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Original Article / Özgün Araştırma

Use of Ultrasound-Measured Optic Nerve Sheath Diameter in the Emergency Department to Differentiate Hypertensive Emergency and Urgency

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Abstract

Objectives: Hypertensive patients may present with varying degrees of clinical severity and target organ damage (TOD). Bedside ultrasound measurement of optic nerve sheath diameter (ONSD) is a rapid and non-invasive bedside imaging method increasingly used in emergency settings. The primary aim of this study was to evaluate the association between baseline ONSD and clinical severity in hypertensive patients presenting to the emergency department (ED).

Methods: This prospective, single-center, observational study included adult patients presenting to the ED with hypertension and suspected acute TOD, consistent with hypertensive emergency (HE). Demographic and clinical data, blood pressure measurements, and pre- and post-treatment ONSD values were recorded. The associations between ONSD, TOD, treatment response, and hospitalization were analyzed, and the discriminative ability of ONSD for clinical outcomes was assessed using receiver operating characteristic (ROC) analysis.

Results: A total of 113 hypertensive patients were included in the study. ONSD values were significantly higher in patients with TOD compared to those without (4.88±0.76 mm vs. 4.45±0.46 mm, p=0.007). A significant decrease in ONSD values was observed after antihypertensive treatment (p<0.001). ROC analysis revealed that the ONSD threshold value associated with HE was 4.62 mm (sensitivity: 69%, specificity: 69%), and for predicting hospitalization it was 4.57 mm (sensitivity: 65%, specificity: 60%). A moderate positive correlation was found between ONSD and age, systolic and diastolic blood pressure, and TOD.

Conclusion: Bedside ultrasound measurement of ONSD may serve as an adjunctive, non-invasive parameter associated with clinical severity and hospitalization requirement in hypertensive patients presenting to the ED.

Keywords: Hypertensive Crisis; Hypertension; Optic Nerve Sheath Diameter; Ultrasonography; Emergency Department; Target Organ Damage

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Acil Serviste Hipertansif Acil ve İvedi Ayrımında Ultrason ile Ölçülen Optik Sinir Kılıf Çapı Kullanımı

Öz

Amaç: Hipertansif hastalar, farklı klinik şiddet dereceleri ve hedef organ hasarı (HOH) ile başvurabilmektedir. Yatak başı ultrason ile optik sinir kılıf çapı (OSKÇ) ölçümü, acil servis ortamlarında giderek daha yaygın olarak kullanılan hızlı ve non-invaziv bir yatak başı görüntüleme yöntemidir. Bu çalışmanın temel amacı, acil servise (AS) başvuran hipertansif hastalarda başlangıç OSKÇ değerleri ile klinik şiddet arasındaki ilişkiyi değerlendirmektir.

Yöntemler: Bu prospektif, tek merkezli, gözlemsel çalışma; AS'ye yüksek kan basıncı ve hipertansif acil (HA) ile uyumlu şüpheli akut HOH ile başvuran yetişkin hastaları dahil etmiştir. Hastaların demografik ve klinik verileri, kan basıncı ölçümleri, tedavi öncesi ve sonrası OSKÇ değerleri kaydedilmiştir. OSKÇ ile HOH, tedavi yanıtı ve hastaneye yatış arasındaki ilişkiler analiz edilmiş; OSKÇ'nin klinik sonuçları öngörme yeteneği "Alıcı İşletim Karakteristiği" (ROC) analizi ile değerlendirilmiştir.

Bulgular: Çalışmaya toplam 113 hipertansif hasta dahil edilmiştir. Hedef organ hasarı olan hastaların OSKÇ değerleri, olmayanlara göre anlamlı derecede yüksek bulunmuştur (4,88±0,76 mm ve 4,45±0,46 mm, p=0,007). Antihipertansif tedavi sonrası OSKÇ değerlerinde anlamlı bir azalma gözlenmiştir (p<0,001). ROC analizi sonucunda, hipertansif acil durum ile ilişkili OSKÇ eşik değeri 4,62 mm (duyarlılık: %69, özgüllük: %69); hastaneye yatışı öngören eşik değer ise 4,57 mm (duyarlılık: %65, özgüllük: %60) olarak saptanmıştır. OSKÇ ile yaş, sistolik ve diyastolik kan basıncı ve HOH arasında orta düzeyde pozitif bir korelasyon saptanmıştır.

