The Importance of Optic Nerve Sheath Diameter in Post-dural Puncture Headache Diagnosis and Follow-up

Ahmet BEŞİR¹ , Oktay Faysal TERTEMİZ² , Ali AKDOĞAN¹ , Erdem Nail DUMAN¹

¹Anesthesiology and Reanimation, Karadeniz Technical University Faculty of Medicine, Trabzon, Turkey

²Department of Algology, Balıkesir Atatürk Hospital, Balıkesir, Turkey

ABSTRACT

Introduction: Intracranial hypotension-induced headache is caused by reduction in the volume or pressure of the cerebrospinal fluid. Headache might develop secondary to lumbar puncture. In the detection of intracranial hypotension, when compared with invasive methods, there is a good correlation between ultrasound-guided optic nerve sheath diameter (ONSD) and invasive methods. The aim of the study is to investigate the effectiveness of alteration in ultrasound-guided ONSD in diagnosis and treatment of post-dural puncture headache (PDPH) induced by intracranial hypotension.

Methods: Our study involved 40 adult patients aged 18-65 scheduled to have surgery under spinal anesthesia. Patients were randomized into two groups consisting of PDPH (Group H, n=20), and control (Group C, n=20) during their post-operative period. The ONSDs of patients were measured via ultrasound, pain severity with Numeric Rating Scale (NRS) pre-operatively, at 24th, 26th and 48th hours post-operatively. Conservative treatment was started on the 24th hour in PDPH group.

Results: There was no significant difference between the groups in terms of demographic data. In Group H, the reduction in ONSD from 3.8±0.2 to 3.2±0.3 mm in postoperative 24th hours (p=0.001) and an increase to 4.4±0.3 mm in postoperative 48th hours (p=0.03) were significant. When compared to postoperative 24th hours, ONSD in postoperative 26th (3.9±0.3 mm) and 48th hours (4.4±0.3 mm) were significantly higher (p=0.007 and p=0.01; respectively) in Group H. NRS values in Group H at postoperative 26th and 48th hours were significantly lower compared to postoperative 24th hours (p=0.001).

Conclusion: We believe that serial measurement of ultrasound-guided ONSD, which is considered a simple and non-invasive procedure in the determination of intracranial pressure changes, is a more objective method in the follow-up of intracranial hypotension-induced headache compared to NRS evaluation.

Keywords: Optic nerve sheath diameter (ONSD), intracranial hypotension, post-dural puncture headache (PDPH)

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INTRODUCTION

Regional anesthesia has become more common especially in gynecology, urology, and lower extremity surgeries (1). Post-dural puncture headache (PDPH) is one of the serious complications of spinal and epidural anesthesia with an incidence of 10-50% (2, 3). PDPH generally increases with laughing, coughing, jugular venous compression, and Valsalva maneuver; it is usually resistant to analgesic treatment. Headache might be accompanied with nausea, vomiting, neck ache, dizziness, horizontal diplopia, changes in hearing ability, tinnitus, numbness of face, and radicular symptoms in upper extremities (4). PDPH rarely emerges right after the dural puncture. In 60% of cases, the symptoms emerge within two days following dural puncture, whereas 90% manifest within three days, and even up to 14 days (5). In 2013, the International Headache Society (IHS) classified the low CSF-induced headache in the "headache attributed to non-vascular intracranial disorder" class in the beta version of international classification (ICHD-III) (6).

Pain guidelines indicate that pain should be regularly measured with appropriate pain measurement scales (1-7). Several scales are used in the assessment of pain. The numerical rating scale (NRS) is a 11-point

measure that most patients prefer, with 0 being the absence of pain and 10 being the worst possible pain (2-8).

In several clinical studies, intracranial pressure (ICP) has been monitored by both invasive and non-invasive methods (9-11). Lately, in systematic reviews and meta-analysis, a strong correlation has been shown between monitorization of ICP, and ultrasound of ONSD (12).

The optic nerve is a part of the nervous system surrounded by dural sheath. Intraorbital subarachnoid space pressure changes similar to the pressure changes in intracranial and lumbar compartments (13). Optic nerve sheath diameter can be measured using ultrasound, and magnetic resonance (14, 15). Changes in cerebrospinal fluid (CSF) pressure have been suggested to lead to changes in the anterior dural optic nerve due to the PDPH-induced cerebral hypotension, and can be measured via ONSD (16). Compared to invasive methods, USG-guided ONSD measurement is a non-invasive, reliable technique that simultaneously reflects the changes in ICP (17).

