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ORIGINAL INVESTIGATION

Cerebral oxygenation assessed by near-infrared spectroscopy in the sitting and prone positions during posterior fossa surgery: a prospective, randomized clinical study

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Abstract
Objectives: Sitting position (SP) or prone position (PP) are used for posterior fossa surgery. The SP induced reduction in cerebral blood flow and cerebral oxygen saturation (rSO_2) has been shown in shoulder surgeries, but there is not enough data in intracranial tumor surgery. Studies showed that PP is safe in terms of cerebral oxygen saturation in patients undergoing spinal surgery. Our hypothesis is that the SP may improve cerebral oxygenation in the patients with intracranial pathologies due to reduction in intracranial pressure. Therefore, we compared the effects of the SP and PP on rSO_2 in patients undergoing posterior fossa tumor surgery.
Methods: Data were collected patients undergoing posterior fossa surgery, 20 patients in SP compared to 21 patients in PP. The rSO_2 was assessed using INVOS monitor. Heart rate (HR), mean arterial pressure (MAP), $EtCO_2$, BIS, and bilateral rSO_2 were recorded preoperatively, and at 5, 8, and 11 minutes after the intubation and every 3 minutes after patient positioning until the initial surgical incision.
Results: Cerebral oxygenation slowly reduced in both the sitting and prone position patients following the positioning ($p < 0.002$), without any difference between the groups. The HR and MAP were lower in the sitting SP after positioning compared to the PP.
Conclusion: Neurosurgery in the SP and PP is associated with slight reduction in cerebral oxygenation. We speculate that if we rise the lower limit of MAP, we might have showed the beneficial effect of the SP on rSO_2.

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Introduction

The sitting (SP) or prone positions (PP) are used for posterior fossa surgery. The SP provides optimum access to midline lesions in the posterior fossa, improves blood and cerebral spinal fluid drainage, and decreases intracranial pressure.[1] However, the SP in anesthetized patients may result in a decrease in mean arterial pressure (MAP) and cardiac output.[2] These hemodynamic changes may cause a reduction in cerebral blood flow and cerebral oxygen saturation. Although the beach chair position related cerebral ischemia has been reported in shoulder surgery, recent studies suggest that prevention of position-induced hypotension may reduce the risk of cerebral desaturation in the sitting position for neurosurgical procedures.[3,4]

The PP is used in posterior fossa surgery to avoid SP-induced hemodynamic changes and venous air embolism. However, PP-induced visual loss has been reported.[5] In addition to direct ocular pressure, cerebral hypoperfusion may facilitate ocular injury in PP as well.[6] The effect of the PP on cerebral oxygenation has been investigated in spinal surgery patients and studies showed that PP is safe in terms of cerebral oxygen saturation.[7,8]

Near-infrared spectroscopy is a noninvasive method which uses infrared light like pulse oximetry, to assess regional tissue oxygenation (rSO_2) by measuring the absorption of infrared light by tissue. An electrode formed by a sensor and light source is placed on the forehead to measure cerebral tissue oxygenation. The amount of sensoring light represents mostly venous oxygen saturation (75-80%) and the range varies between 0-99%.

Our hypothesis is that the sitting position may improve cerebral oxygenation in the patients with intracranial pathologies, due to reduction in intracranial pressure. Therefore, we compared the effects of the sitting and prone positions on the cerebral oxygenation in patients undergoing posterior fossa tumor surgery by the near infrared spectroscopy (NIRS).

Methods

The Ethics Committee of Istanbul University-Cerrahpasa, Cerrahpasa Medical Faculty (Chairperson Prof Ozgur Kasapcapur) provided ethical approval for this study on 4 October 2016 (Ethical Committee No 355075). This study was registered to ''clinicaltrials.gov'' with the identifier NCT02933749. This prospective, randomized, and observational study was performed between October 2016 and June 2019 in the Istanbul University-Cerrahpasa, Cerrahpasa Medical Faculty, Neurosurgical Operation Rooms. After written informed consent, 44 ASA I–III patients aged between 18 to 70 years scheduled for elective posterior fossa tumor surgery were included in the study.

Exclusion criteria were presence of carotid artery disease, chronic obstructive lung disease, history of cerebrovascular disorder, history of orthostatic hypotension, uncontrolled hypertension, symptomatic coronary artery disease, and hemoglobin concentration less than 9 $g.dL^{-1}$.

