Measuring Optic Nerve Sheath Diameter with Bedside Ocular Ultrasonography in Patients with Carbon Monoxide Poisoning

Halil Kaya*, Esra Aşkın Baş†, Zülfi Engindeniz*, Sibel Gafuroğulları*,
Dilek Durmaz*, Mahmut Fırat Kaynak‡

Objective: To investigate the relationship between optic nerve sheath diameter (ONSD) and clinical and carboxyhemoglobin levels in patients with carbon monoxide poisoning.

Material and methods: This prospective cross-sectional study enrolled 55 consecutive adult patients with carbon monoxide poisoning. The demographic and clinical characteristics of the patients and the diameters of the optic nerve sheaths of both eyes of those patients at the time of admission and at the 6th hour after receiving 100% oxygen therapy and/or hyperbaric oxygen therapy were determined. The ages, genders, arterial blood pressure values, symptoms, carboxyhemoglobin levels, and bilateral ONSD values (measured sonographically before and after the oxygen therapy) of the patients were recorded in a data collection form.

Results: Measurements of ONSD before and after treatment were observed significantly (P = .01). Significant decreases were observed in ONSDs after treatment (P < .05). However, no significant difference was observed between ONSDs at the time of admission and after the treatment of patients receiving 2-hour single-session hyperbaric oxygen therapy and 100% oxygen therapy with a reservoir mask (P > .05).

Conclusion: The changing of ONSD, which is an indirect indicator of increased intracranial pressure, is a promising method to use at emergency service for patients with carbon monoxide poisoning. [*P R Health Sci J 2021;40:180-184*]

Key words: Carbon monoxide, Poisoning, Optic nerve, Diameter, Ultrasonography

Carbon monoxide (CO) is a gas that is odorless, colorless, tasteless, and non-irritating; it is a product of the incomplete combustion of carbonaceous compounds (1). Carbon monoxide poisoning in humans is most often caused by the inhalation of factory gases, exhaust fumes, or smoke from a fire (wood or coal) or the use of water heaters in poorly ventilated areas (1). Carbon monoxide intoxication, which especially increases in the cold winter months, is a major social health problem in the world (1). It ranks first among the causes of death due to poisoning in the United States (1,2). It has been reported as the most common cause of poisoning resulting in death (31%) in Turkey (3).

Since the ability of CO to bind to hemoglobin is 200–300 times higher than that of oxygen, the blood oxygen content decreases, and the formed carboxyhemoglobin (COHb) causes tissue hypoxia, resulting in reduced oxygen delivery to the tissues. In CO poisoning, the toxic effects are high in hypoxia-sensitive tissues, especially those of the brain and heart. Tissue hypoxia predisposes the patient to brain edema by increasing cerebral blood flow, cerebrospinal fluid pressure, and cerebral capillary permeability (4).

The optic nerve is a central nervous system structure that is wrapped by a dural sheath. The optic nerve has a direct anatomic relationship with the intracranial subarachnoid space (4). Optic nerve sheath diameter (ONSD) increased in parallel with intracranial pressure (ICP) elevation has been shown to correlate well with other indicators of ICP elevation (4). Recent studies show that the measurement of ONSD by ultrasound is indirectly an indicator of ICP (5).

Although elevated intraparenchymal or intraventricular pressure is the best indicator of an increase in ICP, detecting this kind of elevation of pressure requires invasive and painful procedures; there are a number of studies in the literature indicating that ONSD can be evaluated noninvasively, thus making the (indirect) detection of elevated ICP easier to accomplish. The results—which are promising—are consistent

*Sağlık Bilimleri University, Faculty of Medicine, Department of Emergency Medicine, Yüksek İhtisas Training and Research Hospital, Bursa, Turkey MD; †Yunus Emre State Hospital, Department of Emergency Medicine, Eskişehir, Turkey MD; ‡Sağlık Bilimleri University, Faculty of Medicine, Department of Emergency Medicine, Kayseri Training and Research Hospital, Kayseri, Turkey MD

