ISSN: 2717-8161 REVIEW ARTICLE

New Trend Med Sci 2024; 5(Supplement Issue):126-131 https://dergipark.org.tr/tr/pub/ntms

How Surgical Positions Affect Cerebral Oxygenation

Zubeyir Cebeci[1*]

[1]Department of Anesthesiology and Reanimation, Faculty of Medicine, Ordu University, Ordu, Türkiye

Article History
Received 10 Dec 2023
Accepted 17 July 2024
Published Online 28 July 2024

[*]***Corresponding Author***
Zubeyir Cebeci
Department of Anesthesiology and Reanimation
Faculty of Medicine
Ordu University
Ordu Türkiye.
Phone: +90 5056436839
E-mail: zubeyircebeci@gmail.com

Doi:10.56766/ntms.1402709

Authors' ORCIDs
Zubeyir Cebeci
https://orcid.org/0000-0001-7862-4268

Abstract: This study investigates the use of cerebral oximetry in various surgical positions and its impact on cerebral oxygenation. We conducted a literature review through Medline, and Ebscohost, focusing on articles published until October 30, 2023. Our findings indicate that: Cerebral oxygenation is affected by all surgical positions, with the most significant clinical impact observed in the seated position. Maintaining cerebral autoregulation is crucial for preventing cerebral hypoxia or desaturation. Upholding a mean arterial pressure above 60 mmHg is essential for this purpose. Anesthesia can negatively impact cerebral oxygenation by potentially impairing cerebral autoregulation. Inhalation anesthetics may have a more beneficial effect on cerebral oxygenation compared to intravenous anesthetics. The risk of cerebral desaturation increases in elderly patients and those with comorbidities. Standardization of cerebral desaturation definitions is needed to better assess its relationship with postoperative complications. The position of the blood pressure transducer can affect the accuracy of intraoperative monitoring. In the seated position, placing it at the level of the acoustic meatus provides a more precise assessment. Our study highlights the importance of considering the effects of different surgical positions on cerebral oxygenation. This knowledge can assist anesthesiologists in monitoring patients intraoperatively and potentially preventing postoperative neurological complications.

Keywords: Cerebral oximetry; Beach chair; cerebral oxygenation; Prone; Near-infrared spectroscopy.

1. Introduction

Surgery is usually performed with the patient supine, but the efficiency of the operation can be improved by offering patients different positions during surgical procedures. The preferred surgical positions include supine, prone, lateral decubitus, sitting, reverse trendelenburg, and trendelenburg, each of which carries some risk. The body's position can impact respiratory, cardiopulmonary physiology, and tissue oxygenation, including that of the brain [1,2]. The anesthesiologist needs to comprehend the effects of the surgical position on intraoperative physiology.

The assessment of brain oxygenation can be accomplished through the utilization of jugular vein oxygen saturation and microdialysis techniques. The utilization of both methodologies is constrained because of their invasive and the inclusion of numerous additional risks. Near-infrared spectroscopy (NIRS) was first used by Frans Jobsis in 1977 for brain tissue. It is a non-invasive method that utilizes infrared light, akin to pulse oximetry, for assessing regional tissue oxygenation (rSO2) through the measurement of the absorption of infrared light by the tissue [3-5]. The frontal

Cite this article as: Cebeci Z. How Surgical Positions Affect Cerebral Oxygenation. *New Trend Med Sci.* 2024; 5(Supplement Issue):126-131.Doi:10.56766/ntms.1402709

cortex's regional cerebral oxygen saturation (rScO2) can be determined by comparing the specific absorbance patterns of oxygenated and non-oxygenated haemoglobin to NIRS. NIRS technology makes it possible to recognize and treat cerebral desaturation events (CDEs) without the need for conventional intraoperative monitoring.

Our study attempted to determine whether cerebral oximetry is useful for different surgery positions and effects on cerebral oximetry.

2. Method

The literature search consisted of retrieving articles from Medline, and Ebscohost from inception until October 30, 2023.