Patients were randomized to one of two groups (the SP or PP) using opaque envelopes. The chief anaesthesia nurse generated the random allocation sequence; the consultant anaesthesiologist has enrolled participants and on duty neurosurgeon assigned cases to the surgical position.

Patients were sedated with intravenous (IV) midazolam (0.05 $mg.kg^{-1}$) before the surgery in the anesthesia preparation room. In the operating room, after routine monitoring, bispecteral index (BIS) and regional cerebral oxygen saturation (rSO_2) monitoring were performed. Regional cerebral oxygen saturation was assessed continuously using the INVOS cerebral oximeter (Medtronic USA). Sensors of oximeter were positioned on the right and left forehead in the frontotemporal position. Anesthesia was induced with propofol (1.5–2 $mg.kg^{-1}$), rocuronium (0.5 $mg.kg^{-1}$) and remifentanil, (0.1 $\mu g.kg^{-1}.min^{-1}$). After 3 minutes of manual ventilation with oxygen/air (F_iO_2 = 0.8), patients were intubated. Patients were ventilated in volume-controlled mode, tidal volume: 8 $mL.kg^{-1}$ (ideal body weight), F_iO_2 = 0.4, inspiration: expiration ratio of 1:2, PEEP: 5 cmH_2O and respiratory rate (9–12 per minute) was adjusted to maintain $PaCO_2$ in the range of 36 to 38 mmHg. The F_iO_2 was maintained at 0.4 throughout the study. Anesthesia was maintained with sevoflurane 0.8 MAC in oxygen/air (FiO_2 = 0.40), remifentanil (0.05–0.1 $\mu g.kg^{-1}.min^{-1}$) and rocuronium (0.01 $mg.kg^{-1}.min^{-1}$). After orotracheal intubation right radial artery and urinary catheters were placed and scalp nerve block was performed. Two miligrams per kg 0.05 % bupivacaine was applied in 3 mL injection on auriculotemporal, zygomaticotemporal, supraorbital, supratrochlear, greater occipital, and lesser occipital nerves. Right subclavian vein catheterization was performed, and 500 mL colloid bolus (Gelofusine, Braun, Germany) administered to the patients planned to undergo surgery in the SP. Following the pin head holder placement surgical position was given.

Patients heart rate (HR), mean arterial pressure (MAP), end tidal CO_2 ($EtCO_2$), peripheral oxygen saturation (sPO_2), BIS values, left and right rSO_2 were recorded at the preoperative period 5 minutes after the intubation (baseline), 8 and 11 minutes after the intubation, and every 3 minutes after positioning until the initial surgical incision. All recorded data were compared between the sitting and prone position groups. Arterial blood gas analysis was performed 2 minutes before the surgical incision and $PaCO_2$ values were recorded and compared between the sitting and prone position groups. A clinically relevant change in cerebral oxygen saturation was defined as a change greater than 7%. The critical rSO_2 level was defined as lower than 55 %. If MAP decreased below 55 mmHg, intravenous 5 mg ephedrine was administered.

Statistical analysis and sample size

Based on our pilot study, 20 patients are needed in each group to detect a minimum difference of 7 % in rSO_2 between the groups, with a probability of error type II of 20% (β = 0.2) and error type I of 5 % (α = 0.05).

All data were expressed as a number or mean (SD). SPSS 15.0 (SPSS Inc, Chicago) was used for statistical analysis. Pearson $\chi 2$ test was used for comparison of qualitative variables between the groups such as gender, ASA physical status, critical rSO_2 and ephedrine administration, which showed binary change. Pearson $\chi 2$ or Fisher's exact test was