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Address correspondence to: Prof. Dr. Halil Kaya, Sağlık Bilimleri University, Faculty of Medicine, Department of Emergency Medicine, Yüksek Ihtisas Training and Research Hospital, Bursa, Turkey. Email: drhalilkaya@gmail.com

with those found when the levels of ICP were measured invasively (6,7). It is advantageous to use noninvasive methods in terms of cost reduction and repeatability. There is no definite and agreed-upon cut-off value regarding what would be considered a "normal" ONSD value, possibly because it is dependent on the technical experience of the operator. However, there are various studies that have explored the issue (8,9).

Optic nerve sheath diameter measurement is an increasingly used investigated tool in many conditions that are marked by ICP increases; there are many studies evaluating the relationship of the 2 (ONSD and elevated ICP) in the literature; however, to the best of our knowledge, this study is the first to assess the connection of ONSD and CO poisoning. In the present study, we aimed to investigate the relationship between ONSD and clinical and COHb levels in patients with CO poisoning. After receiving 100% oxygen therapy and/or hyperbaric oxygen therapy, the ONSDs of the patients with CO poisoning were reevaluated.

Materials and methods

Study design and setting

This study was conducted in accordance with the 1989 Declaration of Helsinki and was approved by the Ethics Committee of Bursa Higher Education Training and Research Hospital. (No.: KAEK-25 2015/23-10)

From December 2015 through February 2016, 55 patients who were admitted to the Bursa Higher Education Training and Research Hospital Emergency Department with CO poisoning were examined prospectively.

Procedures

Patients suspected of suffering from CO poisoning who were 18 years of age or over and who had 10% and above venous blood gas COHb values were included in the study. The ages, genders, arterial blood pressure values, clinical symptoms, COHb levels, and bilateral ONSD values of (measured sonographically before and after the oxygen therapy) of the patients were recorded in the data collection form.

Patients suspected of suffering from CO poisoning but who were younger than 18 years of age and who had any kind of eye trauma that might interfere with ultrasonograhpy, any known glaucoma, orbital neoplasms, orbital abscesses and ophthalmic artery pathologies, hypertension, diabetes mellitus, heart failure, intracranial space occupying lesions, or were smokers were excluded from the study.

Measurements

A standard ultrasonography (USG) device with 12 MHZ and 5 MHZ linear variable frequency probes was used to perform the ONSD measurement. We used the Hitachi Aloka F31, and the measurements were made by 2 emergency medicine specialists and 2 emergency medical assistants who had completed 2 years of training and had specific USG experience. Carboxyhemoglobin values were measured with venous blood, and each patient was subjected to an orbital USG examination in a supine position, with his or her eyes closed and a thin layer of gel applied to the face. The optic nerve was seen in both eyes by scanning the vertical and horizontal planes. Each evaluation was made by measuring sagittally and transversely from 3 mm distal to the area between the hyperechoic dural sheaths located at the edge of the hypoechoic subarachnoid space surrounding the optic nerve. The ONSDs were determined at the time of admission and at the 6th hour after the respective treatment.

Statistical analysis

The program SPSS 22.0 (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.) was used for the statistical evaluations. In addition to descriptive statistical methods (mean, standard deviation, frequency), Student's t-test was used for the quantitative data analysis to compare the variables between the 2 groups showing standard deviations. Significance was evaluated as $P < .05$.

Results

During the period of the study, 31 (56.4%) women and 24 (43.6%) men (for a total of 55 patients) diagnosed with CO poisoning were included in the study.

The ages of the patients ranged from 18 to 68 years, and the mean age was found to be 32.67 years. Arterial pressure values of above 130/80 mmHg on admission were considered to be hypertension; in the present study, 4 (7.3%) of the patients had hypertension. The demographic and clinical characteristics of the 55 patients with CO poisoning can be seen in Table 1.