The utilization of both keywords and subject headings was employed in this instance. The search strategy incorporated the following keywords: beach chair, sitting position, cerebral oxygenation, cerebral oximetry, Trendelenburg, Lateral decubitus, prone, and near-infrared spectroscopy. In Medline the advanced search engine was used with the following MeSH (medical subject headings) terms and keywords: (beach chair or sitting or upright), (trendelenburg), (prone), (lateral decubitus), (NIRS or near-infrared spectroscopy, oximetry), (cerebral oxygenation or cerebral oximetry). The inclusion criteria encompassed the utilization of intraoperative cerebral saturation monitoring with NIRS in adult patients who were undergoing operating in different surgery positions under general anesthesia or regional anesthesia, as documented in the English-language literature.

Sitting/Seated positions

Surgeons utilize the sitting position and the deck chair position in certain neurosurgery and shoulder surgery procedures. The beach chair position (BCP) is preferred over the lateral decubitus technique for several reasons in orthopedic surgery. Firstly, the traditional BCP places less tension on the brachial plexus, which may help to minimize potential complications. Secondly, the BCP is less likely to cause direct neurovascular trauma associated with the position. In addition, traditional BCP provides better visualisation within the joint, allowing for better intervention during the procedure. Finally, if open surgical intervention is necessary, traditional BCP offers easier access [7–9]. While the sitting position is associated with fewer complications, it is important to note that serious neurological complications can still occur. The utilization of cerebral oximetry has garnered heightened attention following the documentation of four instances of ischemic brain injury in patients undergoing orthopaedic surgery while positioned in a sitting position [10].

The cerebral oxygen saturation drops more significantly when the patient is in the BCP in comparison to the more markedly compared to baseline values (supine position) [11–14]. The changes in body posture, specifically transitioning from a supine to a sitting position, result in decreases in cardiac output, mean arterial pressure (MAP), cerebral blood flow (CBF) and cerebral perfusion pressure (CPP), leading to a reduction in cerebral oxygen supply[15,16]. The primary cause for this alteration is the accumulation of blood in the lower limbs as a result of gravitational force and the reduction in the volume of blood flowing back to the heart [17]. Normally, the autoregulation mechanism ensures the maintenance of cerebral perfusion pressure, hence restricting the reduction in cerebral oxygen saturation caused by the change in position [18]. However, a reduction in the mean blood pressure beyond the limit of autoregulation results in a decrease in cerebral perfusion pressure, leading to impaired cerebral oxygenation [19,20].

Prone positions

Patients who undergo spine surgery in the prone position, especially elderly ones, are more than twice as likely to have cerebral desaturation compared with patients in the supine position[21,22]. Although the prone position is known to increase arterial oxygen saturation, especially in patients with ARDS [23,24], no change in Spo2 was observed in patients who underwent spinal surgery in the prone position, whereas the decrease in bilateral regional cerebral oxygen saturation was accompanied by decreases in heart rate and mean arterial pressure [21,22]. Impaired venous drainage and reduced cerebral perfusion both play a role in the cause of cerebral desaturation in the prone position, which in turn leads to inadequate cerebral oxygenation [25].

Cerebral oxygenation can be impacted by these interventions when the head is raised off the head support or rotated to the left or right in the prone position. The median value of the measured rScO2 considerably increased by 3 to 5 units when the head was raised from the head support. The lifting of the head may have relieved the pressure on the tissue sensors, which is why this may happen. In addition to this, when the head was moved to the left or right, it dropped on the opposite side. The decrease in brain oxygenation to the contralateral side when the head is shifted to the left or right may be attributed to a decrease in blood flow in the contralateral vertebral artery[26].

Lateral Decubitus

Although the lateral decubitus position is preferred in thoracic surgeries where one-lung ventilation is applied, it is also preferred in shoulder surgeries. When the effect of two different positions on cerebral oxygenation was examined in patients operated on under general anaesthesia in the beach chair position (BCP) and the lateral decubitus position (LDP), the percentage of patients with cerebral desaturation events was significantly higher in the BCP group [12,27]. These studies collectively indicate that the lateral decubitus position may have a more favourable effect on cerebral oxygenation compared to the beach chair position.