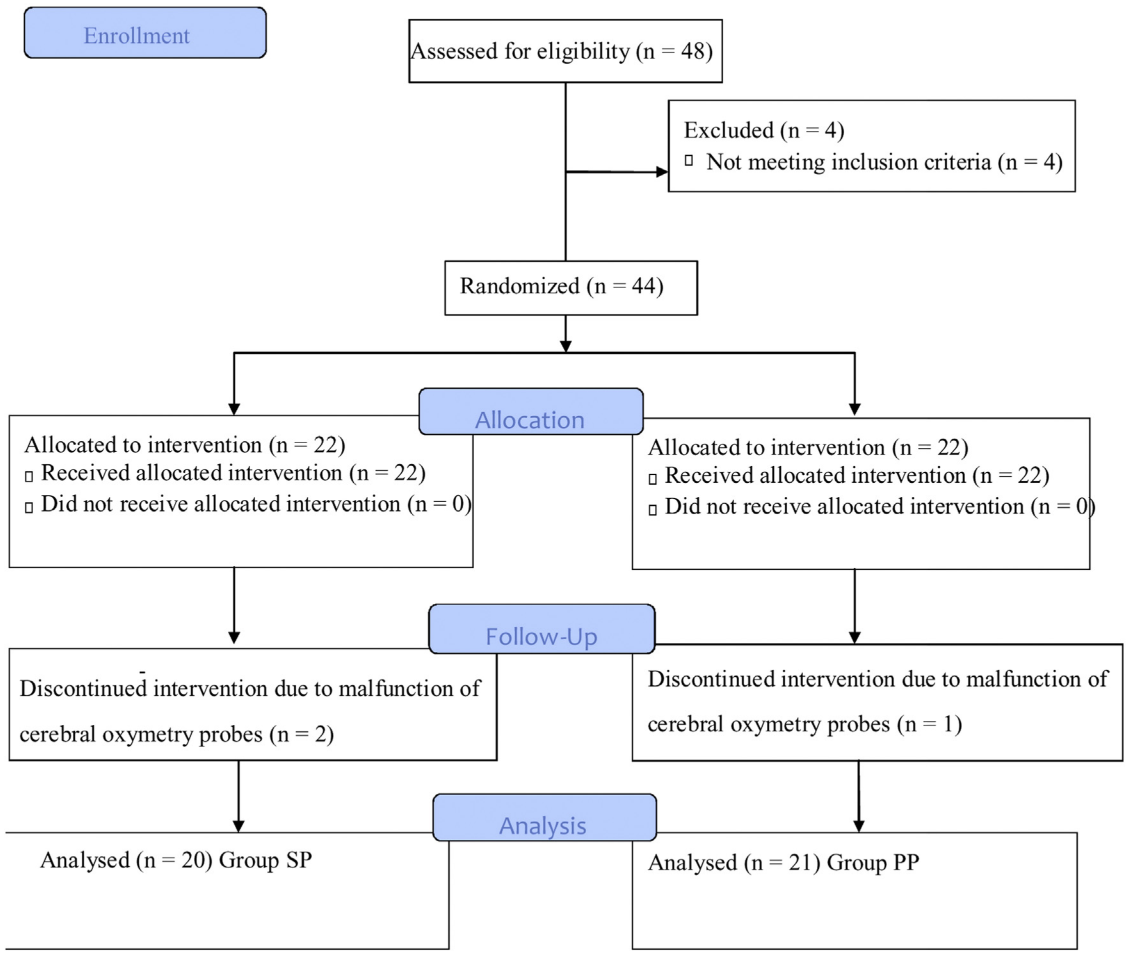

Figure 1 Flow of participants in the study.

used for comparison of diagnosis between the groups. The Kolmogorov-Smirnov test was used to evaluate the distribution of data. All data was normally distributed; therefore, *t*-test was used for comparisons between the groups and one-way ANOVA was used for within group comparisons; $p < 0.05$ was considered statistically significant.

Results

Forty-four patients were enrolled in this study. Two patients randomized to Group SP and one patient randomized to Group PP were excluded from the study due to malfunction of the cerebral oximetry probes (Fig. 1).

The study groups were similar with respect to ASA physical status, gender, age, body weight, height, and body mass index (Table 1). Patients' diagnoses are shown in Table 2.

There was no statistically significant difference with respect to heart rate at the preoperative period, baseline, 8 minutes after intubation, 11 minutes after intubation, and the surgical incision periods ($p = 0.814$, 0.847, 0.528, 0.528, and 0.06 respectively; Fig. 2). The heart rate was lower in the Group SP compared to the Group PP at the measurement intervals 3, 6, 9 and 12 minutes after positioning ($p = 0.013$, 0.029, 0.024 and 0.044, respectively; Fig. 2). The heart rate was statistically significantly reduced from baseline to following measurement intervals in each group ($p < 0.001$, Fig. 2).

There was no statistically significant difference with respect to MAP at the preoperative period, baseline, 8 minutes after intubation, 12 minutes after positioning, and the surgical incision periods ($p = 0.300$, 0.144, 0.203, 0.051 and 0.053, respectively; Fig. 2). The MAP was lower in the Group SP compared to the Group PP at the measurement intervals 11 minute after intubation, 3, 6 and 9 minutes after positioning ($p = 0.020$, 0.001, 0.001, and 0.005 respectively; Fig. 2). The MAP levels statistically significantly reduced from baseline to following measurement intervals in each group ($p < 0.001$, Fig. 2).