Carbon monoxide exposure times ranged from 30 minutes to 10 hours, and the average exposure time was 4.76 hours; 1 (1.8%) patient was pregnant.

Table 1. Demographic and clinical characteristics of 55 patients with carbon monoxide poisoning

Gender	**n**	**(%)**
Male	24	43.6
Female	31	56.4
Mean age (years), range	32.67	18–68
Mean CO exposure time (hours), range	4.76	0.5–10
Clinical findings	**n**	**(%)**
Hypertension	4	7.3
Nausea, vomiting	25	45.5
Headache	38	69.1
Dizziness	21	38.2
Syncope	12	21.8
Mean COHb value (%), range		
During the application	26.95	14–47.2
After treatment	4.2	0–9.2

At the time of admission, COHb values ranged from 14% to 47.2%, with an average of 26.95%. Post-treatment COHb levels ranged from 0% to 9.2%, with an average of 4.2%.

Twenty-five patients (45.5%) complained of nausea and vomiting, 38 patients (69.1%) complained of headache, 21 patients (38.2%) complained of dizziness, and 12 patients (21.8%) complained of syncope.

Of the 14 (25.5%) patients who received hyperbaric oxygen therapy, 6 (10.9%) had COHb value of over 30%. Five (9.1%) patients had syncope, 1 (1.8%) was pregnant, and 2 (3.6%) had COHb values of over 30% and syncope, both.

Optic nerve sheath diameters ranged from 2.81 mm to 6.16 mm for the right eyes (average: 4.38 mm) and from 2.98 mm to 7.0 mm for the left eyes (average: 4.42 mm) at the time of admission. After treatment, the ONSDs for the right eyes ranged from 2.54 mm to 5.39 mm (average: 3.87 mm), while those for the left eyes ranged from 2.66 mm to 5.45 mm (average: 3.94 mm), which was found to be statistically significant (P = .01). Evaluations of the right- and left-eye ONSDs at the first application and after treatment are seen in Figure 1.

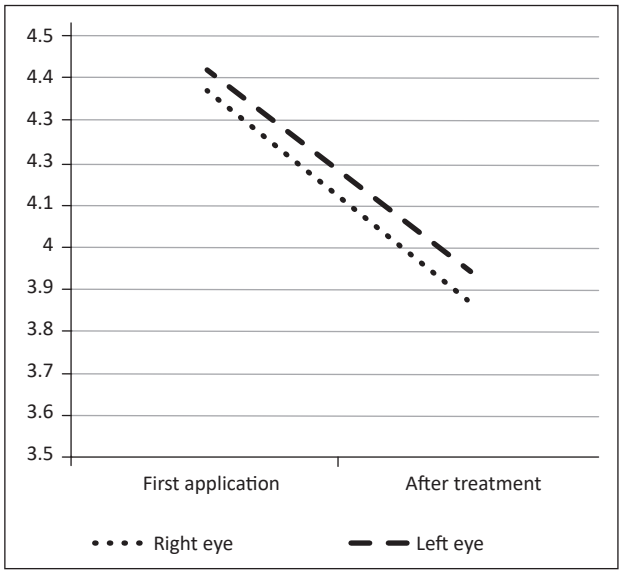


Figure 1. Evaluation of right- and left-eye ONSDs at the first application and after treatment.

The patients receiving 2-hour single-session hyperbaric oxygen therapy and 100% oxygen therapy with a reservoir mask were found to have average ONSDs of 4.48 mm and 4.35 mm, respectively, in the right eye and 4.57 mm and 4.37 mm, respectively, in the left eye at the time of admission. Six hours after treatment, the right-eye ONSDs were found to be 4.07 mm and 3.81 mm, respectively, and the left-eye ONSDs were found to be 4.13 mm and 3.87 mm, respectively. There was no statistically significant difference (P > .05). The distribution of the mean values of right- and left-eye ONSDs before and after treatment (according to treatment methods) can be seen in Figure 2.