On the other hand, the situation is a little bit different in thoracic surgery, where one-lung ventilation is performed. A decline in cerebral oxygenation occurs in thoracic surgery after positioning, although it may not be clinically significant, and it increases when one-lung ventilation (OLV) is switched. During OLV, the collapsed lung receives a hypoxic gas mixture, resulting in atelectasis and ventilation-perfusion mismatch. This decreased oxygen delivery can lead to hypoxemia, which can subsequently impair cerebral oxygenation. Also, It leads to increased airway pressures and decreased lung compliance. This can decrease venous return, potentially compromising cardiac output and cerebral blood flow. These changes in cerebral oxygenation may be caused by intrapulmonary shunts, hypoxia, and hypercarbia that develop during one-lung ventilation [28-30].

Table 1: Identification cerebral desaturation events.

Author	Year	Definitionof CDE	Definitionof Baseline
Aguirre et al [14]	2016	rScO2 value decrease of ≥20% from baseline	Postoxygenation/preinduction
Aguirre et al [47]	2018	rScO2 value decrease of ≥20% from baseline	Postoxygenation/preinduction
Cox et al [51]	2017	Decrease in rSO2 of 20% or greater from baseline or an absolute rSO2 <55%	Preoxygenation/upright
Hayashi et al [45]	2022	rSO2 values decreased 20% of the baseline value or when the absolute rSO2 values were <50%	Pre OLV
Murphy et al [27]	2014	2-min time interval with a ≥20% decrease in SctO2 from baseline values	Preinductions;no details of oxygenation
Woo et al [50]	2018	Decrease in rSO2 of 20% or greater from baseline for 15s or more in either hemisphere of the brain	Postinduction/presitting
Koh et al [11]	2013	SctO2 decreased ≥20% from baseline awake values or SctO2 ≤55%	Preinduction
Doe et al [44]	2016	SctO2 decreased ≥30%	Before surgery
Hayashi et al [49]	2017	Decrease of ≥20% from the baseline rSO2 value or an absolute rSO2 value of <50%	Postinduction/presitting
Picton et al [43]	2015	Absolute rSo2 value < 55% or a decrease from baseline of ≥ 20% sustained for ≥ 3 min	Preoperative holding room (Room air)
Jeong et al [50]	2012	Decline in SctO2 more than 20% from baseline for more than 15 s	Preinduction

Trendelenburg

The Trendelenburg position is widely used in laparoscopic and robotic surgeries and involves placing the patient in a head-down tilt to facilitate visualisation of the surgical field. The potential effects of this position on cerebral oxygenation have been a subject of interest in recent years. The Trendelenburg position leads to increased intracranial pressure with elevated mean arterial pressure (MAP) and central venous pressure, resulting in a downward trend in cerebral perfusion pressure [31]. Another reason is that the position increases the pressure in the abdomen, which can compress the inferior vena cava (IVC). IVC compression decreases venous return to the heart, which can lead to decreased cerebral blood flow and decreased cerebral oxygenation. The elevation of the angle of the Trendelenburg position results in an exacerbated occurrence of this effect, resulting in a reduction in cerebral saturation [32,33].

The combined effect of the Trendelenburg position and carbon dioxide (CO2) pneumoperitoneum has been shown to impact cardiovascular, cerebrovascular, and respiratory homeostasis during robotic prostatectomy. Furthermore, the creation of a pneumoperitoneum and placement in a Trendelenburg position may lead to a significant increase in intracranial pressure (ICP), potentially affecting patients with cerebral ischemia or cerebrovascular disorders [31,34–37].

The effects of Trendelenburg position on cerebral oxygenation may vary depending on several factors, such as the angle of the position, and the patient's underlying medical conditions.

