN-Somanetics) by placing probes on the foreheads of patients in both groups; and spinal oxygen saturation (NIRSp) was measured by placing NIRS probes which were sterilized by immersing into ethylene oxide on the distal dermis of the spinal segment to be operated.

Table 1. Descriptive demographical information of groups

	Group 1 (n = 31)	Group 2 (n = 33)	p
Age (years)	53.77 ± 13.90	52.87 ± 13.29	0.690
Weight (kg)	78.70 ± 14.56	79.66 ± 12.31	0.590
BMI (kg/m ²)	26.69 ± 6.11	27.03 ± 5.27	0.610
Gender (male/female)	17/14	19/11	
ASA (1/2/3)	10/16/5	11/15/7	
Anesthesia duration (min)	154.35 ± 38.29	160.15 ± 39.30	0.710
Surgery duration (min)	137.25 ± 38.79	137.72 ± 35.99	0.680

Data are shown as mean ± standard deviation or number. Group 1 =cases who had posterior spinal instrumentation, Group 2 = cases who had at least two levels of disk operation (Laminectomy), ASA = American Society of Anesthesiologists classification, BMI = body mass index

Simultaneously; SpO₂, HR, invasively monitored systolic arterial pressure (SAP), diastolic arterial pressure (DAP), mean arterial pressure (MAP) values were recorded.

Measurement times include T1: Before induction (Supine position), T2: After induction (Supine), T3: Right before surgery (after turning to prone position), T4: After starting the surgery (Prone), T5: Mid-surgery (Prone), T6: End of surgery—at the time of skin suturing (Prone), and T7: After the final positioning of the patient (Supine).

When there is an instant changing in the recorded cerebral oxygenation values the surgery teams were simultaneously warned.

Statistical Analysis

SPSS (statistical package for social sciences for Windows 15.0) program was used for the statistical analysis of the study. Data were evaluated through descriptive statistical analysis by using mean, standard deviation, minimum, maximum, interval and percentage distributions. Analytically, the two groups were evaluated by applying T test in independent groups. Pearson correlation test was applied for comparing numeric data. In all analytical evaluations, *p* < 0.05 was the significance limit value.

RESULTS

We found no significant difference between two groups in terms of the variables of age, weight, anesthesia and surgery duration (*p* > 0.05) (Table 1).

In inter-group comparisons, there was no significant difference between two groups in HR, SAP, DAP, MAP, NIRs and NIRSp parameters compared at all times (*p* > 0.05). But, there were significant differences between the values taken different measure-times for each group of patients.

Among group 1, there was a significant difference between T1 and T2 MAP values (*p* < 0.001). T2 MAP value was significantly different from T3 MAP value (*p* = 0.0019). Among group 2, there was a significant difference between T1 and T2, T2 and T3 MAP values (*p* < 0.001 and *p* = 0.015, respectively). Group 1 and Group 2 MAP values were given in Table 2.

Among group 1, there was a significant difference between T1 NIRs value and T3 NIRs value (*p* = 0.04). T3 NIRs value was significantly different from T5 and T6 NIRs values (*p* = 0.018 and *p* = 0.032,

Table 2. Group 1 and Group 2 MAP values

	Group 1 (mean ± SD)	Group 2 (mean± SD)
MAP T1	96.48 ± 15.09	97.33 ± 14.96
MAP T2	79.58 ± 12.70	80.60 ± 13.52
MAP T3	73.19 ± 12.73	74.39 ± 13.96
MAP T4	75.16 ± 11.85	74.90 ± 11.51
MAP T5	71.54 ± 8.64	72.06 ± 8.70
MAP T6	76.48 ± 15.83	77.24 ± 15.64
MAP T7	91.83 ± 11.44	91.87 ± 11.07

Group 1 =cases who had posterior spinal instrumentation, Group 2 = cases who had at least two levels of disk operation (Laminectomy), MAP = mean arterial pressure, SD = standarddeviation

Table 3. Group 1 and Group 2 NIRSs values

	Group 1 (mean ± SD)	Group 2 (mean ± SD)
NIRSs T1	77.83 ± 12.84	77.15 ± 12.76
NIRSs T2	73.80 ± 11.42	73.63 ± 11.10
NIRSs T3	71.25 ± 12.89	70.84 ± 12.65
NIRSs T4	69.06 ± 9.50	68.81 ± 9.29
NIRSs T5	66.67 ± 9.77	66.57 ± 9.52
NIRSs T6	67.06 ± 11.75	67.37 ± 11.51
NIRSs T7	70.76 ± 11.69	71.00 ± 11.15

Group 1 =cases who had posterior spinal instrumentation, Group 2 = cases who had at least two levels of disk operation (Laminectomy), NIRSs = cerebral oxygen saturation, SD = standard deviation

respectively). Among group 2, there was a significant difference between T1 and T3, T3 and T5 NIRSs values ($p = 0.038$ and $p = 0.021$, respectively). NIRSs values of Group 1 and Group 2 patients were detailed in Table 3.