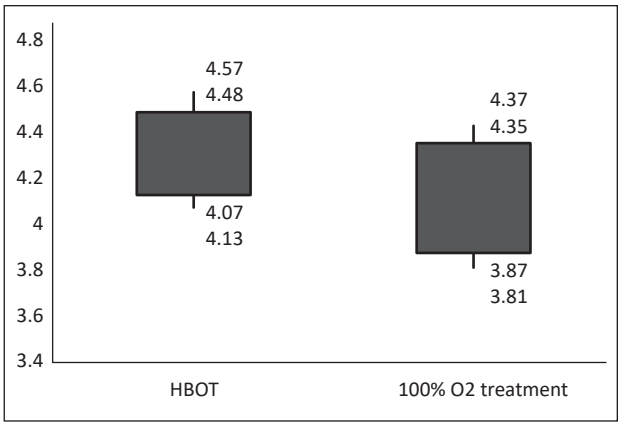


Figure 2. Distribution of mean values of right- and lefteye ONSDs before and after treatment, according to treatment method.

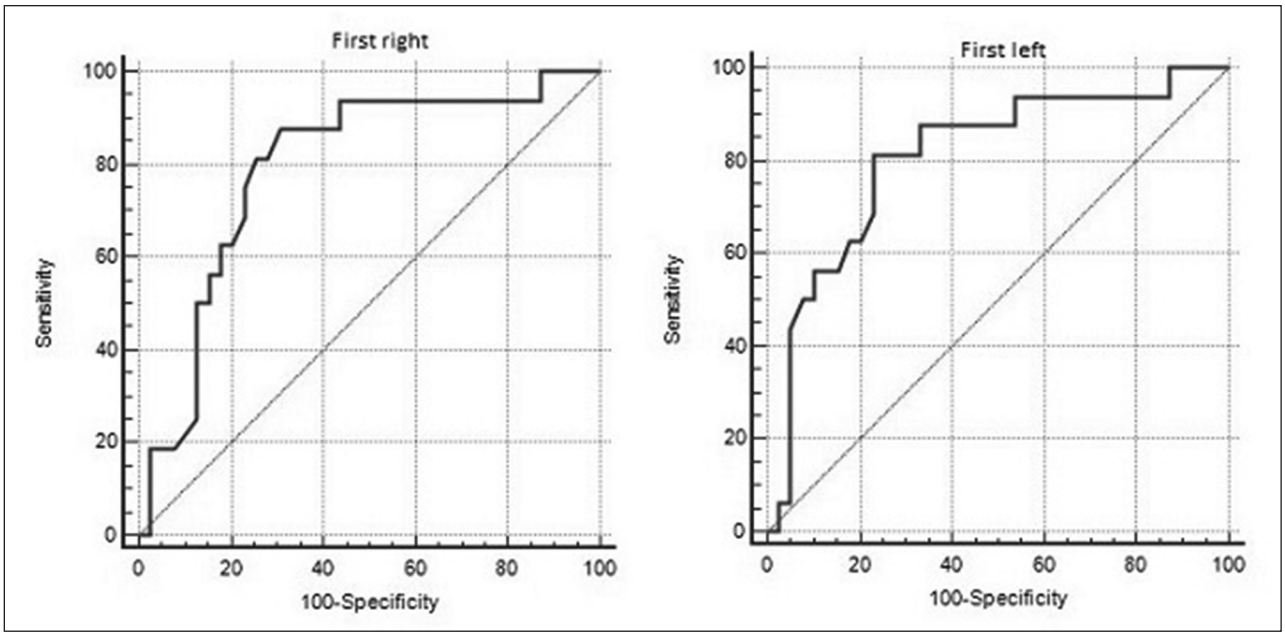
When the patients with COHb values of 30% or higher were evaluated as severe CO poisoning, sensitivity was 87.5% when the right-eye ONSD was greater than 4.39 mm and 81.25% when the left-eye ONSD was greater than 4.66 mm at the time of the admission. There was no significant difference between the right- and left-eye measurements (P > .05). The receiver operating characteristic curve of ONSD for COHb was 30% or greater, and the areas under the curve were 87.5% and 81.25% (Figures 3 and 4).