Reverse Trendelenburg

The reverse trendelenburg position is generally preferred in endoscopic sinus surgery because it reduces bleeding and venous congestion, thus providing a better view of the surgical field [38]. In a

manner akin to the seated posture, this position elicits a gravitational impact whereby the blood tends to accumulate in the peripheral regions of the body. As a result, there is a reduction in cardiac output, leading to a subsequent decline in the perfusion of the cerebral region. There appears to be a reduction in cerebral oxygenation, although it is not deemed clinically significant, as the angle of the position increases [39].

The impact of various surgical positions on cerebral oxygenation when considered collectively;

1) Cerebral oxygenation is altered in all surgical positions, whether clinically significant or not, and the most crucial clinical effect is seen in the seated position [10,12–14].

2) The maintenance of cerebral autoregulation is important for the prevention of cerebral hypoxia or cerebral desaturation. To achieve the desired outcome, it is imperative to uphold the mean arterial pressure above 60 mmHg [4,17,19,21].

3) The oxygenation of the brain decreases in anaesthetised patients. It is kept in mind that the administration of general anesthesia can potentially elicit unfavourable consequences on cerebral autoregulation [40–42].

4) Inhalation anesthetics have a more positive effect on cerebral oxygenation than i.v anesthetics. Propofol has both cerebrovascular and cardiovascular effects, which result in an enhanced negative impact on cerebral autoregulation [22,24,43]

5) The frequency of cerebral desaturation increases in patients with elderly and comorbidities [5,22,28,30].

6) Different definitions of cerebral desaturation in studies may not be sufficient to demonstrate the relationship between cerebral oxygenation and postoperative complications [11,14,43–46]. Thresholds, baseline measurements and time below threshold may have different effects or relationships on postoperative complications.

7) The position of the transducer for blood pressure measurement may cause inaccurate measurements and assessments during intra-operative patient monitoring using conventional hemodynamic monitoring methods. Particularly when in the seated position, placing the transducer at the level of the acoustic meatus yields a more precise evaluation of blood pressure, specifically in terms of reflecting the mean blood pressure at the cranial level [14,47,48]. In the seated position, it is necessary to make an arithmetic correction to the mean arterial pressure (MAP) measured at different locations to determine the blood pressure at the level of the brain. This correction involves adding 1 millimetre of mercury (mmHg) for every 1.35 centimetres of distance [10].

3. Conclusion

The cerebral oximetry is subject to alteration based on the positioning of the patient. Cerebral autoregulation plays a role as a crucial factor in the regulation of cerebral oxygenation. Knowledge of the effects of different surgical positions on cerebral oximetry may assist the anaesthetist in intraoperative patient follow-up. In addition, early recognition of cerebral desaturation and hypoxia may prevent adverse effects of postoperative neurological complications.

Limitations of the Study

The limitation of the study is small sample size.

Acknowledgement

None.

Conflict of Interests

The authors have no conflicts of interest to declare.

Financial Support

None.

Author Contributions

Concept, study design, conduct the study, data collection, analyze the data, literature rewiev, write the manuscript.

Ethical Approval

None.

Data sharing statement

None.

Consent to participate

None.

Informed Statement

None.