Sonuç: Yatak başı ultrason ile OSKÇ ölçümü, acil servise başvuran hipertansif hastalarda klinik şiddet ve hastaneye yatış gerekliliği ile ilişkili, yardımcı ve invaziv olmayan bir parametre olarak hizmet edebilir.

Anahtar kelimeler: Hipertansif Kriz; Hipertansiyon; Optik Sinir Kılıf Çapı; Ultrasonografi; Acil Servis; Hedef Organ Hasarı.

INTRODUCTION

Hypertension (HT) is a public health problem affecting approximately one-third of the adult population[1,2]. A substantial proportion (23.6%) of emergency department (ED) visits are related to HT3. In instances where systolic blood pressure (SBP) is ≥180 mmHg and/or diastolic blood pressure (DBP) is ≥120 mmHg, the clinical condition is defined as hypertensive emergency (HE) if target organ damage is present, whereas it is classified as hypertensive urgency (HU) in its absence[3,4]. Acute renal failure, unstable angina pectoris, acute ischemic stroke, pulmonary edema, hypertensive encephalopathy, intraparenchymal hematoma, and hypertensive retinopathy are life-threatening complications that may occur in patients diagnosed with HE[4]. Therefore, comprehensive organ function assessment, multidisciplinary approach, and timely intervention are critically important in patients diagnosed with HE[5,6]. The literature has established that HT causes damage to the blood–brain barrier and cerebral vessels, resulting in intracranial hypertension (IH)[7]. Since clinical findings in IH may be subtle, intracranial pressure measurement is recommended; however, invasive intracranial pressure measurement methods have limited applicability in the ED due to complication risk and resource requirements[8]. Bedside ultrasonography (B-USG) measurement of optic nerve sheath diameter (ONSD) is a non-invasive, rapid, and reproducible method that has been used as an adjunctive parameter in previous studies for the evaluation of patients with suspected intracranial pressure changes. Numerous studies have evaluated the relationship between increased ONSD and IH, TOD, and hospitalization requirement, suggesting possible associations[9]. We examined

whether ONSD is related to blood pressure measurements, clinical severity, and hospitalization necessity in hypertensive patients presenting to the ED.

METHODS

Study Design and Setting

This prospective, single centre, observational study was conducted between 5 February 2023 and 5 February 2024 at the Adult ED of Afyonkarahisar Health Sciences University. Adult patients presenting to the ED with severe HT and suspected acute TOD were screened for eligibility.

Participants

Patients aged ≥18 years presenting to the ED with SBP ≥180 mmHg and/or DBP ≥120 mmHg who provided informed consent were included in the study.

Patients were excluded if informed consent could not be obtained; if they were under 18 years of age; if adequate ultrasonographic assessment could not be performed; if follow-up blood pressure or ONSD measurements were unavailable; if they had a history of ocular surgery or known optic nerve pathology; if they experienced cardiac arrest or hemodynamic instability; or if they had known intracranial conditions such as intracranial mass lesions or hydrocephalus that could influence intracranial pressure.