In this study, we aimed to evaluate the efficiency of ONSD, and compare with NRS in the diagnosis and follow-up of PDPH.

METHODS

A randomized, double-blind study was planned after obtaining the approval of local ethical committee. ASA I-III patients aged between 18 and 65, undergoing surgery under spinal anesthesia were included, and patients' informed consent was taken. Forty patients were randomized into two groups: headache (Group H; n=20) and control (Group C; n=20) based on the beta version of the international classification of headache (ICHD-III) (6). Exclusion criteria were defined as previously-known conditions that might lead to intracranial pressure change (cerebrovascular conditions, bleeding, intracranial tumor, etc.), psychiatric history, alcohol or substance addiction, multiple trauma, coagulopathy, and cerebral infarcts). Anesthesia was administered by the same team and with the same method.

Prior to spinal anesthesia, the optic nerve sheath diameter (ONSD) of both eyes were measured by anesthesiologists with least three years of experience using ultrasound, and taken as the basal value (T_0) (18, 19). Patients were told to close their eyes, and when in supine position their upper eyelids were covered with a thin layer of gel. A 7.5 MHz linear probe was placed on the pre-applied gel without exerting excessive pressure to monitor the optic nerve. Four measurements were performed on transverse and sagittal planes for each eye by blinded anesthesiologist, and mean value was recorded as final value (Fig. 1).

Intravenous hydration was provided for all patients for losses prior to spinal anesthesia. Following the administration of IV midazolam (0.03 mg/kg) and fentanyl (1 µg/kg) for sedation and analgesia, spinal anesthesia was performed at L3–4 or L4–5 interspace with a 25G spinal needle by at least two years experienced anesthesia doctors; 2.5 ml 0.5% hyperbaric bupivacaine was administered. The operation was started after sufficient sensorial and motor block.

Twenty-four hours after the operation, USG-guided ONSD measurement was performed, and pain scores were evaluated using NRS (0; no pain, 10; the most severe pain). At the postoperative 24th hour, if NRS >3 (Group H), IV 1000 mL 0.09% saline and 200 mg theophylline infusion was administered within two hours. At the end of treatment (T_{26}) NRS was repeated, and ONSD values were recorded. ONSD measurements and NRS evaluations were at the post-operative 48th (T_{48}) hour. The 26th hour measurements were not performed in the control group as they did not develop headache, or receive treatment.

Figure 1. Preoperative, postoperative 24th and 26th hours sample ONSD measurement.

ONSD: optic nerve sheath diameter
A: The site of ONSD measurement 3 mm behind the ocular globe
B: ONSD: optic nerve sheath diameter

Age, gender, body mass index (BMI), ASA, needle gauge, and number of lumbar puncture attempts were also recorded for each patient. All parameters were recorded by anesthesiologists not involved in the study.

Data was analyzed by the SPSS 23.0 (SPSS Inc, Chicago, USA) package. Descriptive statistical expressions (frequency, mean, standard deviation (SD)) were used. The chi-square test was used for the comparison of two groups. ANOVA and Bonferroni were used to compare intra-group parameters. Pearson's correlation analysis was used for comparisons between measurements. The results were evaluated within the 95% confidence interval and $p < 0.05$ was accepted as statistically significant.

RESULTS

There was no significant difference between groups in terms of age, gender, BMI, ASA, and number of lumbar puncture attempts (Table 1). The surgeries were inguinal hernia, arthroscopy and excision of varices.

In Group H, T_0 ONSD value was significantly higher compared to T_{24} (3.8 ± 0.2 mm vs. 3.2 ± 0.3 mm; $p = 0.001$, respectively). A significant increase was recorded in post-operative T_{26} ONSD value compared to T_{24} ONSD value (3.9 ± 0.3 mm vs. 3.2 ± 0.3 mm; $p = 0.007$, respectively). T_{48} ONSD value was significantly higher compared to T_{26} value (4.4 ± 0.3 mm vs. 3.9 ± 0.3 mm; $p = 0.01$, respectively). Besides, T_{48} ONSD value was significantly higher compared to the T_0 and T_{24} periods ($p = 0.03$ vs. $p = 0.01$, respectively) (Fig. 2).