Discussion

The diameter of the optic nerve sheath have been reported as being a candidate tool to diagnose and monitor patients with elevated ICP (10,11). Ertl et al., in a study of patients with hydrocephalus, reported that ONSD increased in parallel with an increase in cerebrospinal fluid (CSF) volume and that ONSD significantly dropped upon CSF drainage (12).

To our knowledge, this is the first study to evaluate a patient's clinical condition by measuring ONSD in suspected CO poisoning. In CO poisoning, the oxygen content of the blood decreases and hypoxia develops because of decreased oxygen delivery to the tissues due to the formation of COHb (13). At the mitochondrial level, cellular respiration is disturbed, anaerobic respiration increases, and lactic acidosis and cell death occur (14). As a result of hypoxia developing in the brain tissue, cerebral blood flow, cerebrospinal fluid pressure, and cerebral capillary permeability increase; brain edema is provoked, and injury may occur (13,14) There is no correlation between clinical symptoms, morbidity and mortality, and COHb values, and new methods are needed (13,14).

Ultrasonography can be performed easily at the bedside in the emergency department and intensive care units and can be used to evaluate ICP, noninvasively; it has been reported that USG outcomes correlate well with invasive measurements of ICP (15,7). The results of different studies done on healthy populations are similar, finding a mean ONSD of 3.45 mm (8,16,17). Ballantyne et al. evaluated 67 adults in the UK,



Figures 3 and 4. Receiver operating characteristic curve of ONSD for COHb ≥ 30%. The areas under the curve are 87.5% and 81.25%.

and the ONSDs of these patients ranged from 2.4 to 4.7 mm (mean = 3.2 to 3.6 mm) (17). Soldatos et al. studied 26 Greek nationals whose ONSDs ranged from 2.2 to 4.9 mm (mean = 3.6 mm) (17). Lijuan Wang et al. analyzed 230 participants whose ONSDs ranged from 2.65 to 4.30 mm (mean = 3.45 mm) (8). Apart from these, higher mean values and ONSD intervals were reported in Iran (mean = 4.6 mm; 3.8 – 5.4 mm) (15), in Bangladesh (mean = 4.41 mm; 4.24 – 4.83 mm) (18) and in Italy mean = 5.4 mm; 4.3 – 7.6) (19). The authors found the values of ONSD as 4.6 mm for women and 4.8 mm for men and showed that these cut-off values have a high sensitivity and specificity in patients with increased ICP diagnosis on computed tomography and magnetic resonance imaging (20,21). In the present study, patients with CO poisoning were found to have right-eye ONSDs of 2.81 to 6.16 mm (mean = 4.38 mm) and left-eye ONSDs of 2.98 to 7.0 mm (mean = 4.42 mm), at the time of admission. Although we did not identify any study that provided sensitivity and specificity values for ONSD in CO poisoning, one study examining the relationship between ICP increase and ONSD revealed a sensitivity of 88% and a specificity of 93%, with a cut-off value of 5 mm; another found a sensitivity of 74% and a specificity of 100%, with a cut-off value of 5.7 mm. (17,22). In other studies on this subject, sensitivity was reported to be 74 to 98.6%, and specificity, 65 to 92.8% (23,24).

In the present study, when 16 patients with COHb values of 30% (indicative of severe CO poisoning) or more were evaluated, their mean right- and left-eye ONSDs at the time of admission were 4.84 and 4.94 mm, respectively. There was no significant difference between right- and left-eye measurements. It may be thought that the reason for this is the diffuse effect of the CO poisoning on the brain. For this reason, single-eye measurements may be sufficient for patients with CO poisoning.