There was no statistically significant difference with respect to left and right rSO_2 levels at all measurement intervals between the groups ($p > 0.05$, Fig. 3). The baseline left and right rSO_2 levels statistically significantly reduced at following measurement intervals in each group ($p < 0.002$, Fig. 3).

There was no statistically significant difference with respect to BIS and end-tidal CO_2 levels at all measurement intervals between the groups and within group comparisons.

There was no statistically significant difference with respect to critical rSO_2 levels and need of ephedrine administration between the groups ($p = 0.920$ and 0.939

Table 1 Patient characteristics, critical rSO2, ephedrine administration and $PaCO_2$.

	Group SP n = 20	Group PP n = 21	*p**
ASA, I/II/III (n)	11/7/2	14/6/1	0.689
Gender, M/F (n)[a]	7/13	7/14	0.910
Age, years, mean ± SD[b]	38.40 ± 16.24	42.62 ± 13.67	0.373
Height, cm, mean ± SD[b]	166.40 ± 9.04	163.71 ± 8.48	0.333
Weight, kg, mean ± SD[b]	77.35 ± 13.35	71.90 ± 15.32	0.233
BMI, $kg.m^{-2}$, mean ± SD[b]	26.68 ± 4.69	27.79 ± 5.43	0.488
Critical rSO_2, (n)[a]	6/14	6/15	0.920
Ephedrine administration, (n)[a]	4/16	4/17	0.939
$PaCO_2$, mean ± SD[b]	34.71 ± 2.90	36.94 ± 3.73	**0.039**

ASA, American Society of Anesthesiologists; BMI, Body Mass Index; n, number.
Comparison between the groups.
$p < 0.05$ indicates a statistically significant difference.
[a] Pearson $\chi 2$ test.
[b] t-test.

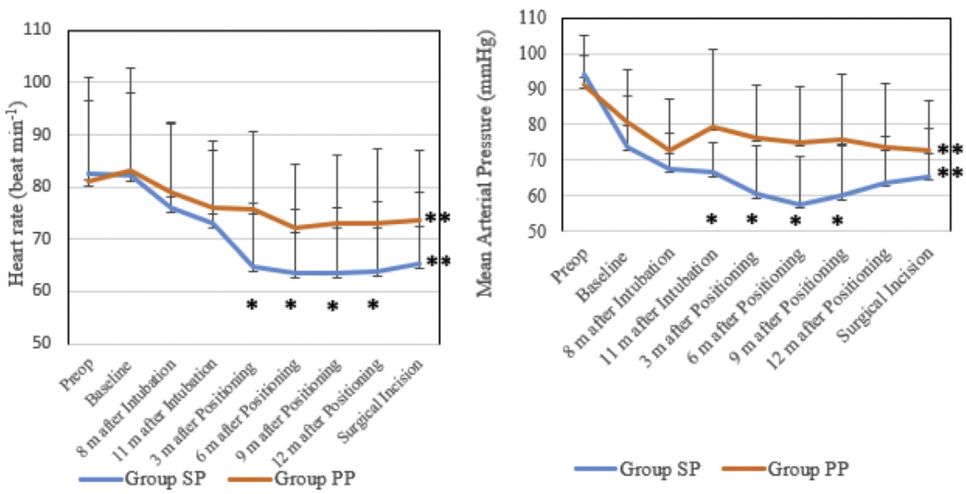

Figure 2 Heart rate and Mean Arterial Pressure.
Heart rate (HR) and mean arterial pressure (MAP) for the patients in the Group SP (Sitting position) and in the Group PP (Prone position). Data are presented as mean (SD).
*p**: comparison between the groups, t-test.
*p***: within group comparisons, one-way ANOVA, ** $p < 0.001$ for all.
* *p* values for HR are 0.013,0.029, 0.024 and 0.044 respectively.
* *p* values for MAP are 0.02, 0.001, 0.001 and 0.005 respectively.

respectively, Table 1). The $PaCO_2$ levels were lower in the Group SP compared to the Group PP ($p = 0.039$, Table 1).