Table 1. Demographic data

	Group C (n=20)	Group H (n=20)	P
Age (years)	36.15±6.47	36.10±7.12	0.98
Sex (F/M)	8/12	9/11	0.14
Weight (kg)	72.85±10.11	71.45±12.19	0.69
Height (cm)	166.55±6.21	165.70±6.55	0.67
BMI (kg/m ²)	26.23±3.14	26.12±4.86	0.93
ASA class (I/II)	13/7	15/5	0.27
Number of lumbar puncture attempts	1.2±0.41	1.35±0.48	0.30

Group C=Control Group; Group H=Headache Group. ASA: American Society of Anesthesiologists. BMI: body mass index. Mean±SD, $p < 0.05$

Figure 2. Comparison of ocular ONSD with USG measurements in Group H.

Figure 3. Comparison of post-treatment NRS measurements in Group H. NRS: numeric rating scale

Table 2. ONSD and NRS changes in the groups

	Group C (n=20)	Group H (n=20)	p
ONSD T ₀ (mm)	3.9±0.02	3.9±0.03	0.803 ^a
ONSD T ₂₄ (mm)	3.8±0.02	3.2±0.03	0.001 ^a
ONSD T ₂₆ (mm)	-	3.9±0.03	-
ONSD T ₄₈ (mm)	3.8±0.02	3.9±0.03	0.421 ^a
NRS T ₀ (0-10)	-	-	-
NRS T ₂₄ (0-10)	-	7.4±1.7	0.001 ^b
NRS T ₂₆ (0-10)	-	3.2±0.9	0.001 ^{bc}
NRS T ₄₈ (0-10)	-	0.9±0.8	0.466 ^a

Data are expressed as mean ± standard deviation.

ONSD: optic nerve sheath diameter, NRS: numeric rating scale.

^aONSD changes in both groups.

^bCompared with preoperative NRS changes in the group H.

^cCompared with 24th NRS changes in the group H.

Figure 4. Scatter plot graphic emphasized the negative significant correlation between NRS24 and ONSD24 values.

NRS values in Group H at T₂₆ and T₄₈ following spinal procedure were significantly lower when compared to T₂₄ hours (p=0.001). A significant reduction was observed in NRS values at T₄₈ compared to T₂₆ hours (p=0.001) (Fig. 3).

In Group C after spinal procedure, there was no significant difference in terms of ONSD measurements, and NRS values between T₀ and T₂₄ and T₄₈, as well as T₂₄ and T₄₈. Compared with group C (not experiencing headache following spinal anesthesia) ONSD value at T₂₄ was significantly lower (0.38±0.21 vs. 0.32±0.35, p<0.001, respectively), and NRS values at T₂₄ were significantly higher (0.00±0.00 vs. 7.45±1.70, p<0.001, respectively) in group H (having headache following spinal anesthesia). However, there was no significant difference among groups at T₄₈.

Statistically significant negative correlation was recorded for only NRS24 and ONSD24 values (r=-0.644, p<0.001) (Fig. 4).

DISCUSSION

In this study, we demonstrated that ONSD in patients with intracranial hypotension-induced headache is lower during the headache period, and then increased after treatment. We observed that the more the ONSD decreased, the more the NRS increased in headache patients.

Intracranial hypotension-induced headache is characterized generally with orthostatic headache. Orthostatic headache is a headache that worsens when standing up in patients with or without a prior headache (20). The headache might be accompanied with nausea, vomiting, neck ache, dizziness, horizontal diplopia, changes in hearing ability, tinnitus, numbness of face, and radicular symptoms in upper extremities (4).