The correlation analysis of the intra-group comparisons of Group 1 MAP and NIRSs values indicated a positively ($r=0.427$) significant ($p = 0.017$) relation between T5 MAP and T5 NIRSs, and a positively ($r=0.486$) significant ($p = 0.006$) relation between T6 MAP and T6 NIRSs (Tables 2 and 3)

The correlation analysis of the intra-group comparisons of Group 2 MAP and NIRSs values indicated a negatively ($r= -0.375$) significant ($p = 0.032$) relation between T1 MAP and T1 NIRSs; a positively ($r= 0.383$) significant ($p = 0.028$) relation between T5 MAP and T5 NIRSs; and a positively ($r= 0.504$) significant ($p = 0.003$) relation between T6 MAP and T6 NIRSs (Tables 2 and 3).

DISCUSSION

We found that, compared to the MAP values measured before induction, MAP values dropped with anesthesia induction and significantly dropped in prone position during operation. With respect to NIRSs; while there was no difference in supineposition before and after induction, there was a decline after turning to prone position. We found a positively significant relation between MAP and NIRSs during the time of ongoing surgery. This finding was also supported by other studies in

literature. The study by Babakhani *et al.* [4], which enrolled 50 patients undergoing lumbar spine surgery in prone position, concluded that cerebral oxygenation can be maintained in prone position and it is very crucial in preventing bradycardia and arterial hypotension. The study by Trafidlo *et al.* [10], which covered 43 patients, that underwent lumbar spondylosis surgery in prone position to assess postoperative cognitive functions, indicated a positive correlation between MAP and cerebral oxygensaturation. The study by Meng *et al.* [11] reported that this change was actually associated with cardiac output (CO) while it was affected by other hemodynamic parameters. In our study, we thought thatthe change in NIRSs actually derived from prone position while it was affected by the decline inMAP. We can say that this effect of prone position is a complex combination of many effects such as increased abdominal pressure, thoracic compression, disrupted venousturn, cardiac output return, effects on respiratory dynamics, and effects on intracranial circulation, as well as MAP. Studies reported that pulmonary infiltration and atelectatic regions, which concentrated in posterior lung in supine position, dissolved in prone position, intrapulmonary shunting decreased, and perfusion increased in ventral [12]. The clear conclusion of all these was an increased oxygenation in prone position [12]. However, the obstruction that occurred in inferior vena cava in prone position caused a decrease in cardiac venous return [13], and resulted in decreased cardiac index and cardiac output [13, 14]. With the help of auto-regulation mechanisms, systemic vascular resistance (SVR) was increased and MAP was maintained [13, 15]. However, anesthesia induction might disrupt the rise in SVR and auto-regulation thereby causing a drop in MAP [16]. When we consider the results of our study and all effects of prone position on systems, we might conclude that cerebral oxygenation might be affected negatively. The study by Babakhani *et al.* [4] indicated the decrease in cerebral oxygenation in prone position while it was within the margin of safety.

Compared to laminectomy, posterior stabilization operations require applying more compression for placing rots and they pose a bleeding risk. The study by Park [17], which covered 40 patients that underwent spinal surgery in prone position, reported that an increase in intraabdominal pressure caused an

increase in blood loss in surgery region. Due to those differences, posterior stabilization operations might have a more negative effect on average arterial pressure change, cerebral and spinal oxygen saturation due to venous return and volume loss, compared to laminectomies. By including these two types of surgeries performed in prone position in our study, we aimed to compare the oxygenation values before, during and after operation in these groups. In our study, the groups had a homogenous distribution in terms of demographic data. The comparison of two groups indicated no difference in terms of hemodynamic data, NIRs and NIRSp values. This led us to think that compared to laminectomy, stabilization surgeries did not pose an additional risk to the patient in terms of cerebral and spinal oxygen saturation values. It is possible to say that accurate surgery technic and proper bleeding intervention decreased cerebral oxygenation risk.

In our study, we saw no significant difference in NIRSp values in any period. Similar to the NIRs values, NIRSp values had a statistically insignificant decrease in prone position. This might have resulted from an increase in venous blood rate in the region covered by NIRSp sensor as a result of venous stasis. Moreover, NIRSp measurement might be affected by differences in skin, subcutaneous fat tissue and muscle tissue volume and blood build-up. There are studies indicating that paravertebral muscle volume changed based on age and gender [18]. However, since our study found no statistically significant difference between groups in terms of age, gender and BMI, we think that NIRSp measurements were not affected by those factors in our study.

Limitations

The limitations of NIRS method in the other studies have also limited our study. Many factors such as the arterial and venous vascular density of the region where sensor is applied, arterio-venous shunts, hemodilution, edema, and patient's bilirubin level might have affected the real value of oxygenation.

CONCLUSION

In conclusion, MAP dropped depending on induction and prone position. Cerebral oxygenation

decreased significantly at the time of mid-operation and at the end of operation but there was no significant decrease for spinal oxygenation. Compared to laminectomy, posterior stabilization surgeries did not pose an additional risk to the patient in terms of cerebral and spinal oxygenation.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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