Weak or no correlation was determined between the MAP and left as well as right rSO_2 levels. Pearson correlation coefficients between MAP and left rSO_2 levels were r = 0.192 at the preoperative period, r = 0.450 at the baseline, r = 0.218 at 8 min after intubation, r = 0.088 at 11 min after intubation, r = 0.281 at 3 min after positioning, r = 0.270 at 6 min after positioning, r = 0.144 at 9 min after positioning, r = 0.148 at 12 min after positioning and r = 0.093 at the surgical incision periods. Pearson correlation coefficients between MAP and right rSO_2 levels were r = 0.043 at the preoperative period, r = 0.311 at the baseline, r = 0.170 at 8 min after intubation, r = 0.114 at 11 min after intubation, r = 0.376 at 3 min after positioning, r = 0.357 at 6 min after positioning, r = 0.316 at 9 min after positioning, r = 0.375 at 12 min after positioning and r = 0.201 at the surgical incision periods. Strong correlation was determined between the left and right rSO_2 levels (r = 0.666 at the preoperative period, r = 0.759 at the baseline, r = 0.837 at 8 min after intubation, r = 0.830 at 11 min after intubation, r = 0.779 at 3 min after positioning, r = 0.770 at 6 min after positioning, r = 0.788 at 9 min after positioning, r = 0.809 at 12 min after positioning and r = 0.499 at the surgical incision periods).

Discussions

The primary endpoint of the present study was cerebral oxygenation. We observed that it slowly reduced in both the

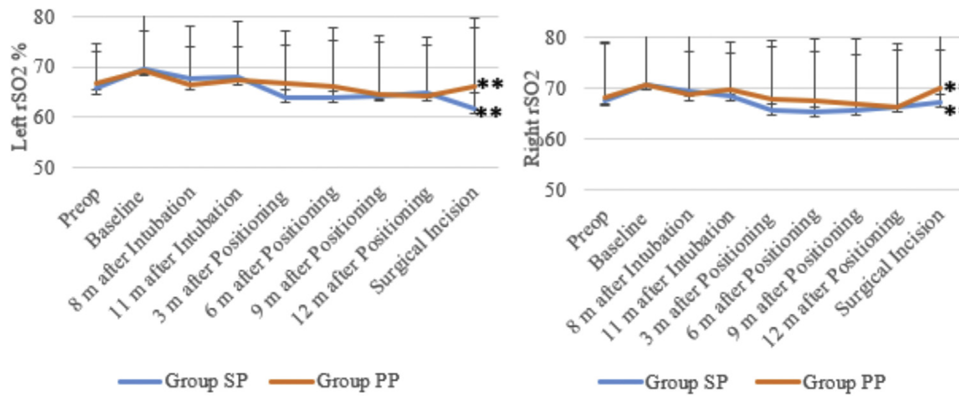

Figure 3 Left and Right rSO_2.
Left and Right rSO_2 for the patients in the Group SP (Sitting position) and in the Group PP (prone position). The data are presented as mean (SD).
p**: within group comparisons, one-way ANOVA, **$p < 0.002$ for all.
There was no statistically significant difference with respect to left and right rSO_2 levels between the groups. p-values for left rSO_2 = 0.694, 0.882, 0.675, 0.812, 0.400, 0.552, 0.929, 0.655, 0.383, and p-values for right rSO_2 = 0.866, 0.985, 0.788, 0.698, 0.562, 0.614, 0.730, 0.999, 0.463, respectively.

Table 2 Patients' diagnosis.

	Group SP n = 20	Group PP n = 21	p*
Schwannoma (n)[a]	6	2	0.130
Meningioma (n)[b]	6	6	0.920
Glial tumor (n)[a]	3	6	0.454
Epidermoid tumor (n)[a]	2	1	0.606
Cavernoma (n)[a]	1	2	1.00
Glomus jugulare tumor (n)[a]	1	0	0.488
Hemangioma (n)[a]	0	1	1.00
Neurofibroma (n)[a]	1	0	0.488
Metastasis (n)[a]	0	2	0.454
Ependymoma (n)[a]	0	1	0.488

n, number.
Comparison between the groups.
$p < 0.05$ indicates a statistically significant difference.
[a] Fisher's exact test.
[b] Pearson $\chi 2$ test.

sitting and prone position patients following the positioning. We did not find any differences in cerebral oxygenation between the sitting and prone position groups. The heart rate and MAP were lower in the sitting position patients after positioning compared to prone position.

Change in posture in anesthetized patients from the supine to the sitting position results in reduction in cardiac output (CO), MAP, and cerebral perfusion pressure (CPP).[9] In awake patients, this type postural changes trigger sympathetic nervous system activation, hence systemic vascular resistance and heart rate are increased to maintain MAP and CO.[10] In anesthetized patients, the sympathetic nervous system activation is attenuated by the vasodilating effect of anesthetic drugs. These hemodynamic changes may cause reduction in cerebral blood flow and cerebral oxygen saturation.