Intracranial hypotension-induced headache often resolves spontaneously within two weeks. However, there are also cases where the patient suffers for months and even years (21). According to IHS diagnosis criteria for low CSF pressure-induced headache, it can start or fade away in a few minutes depending on the position; can be throbbing, and cause a feeling of intense pressure at varying severity (6). Intracranial hypotension can be treated with conservative approach, most of the time (22). Ergun et al. demonstrated that theophylline infusion is also beneficial in the treatment of intracranial hypotension-induced headache (23). Diagnosis is established with typical clinical history, physical examination, and imaging. Abnormal MRI findings of intracranial hypotension are diffused dural thickening, subdural effusion, downwards displacement in the brain, and enlargement of the pituitary gland (24). It has been reported that MRI findings can be normal in 20% of the clinically diagnosed cases. Even though CT or radionuclide cisternography techniques are used, there are restrictions such as high radiation exposure, and low spatial resolution (25). Ultrasound, on the other hand, is easy to use at low cost. It has become increasingly common to determine intracranial pressure changes by measuring ONSD by ultrasound. As optic nerve is surrounded by subarachnoid space, an increase in intracranial pressure might move CSF to the subarachnoid intracranial space, and increase the ONSD (26). Measurement of the ONSD has been shown to be correlated with CSF pressure, and it is a useful method especially in the determination of increased CSF pressure (18, 27). Lee et al. found the cut-off value of ONSD in intracranial pressure increase to be 5.5 mm; sensitivity and specificity being 98.77% and 85.19%, respectively (28). But these measures define intracranial hypertension. Measurement values of our patients were within these values even after treatment. There is no determined value in the literature for the cut-off value of intracranial hypotension-induced ONSD.

It has been reported that gender may significantly affect mean ONSD values, as women had high values than men (29, 30). However, female/

male ratio in both groups in our study was not significantly different statistically (Table 1).

Dubost et al. showed that ONSD increased after the treatment of post-dural puncture headache with epidural blood patch. However, the ONSD remained unchanged after unsuccessful epidural blood patch (31).

In our study, there was a significant decrease in the ONSD value of patients with PDPH of pre-operative compared with post-operative 24th hour values. There was also an increase in the NRS scores of patients. We observed an increase in the ONSD value, and a decrease in the NRS value especially at post-operative 26th and 48th hour following conservative treatment.

The pre-operative ONSD value of patients with headache was 3.8 ± 0.2 mm. USG-guided ONSD value in Chinese population is 3.55 ± 0.38 mm; tomography-guided ONSD of volunteers was 4.4 mm (32, 33). Our measurement was closer to Wang et al.'s. The difference of Ozge and Ariyürek's values could be attributed to methods they used. As USG depends on the experience of the operator, measurements may alter between 0.1 and 0.3 mm (28). Also, the change of body temperature could have affected the ONSD; but body temperature was not measured in our study.

The Numerical Rating Scale (NRS), Verbal Rating Scale (VRS), and Visual Analogue Scale (VAS) were used for evaluating the severity of pain since the 1950's. We preferred to use NRS in our study, as it is distinctive to define chronic pain, easy to use, standardized (34), and can also be used for patients from different cultures (35). We evaluated the relationship between NRS and ONSD.

Our study has some limitations. The experience of the person measuring ONSD by USG is important. The variability of ONSD is another potential limitation. The exclusion of body temperature from the variants that are likely to affect CSF pressure might have had an effect on this study, too. Other factors limiting our study could be the small sample size, and lack of cut-off value for ONSD in intracranial hypotension.

We concluded that the NRS and ONSD were correlated. The more ONSD decreases, the more the NRS increases, and vice versa. Together with this, the cut-off value in intracranial hypotension has not been determined even though the cut-off value of ONSD is known in intracranial pressure. In our study, however, we determined that headache started when the ONSD was below 3.2 ± 0.3 mm.

CONCLUSION

NRS is subjective, so we believe that in the use of ONSD measurement by USG non-invasively, an objective method would be better in the diagnosis and follow-up of intracranial hypotension-induced headache. More studies are required to determine the cut-off value of ONSD in intracranial hypotension.

Ethics Committee Approval: Approval of the ethics committee was taken from the Scientific Research Ethics Committee of the Faculty of Medicine of Karadeniz Technical University.

Informed Consent: Written informed consent was obtained from the participants.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - AB, OFT, AA, END; Design - AB, OFT, AA, END; Supervision - AB, OFT, END; Resource - AB, OFT, AA; Materials - AB, OFT, AA, END; Data Collection and/ or Processing - AB, OFT, AA, END; Analysis and/or Interpretation - AB, OFT, AA, END; Literature Search - AB, OFT, AA; Writing - AB, OFT, AA, END; Critical Reviews - AB, OFT, AA, END.

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