There was a significant decrease in ONSDs after treatment ($P < .05$). There was no significant difference between treatment modalities and ONSDs in patients with CO poisoning and in whom the regression of clinical symptoms was considered to be sufficient in terms of treatment efficacy. While ONSD was greater in patients who had symptoms prior to treatment, we believe that the symptoms regressed as a result of the reduction of ICP that accompanied the administered therapy. We also suggest that ONSD was greater in the presence of the symptoms of elevated ICP caused by CO poisoning.

Limitations

The study had several limitations: the number of patients, the admission into the study of patients with relatively mild clinical presentation (of CO poisoning), the fact that there is no gold standard test (CT/invasive ICP measurement) to show increases in ICP, the fact that there was no assessment of the pressure applied by the operator doing the measuring, and the fact that there is no standardization with regard to ONSD. In addition, this was single-center study; thus, its results are not generalizable.

Conclusion

This is the first study to evaluate a patient's clinical condition by measuring ONSD in suspected CO poisoning. The measurements made before and after the respective treatments show there to have been significant decreases in the ONSDs of the patients. The changing of ONSD, which is an indirect indicator of increased ICP, is a promising method to use at emergency service for patients with CO poisoning. In this regard, it may be possible that it can be used in routine

applications with studies to be carried out with wider case series. Ultrasonic imaging of the ONSD (performed in the emergency department) appears to reflect changes that are consistent with ICP changes in CO poisoning and changes in COHb level.