Murphy GS et al.[11] compared beach chair and lateral decubitus positions in terms of the incidence of cerebral desaturation events by NIRS in patients undergoing shoulder surgery. Although they provide a stringent hemodynamic stability using phenylephrine, ephedrine, and fluid administration to prevent hypotension, they found that rSO_2 levels were lower in the beach chair position (BCP). Similar results were obtained by Closhen et al.,[12] and they found that BCP is associated with a decrease in rSO_2 levels. Distinct from the Murphy's,[11] study they determined a correlation between the MAP and rSO_2 levels in the BCP. On the other hand, another study showed that under general anesthesia the BCP did not alter cerebral oxygenation in patients undergoing shoulder surgery.[13]

Although several studies investigated the effect of sitting position on cerebral oxygenation in patients undergoing orthopedic surgery, very few studies performed in the neurosurgical setting. Schramm et al.[4] evaluated the effect of the SP on cerebral oxygenation in patients undergoing dorsal cranium surgery and they found that the cerebral oxygen saturation slowly increased in SP. Similar to the Schramm et al.[4] trial our hypothesis is that sitting position may improve the cerebral oxygenation in the patients with intracranial pathology because it reduces intracranial pressure. Schramm et al.[4] monitored and provided a constant CO, and they could show the beneficial effect of the SP on cerebral oxygenation. In our study, we did not monitor CO and we kept the MAP > 55 mmHg using ephedrine administration if needed. Cerebral oxygenation slowly reduced in both the sitting and prone position patients following the positioning. In our study population, although the MAP levels were lower in Group SP compared to Group PP, there was no difference in cerebral oxygenation between the groups. At this point, we could speculate that if we could rise the lower limit of the MAP or monitored and kept a stable CO in our study population, we might have showed the beneficial effect of the SP on cerebral oxygenation compared to the PP.

One can also argue that prone position may cause impaired cerebral venous drainage and thus result in a reduction of cerebral perfusion. The effect of the PP on the cerebral oxygenation is still controversial. Closhen et al.[7] investigated the change in cerebral oxygenation in patients undergoing spinal surgery and found a small increase in cerebral oxygenation (less than 5%) in the prone position. Babakhani et al.[8] showed reduction in cerebral oxygenation in the same surgery population following prone positioning, though. This reduction was not clinically important. Similar to Babakhani et al.[8] studies, we showed that a small, clinically unimportant reduction in cerebral oxygenation in the Group PP.

The change in cerebral oxygen saturation may be the result of multiple factors. To eliminate one of these factors, the FiO_2 was maintained at 0.4 after intubation throughout the study period. The ventilation strategy can also impact on cerebral oxygenation. Murphy GS et al[14] showed that cerebral oxygenation was significantly improved in the sitting position when ventilation was adjusted to maintain $EtCO_2$ at 40−42 mmHg compared with 30−32 mmHg. In our study, there was no difference in terms of $EtCO_2$ levels between the groups and although statistically significant, the 2 mmHg higher $PaCO_2$ in the Group PP was not clinically important.

This study has some limitations. Our study period was finished with the surgical incision. Various intraoperative factors may alter the cerebral oxygenation. Intraoperative blood loss, hemoglobin levels, or amount of administered fluids are just a few of these factors that could have meddled the study results if we continued to take further measurements. Our hypothesis was that the sitting position may improve cerebral oxygenation in patients with intracranial tumor, due to reduction in intracranial pressure. After dura opening, intracranial pressure becomes equal to the atmospheric pressure. To establish our hypothesis, we finished our study period at the time of first surgical incision. Thus, we took our final measurement at the time of first surgical incision to evaluate only the effect of position on the cerebral oxygenation. Lack of CO monitoring poses another limitation for our study. CO monitoring and acting on it to keep stable CO could allow us to better show the beneficial effect of the SP on cerebral oxygenation compared to the PP. If we could increase the sample size, we could increase the power of study.

Conclusion

Cerebral oxygenation was slightly reduced in both the sitting and prone position patients following the positioning, without any difference between the groups. The HR and MAP were lower in the sitting SP after positioning compared to the PP. We could speculate that if we could rise the lower limit of the MAP in the SP group, we might have showed the beneficial effect of the SP on cerebral oxygenation compared to the PP. Further and larger sample sized studies are needed to prove that.

Conflicts interests

The authors declare no conflicts of interest.

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