References

1. Bevegård S, Holmgren A, Jonsson B. The Effect of Body Position on the Circulation at Rest and During Exercise, with Special Reference to the Influence on the Stroke Volume. *Acta Physiol Scand.* 1960; 49(2–3):279-98.
2. Rozet I, Vavilala MS. Risks and Benefits of Patient Positioning During Neurosurgical Care. *Anesthesiol Clin.* 2007; 25(3):631.
3. Jöbsis FF. Noninvasive, Infrared Monitoring of Cerebral and Myocardial Oxygen Sufficiency and Circulatory Parameters. *Science.* 1977; 198(4323):1264-66.
4. Tosh W, Patteril M. Cerebral oximetry. *BJA Educ*. 201; 16(12):417-21.
5. Ali J, Cody J, Maldonado Y, Ramakrishna H. Near-Infrared Spectroscopy (NIRS) for Cerebral and Tissue Oximetry: Analysis of Evolving Applications. *J Cardiothorac Vasc Anesth.* 2022; 36(8):2758-66.
6. Fox E, Jöbsis-Vander Vliet FF, Mitnick MH. Monitoring cerebral oxygen sufficiency in anesthesia and surgery. *Adv Exp Med Biol*. 1985; 191:849-54.
7. Gelber PE, Reina F, Caceres E, Monllau JC. A comparison of risk between the lateral decubitus and the beach-chair position when establishing an anteroinferior shoulder portal: a cadaveric study. *Arthroscopy*. 2007; 23(5):522-28.
8. Skyhar MJ, Altchek DW, Warren RF, Wickiewicz TL, O'Brien SJ. Shoulder arthroscopy with the patient in the beach-chair position. *Arthroscopy*. 1988; 4(4):256-59.
9. Peruto CM, Ciccotti MG, Cohen SB. Shoulder