References

1. Ernst A, Zibrak JD. Carbon monoxide poisoning. N Engl J Med. 1998;339(22):1603-1608. doi:10.1056/NEJM199811263392206
2. Cobb N, Etzel RA. Unintentional carbon monoxide-related deaths in the United States, 1979 through 1988. JAMA. 1991;266(5):659-663.
3. Başar L. Türkiye'de zehirlemelere bağlı ölüm olgularının profili [The profiles of the deaths due to poisoning in Turkey]. Specialization thesis. Adalet Bakanlığı Adli tıp Kurumu Başkanlığı/Ministry of Justice Forensic Medicine Institute, İstanbul; 2000.
4. Sekhon MS, McBeth P, Zou J, et al. Association between optic nerve sheath diameter and mortality in patients with severe traumatic brain injury. Neurocrit Care. 2014;21(2):245-252. Doi:10.1007/s12028-014-0003-y
5. Frattalone AR, Stevens RD. Intracranial pressure and its surrogates. Intensive Care Med. 2011;37(7):1051-1053. Doi:10.1007/s00134-011-2226-0
6. Strumwasser A, Kwan RO, Yeung L, et al. Sonographic optic nerve sheath diameter as an estimate of intracranial pressure in adult trauma. J Surg Res. 2011;170(2):265-271. Doi:10.1016/j.jss.2011.03.009
7. Cammarata G, Ristagno G, Cammarata A, Mannanici G, Denaro C, Gullo A. Ocular ultrasound to detect intracranial hypertension in trauma patients. J Trauma 2011;71:779-781.
8. Wang L, Feng L, Yao Y, et al. Ultrasonographic Evaluation of Optic Nerve Sheath Diameter among Healthy Chinese Adults. Ultrasound Med Biol. 2016;42(3):683-688. Doi:10.1016/j.ultrasmedbio.2015.11.020
9. Goeres P, Zeiler FA, Unger B, Karakitsos D, Gillman LM. Ultrasound assessment of optic nerve sheath diameter in healthy volunteers. J Crit Care. 2016;31(1):168-171. Doi:10.1016/j.jcrc.2015.10.009
10. Zeiler FA, Ziesmann MT, Goeres P, et al. A unique method for estimating the reliability learning curve of optic nerve sheath diameter ultrasound measurement. Crit Ultrasound J. 2016;8(1):9. Doi:10.1186/s13089-016-0044-x
11. Brain Trauma Foundation; American Association of Neurological Surgeons; Congress of Neurological Surgeons. Guidelines for the management of severe traumatic brain injury [published correction appears in J Neurotrauma. 2008 Mar;25(3):276-8]. J Neurotrauma. 2007;24 Suppl 1:S1-S106. Doi:10.1089/neu.2007.9999
12. Ertl M, Aigner R, Krost M, et al. Measuring changes in the optic nerve sheath diameter in patients with idiopathic normal-pressure hydrocephalus: a useful diagnostic supplement to spinal tap tests. Eur J Neurol. 2017;24(3):461-467. Doi:10.1111/ene.13225
13. Kao LW, Nañagas KA. Carbon monoxide poisoning. Med Clin North Am. 2005;89(6):1161-1194. Doi:10.1016/j.mcna.2005.06.007
14. Prockop LD. Carbon monoxide brain toxicity: clinical, magnetic resonance imaging, magnetic resonance spectroscopy, and neuropsychological effects in 9 people. J Neuroimaging. 2005;15(2):144-149. Doi:10.1177/1051228404273819
15. Amini A, Kariman H, Arhami Dolatabadi A, et al. Use of the sonographic diameter of optic nerve sheath to estimate intracranial pressure. Am J Emerg Med. 2013;31(1):236-239. Doi:10.1016/j.ajem.2012.06.025
16. Ballantyne SA, O'Neill G, Hamilton R, Hollman AS. Observer variation in the sonographic measurement of optic nerve sheath diameter in normal adults. Eur J Ultrasound. 2002;15(3):145-149. Doi:10.1016/s0929-8266(02)00036-8
17. Soldatos T, Karakitsos D, Chatzimichail K, Papathanasiou M, Gouliamos A, Karabinis A. Optic nerve sonography in the diagnostic evaluation of adult brain injury. Crit Care. 2008;12(3):R67. Doi:10.1186/cc6897
18. Maude RR, Hossain MA, Hassan MU, et al. Transorbital sonographic evaluation of normal optic nerve sheath diameter in healthy volunteers in Bangladesh [published correction appears in PloS One. 2014;9(1). Doi:10.1371/annotation/4e2f88bd-e836-4e0c-a3e0-f6062331702b]. PloS One. 2013;8(12):e81013. Published 2013 Dec 2. Doi:10.1371/journal.pone.0081013
19. Bäuerle J, Lochner P, Kaps M, Nedelmann M. Intra- and interobsever reliability of sonographic assessment of the optic nerve sheath diameter in healthy adults. J Neuroimaging. 2012;22(1):42-45. Doi:10.1111/j.1552-6569.2010.00546.x
20. Shirodkar CG, Munta K, Rao SM, Mahesh MU. Correlation of measurement of optic nerve sheath diameter using ultrasound with magnetic resonance imaging. Indian J Crit Care Med. 2015;19(8):466-470. Doi:10.4103/0972-5229.162465
21. Shirodkar CG, Rao SM, Mutkule DP, Harde YR, Venkategowda PM, Mahesh MU. Optic nerve sheath diameter as a marker for evaluation and prognostication of intracranial pressure in Indian patients: An observational study. Indian J Crit Care Med. 2014;18(11):728-734. Doi:10.4103/0972-5229.144015
22. Kimberly HH, Shah S, Marill K, Noble V. Correlation of optic nerve sheath diameter with direct measurement of intracranial pressure. Acad Emerg Med. 2008;15(2):201-204. Doi:10.1111/j.1553-2712.2007.00031.x
23. Karakitsos D, Soldatos T, Gouliamos A, et al. Transorbital sonographic monitoring of optic nerve diameter in patients with severe brain injury. Transplant Proc. 2006;38(10):3700-3706. Doi:10.1016/j.transproceed.2006.10.185
24. Goel RS, Goyal NK, Dharap SB, Kumar M, Gore MA. Utility of optic nerve ultrasonography in head injury. Injury. 2008;39(5):519-524. Doi:10.1016/j.injury.2007.09.029