arthroscopy positioning: lateral decubitus versus beach chair. *Arthroscopy*. 2009; 25(8):891-96.
10. Pohl A, Cullen DJ. Cerebral ischemia during shoulder surgery in the upright position: a case series. *J Clin Anesth.* 2005; 17(6):463-69.
11. Koh JL, Levin SD, Chehab EL, Murphy GS. Neer Award 2012: Cerebral oxygenation in the beach chair position: a prospective study on the effect of general anesthesia compared with regional anesthesia and sedation. *J Shoulder Elb Surg*. 2013; 22(10):1325-31.
12. Murphy GS, Szokol JW, Marymont JH, et al. Cerebral oxygen desaturation events assessed by near-infrared spectroscopy during shoulder arthroscopy in the beach chair and lateral decubitus positions. *Anesth Analg.* 2010; 111(2):496-505.
13. Salazar D, Sears BW, Aghdasi B, Only A, Francois A, Tonino P, et al. Cerebral desaturation events during shoulder arthroscopy in the beach chair position: patient risk factors and neurocognitive effects. *J Shoulder Elb Surg.* 2013; 22(9):1228-35.
14. Aguirre JA, Märzendorfer O, Brada M, Saporito A, Borgeat A, Bühler P. Cerebral oxygenation in the beach chair position for shoulder surgery in regional anesthesia: impact on cerebral blood flow and neurobehavioral outcome. *J Clin Anesth.* 2016; 35:456-64.
15. Rains DD, Rooke GA, Wahl CJ. Pathomechanisms and complications related to patient positioning and anesthesia during shoulder arthroscopy. *Arthroscopy*. 2011; 27(4):532-41.
16. Soeding P. Effects of Positioning on Cerebral Oxygenation. *Curr Anesthesiol Rep.* 2013; 3(3):184-96.
17. Smelt WL, de Lange JJ BL. Cardiorespiratory effects of the sitting position in neurosurgery. *Acta Anaesthesiol Belg*. 1988; 39(4):223-31.
18. Armstead WM. Cerebral Blood Flow Autoregulation and Dysautoregulation. *Anesthesiol Clin*. 2016; 34(3):465-77.
19. Rains DD, Rooke GA, Wahl CJ. Pathomechanisms and complications related to patient positioning and anesthesia during shoulder arthroscopy. *Arthroscopy*. 2011; 27(4):532-41.
20. Silverman A, Petersen NH. Physiology, Cerebral Autoregulation. StatPearls. 2023.
21. Babakhani B, Heroabadi A, Hosseinitabatabaei N, et al. Cerebral Oxygenation Under General Anesthesia Can Be Safely Preserved in Patients in Prone Position: A Prospective Observational Study. *J Neurosurg Anesthesiol*. 2017; 29(3):291-17.
22. Deiner S, Chu I, Mahanian M, Lin HM, Hecht AC, Silverstein JH. Prone Position Is Associated with Mild Cerebral Oxygen Desaturation in Elderly Surgical Patients. *PLoS One.* 2014; 9(9):e106387.
23. Jha A, Chen F, Mann S, Shah R, Abu-Youssef R, Pavey H, et al. Physiological effects and subjective tolerability of prone positioning in COVID-19 and healthy hypoxic challenge. *ERJ Open Res.* 2022; 8(1): 00524-2021.
24. Dell'Anna AM, Carelli S, Cicetti M, Stella C, Bongiovanni F, Natalini D, et al. Hemodynamic response to positive end-expiratory pressure and prone position in COVID-19 ARDS. *Respir Physiol Neurobiol*. 2022; 298:103844.
25. Closhen D, Engelhard K, Dette F, Werner C, Schramm P. Changes in cerebral oxygen saturation following prone positioning for orthopaedic surgery under general anaesthesia. *Eur J Anaesthesiol.* 2015; 32(6):381-86.
26. Andersen JDH, Baake G, Wiis JT, Olsen KS. Effect of head rotation during surgery in the prone position on regional cerebral oxygen saturation: A prospective controlled study. *Eur J Anaesthesiol*. 2014; 31(2):98-103.
27. Murphy GS, Szokol JW, Avram MJ, Greenberg SB, Shear TD, Vender JS, et al. Effect of ventilation on cerebral oxygenation in patients undergoing surgery in the beach chair position: A randomized controlled trial. *Br J Anaesth.* 2014; 113(4):618-27.
28. Zhang CJ, Ma JH, Jin F, Li XH, Jia HQ, Mu DL. Effect of one-lung ventilation on the correlation between left and right cerebral saturation. *BMC Anesthesiol*. 2023; 23(1):1-9.
29. Kübra T, Arslan G, Geyik FD, Akın C, Demirhan R, Cevik B. The Effect of One-Lung Ventilation on Cerebral Oxygenation and Neurocognitive Functions. *GKDA Derg.* 2022; 28(1):7-14.
30. Tobias JD, Johnson GA, Rehman S, Fisher R, Caron N. Cerebral oxygenation monitoring using near infrared spectroscopy during one-lung ventilation in adults. *J Minim Access Surg*. 2008; 4(4):104.
31. Schramm P, Treiber AH, Berres M, Pestel G, Engelhard K, Werner C, et al. Time course of cerebrovascular autoregulation during extreme Trendelenburg position for robotic-assisted prostatic surgery. *Anaesthesia*. 2014; 69(1):58-63.
32. Lee JR, Lee PB, Do SH, Jeon YT, Lee JM, Hwang JY, et al. The Effect of Gynaecological Laparoscopic Surgery on Cerebral Oxygenation. *J Int Med Res.* 2006; 34:531-36.
33. Wiesinger C, Schoeb DS, Stockhammer M, et al. Cerebral oxygenation in 45-degree trendelenburg position for robot-assisted radical prostatectomy: a single-center, open, controlled pilot study. BMC Urol. 2020; 20(1): 198.
34. Kim YJ, Chung RK, Kim DY, Kim YJ, Kim JH, Han JI. The effect of Trendelenburg position and pneumoperitoneum on regional cerebral oxygen saturation during gynecological laparoscopic surgery. *Anesth Pain Med.* 2012; 7(2):174-77.
35. Özgün A, Sargin A, Karaman S, Günüşen İ, Alper I, Aşkar FZ. The relationship between the Trendelenburg position and cerebral hypoxia inpatients who have undergone robot-assisted hysterectomy and prostatectomy. *Turk J Med Sci.* 2017; 47(6):1797-803.
36. Park EY, Koo BN, Min KT, Nam SH. The effect of pneumoperitoneum in the steep Trendelenburg

position on cerebral oxygenation. *Acta Anaesthesiol Scand.* 2009; 53(7): 895-99.
37. Kalmar AF, Foubert L, Hendrickx JFA, Mottrie A, Absalom A, Mortier EP, et al. Influence of steep Trendelenburg position and CO2 pneumoperitoneum on cardiovascular, cerebrovascular, and respiratory homeostasis during robotic prostatectomy. *Br J Anaesth.* 2010; 104(4):433-39.
38. Heller JA, Demaria S, Govindaraj S, et al. Cerebral oximetry monitoring during sinus endoscopy. *Laryngoscope*. 2015; 125(4):E127-31.
39. Yang W, Wang G, Li H, et al. The 15° reverse Trendelenburg position can improve visualization without impacting cerebral oxygenation in endoscopic sinus surgery-A prospective, randomized study. *Int Forum Allergy Amp; Rhinol.* 2021; 11(6):993-1000.
40. Shilpakar O, Karki B, Rajbhandari B. Amitraz poisoning-tale of an unusual pesticide poisoning: A case report. *J Nepal Med Assoc.* 2020; 58(225):338-40.
41. O'Grady JG, Schalm SW, Williams R. Acute liver failure: redefining the syndromes. *Lancet* 1993; 342(8866):273-75.
42. Carvounis CP, Feinfeld DA. A simple estimate of the effect of the serum albumin level on the anion gap. *Am J Nephrol.* 2000;20(5):369-72.
43. Picton P, Dering A, Alexander A, et al. Influence of Ventilation Strategies and Anesthetic Techniques on Regional Cerebral Oximetry in the Beach Chair Position: A Prospective Interventional Study with a Randomized Comparison of Two Anesthetics. *Anesthesiology*. 2015; 123(4):765-74.
44. Doe A, Kumagai M, Tamura Y, Sakai A, Suzuki K. A comparative analysis of the effects of sevoflurane and propofol on cerebral oxygenation during steep Trendelenburg position and pneumoperitoneum for robotic-assisted laparoscopic prostatectomy. *J Anesth.* 2016; 30(6):949-55.
45. Hayashi K, Yamada Y, Ishihara T, Tanabe K, Iida H. Comparison of regional cerebral oxygen saturation during one-lung ventilation under desflurane or propofol anesthesia: A randomized trial. *Medicine.* 2022; 101(41): e30030.
46. Jeong H, Jeong S, Lim HJ, Lee J, Yoo KY. Cerebral oxygen saturation measured by near-infrared spectroscopy and jugular venous bulb oxygen saturation during arthroscopic shoulder surgery in beach chair position under sevoflurane-nitrous oxide or propofol-remifentanil anesthesia. *Anesthesiology*. 2012; 116(5):1047-56.
47. Aguirre J, Borgeat A, Trachsel T, Cobo del Prado I, De Andrés J, Bühler P. Cerebral oxygenation in patients undergoing shoulder surgery in beach chair position: comparing general to regional anesthesia and the impact on neurobehavioral outcome. *Rev Esp Anestesiol Reanim.* 2014; 61(2):64-72.
48. Kocaoglu B, Ozgen SU, Toraman F, Karahan M, Guven O. Foreseeing the danger in the beach chair position: Are standard measurement methods reliable? *Knee Surg Sports Traumatol Arthrosc.* 2015; 23(9):2639-44.
49. Hayashi K, Tanabe K, Minami K, Sakata K, Nagase K, Iida H. Effect of blood pressure elevation on cerebral oxygen desaturation in the beach chair position. *Asian J Anesthesiol*. 2017; 55(1):13-16.
50. Woo JH, Kim YJ, Jeong JS, Chae JS, Lee YR, Chon JY. Compression stockings reduce the incidence of hypotension but not that of cerebral desaturation events in the beach-chair position: a randomized controlled trial. *Korean J Anesthesiol.* 2018; 71(2):127-34.
51. Cox RM, Jamgochian GC, Nicholson K, Wong JC, Namdari S, Abboud JA. The effectiveness of cerebral oxygenation monitoring during arthroscopic shoulder surgery in the beach chair position: a randomized blinded study. *J shoulder Elb Surg.* 2018; 27(4):692-700.