Measurements and Data Collection

Blood pressure measurements were taken from the left arm, with the patient in the supine position, using an appropriately sized cuff and a Mindray uMEC12® monitor (Mindray, Shenzhen, China), following a minimum of five minutes of rest, and recorded as the initial non-invasive blood pressure measurement. Measurements were recorded upon presentation to the ED and at the 1-hour time point after achieving the target blood pressure as determined by the treating physician based on clinical assessment. Treatment protocols appropriate to each patient's clinical condition were initiated in accordance with routine ED practice. Clinical diagnoses were established through history taking, physical examination, and diagnostic tests including complete blood count and biochemistry panels, with appropriate consultations requested when clinically indicated. Imaging modalities included electrocardiography (ECG) using a GE MAC 2000 (General Electric, Milwaukee, WI, USA), echocardiography (ECHO) performed with a Terason USMART 3200T® ultrasound device (Terason, Burlington, MA, USA), computed tomography (CT) with a Siemens SOMATOM Force scanner (Siemens Healthineers, Erlangen, Germany), and magnetic resonance imaging (MRI) using a Siemens Aera 1.5T (Siemens Healthineers, Erlangen, Germany). ONSD measurements were performed using B-USG with a Terason USMART 3200T® device equipped with a 7.5 MHz linear probe (Terason, Burlington, MA, USA), from both eyes in axial and sagittal planes at the time of ED presentation and at the 1st hour after achieving target blood pressure. ONSD was measured at approximately 3 mm posterior to the globe, in accordance with commonly used ultrasonographic measurement techniques described in the literature. All measurements were performed in a blinded fashion by a single emergency medicine resident trained in ocular ultrasonography who had no knowledge of the patients' clinical diagnosis and treatment processes. Patients were positioned supine with eyelids closed. Maintaining sterile technique, the probe was applied using a separate sterile glove for each patient. ONSD measurements were repeated at the 1st hour following antihypertensive treatment.

Variables

The primary variables analyzed included age, sex, SBP and DBP, pre- and post-treatment

ONSD values, presenting symptoms, presence of TOD, hypertensive condition (HE or HU), comorbidities, and hospitalization requirement.

Statistical Analysis

Statistical analyses were carried out using IBM SPSS Statistics software (version 27.0; IBM Corp., Armonk, NY, USA). Continuous variables were summarized using mean and standard deviation values, whereas categorical variables were expressed as numbers and percentages. The normality of data distribution was evaluated using the Kolmogorov-Smirnov test for sample sizes greater than 50 and the Shapiro-Wilk test for samples of 50 or fewer participants. Comparisons between independent groups were performed using the Student's t-test for normally distributed variables and the Mann-Whitney U test for variables without normal distribution. Paired comparisons were conducted using either the Paired t-test or the Wilcoxon signed-rank test, depending on data distribution. Relationships between categorical variables were examined using the chi-square test. Receiver operating characteristic (ROC) curve analysis was used to assess the ability of ONSD to discriminate selected clinical outcomes. A two-sided p value of <0.05 was accepted as statistically significant.

Sample Size

In sample size calculation, the target correlation coefficient was set at 0.70 with a 95% confidence interval of 0.60 to 0.80. A minimum sample size of 105 patients was determined, and considering a potential attrition rate of approximately 8%, recruitment of 113 hypertensive patients was planned. A total of 113 patients with complete follow-up measurements were included in the study.

RESULTS

During the study period, a total of 150 patients who met the specified criteria were identified among those presenting to the a tertiary care adult ED. Of these, 15 patients voluntarily withdrew from the study, and 22 patients were excluded because follow-up ONSD measurements could not be obtained (Figure 1). Thus, 113 patients with complete follow-up measurements were included in the final analysis (Figure 2). The mean age of the included patients was 61.05 ± 15.23 years, and 63 (55.8%) were female. The proportion of patients without a prior diagnosis of HT who were newly diagnosed in the ED was 30.1% (n = 34). ONSD values were significantly higher in patients with a previous HT diagnosis compared with newly diagnosed patients ($p = 0.048$, 95% Confidence Interval (CI): 0.00–0.47; t-test). No significant association was observed between ONSD values and the presence of other comorbidities, including DM, chronic kidney disease, stroke, chronic obstructive pulmonary disease (COPD) / asthma, heart failure, coronary artery disease, or malignancy ($p > 0.05$ for all comparisons). Some patients presented with more than one complaint. The distribution of presenting symptoms was as follows: headache 26% (n=30), fever 13% (n=15), neurological symptoms (altered consciousness, visual and speech disturbances, hemiparesis or hemiplegia, vertigo) 13% (n=15), gastrointestinal symptoms (abdominal pain, nausea, loss of appetite, vomiting, anorexia, diarrhea, constipation) 9% (n=10), chest pain 7% (n=8), dyspnea 7% (n=8), epistaxis 4% (n=4), genitourinary symptoms (dysuria, suprapubic pain, urinary incontinence, hematuria) 1% (n=1), visual impairment 1% (n=1), intraocular hemorrhage 1% (n=1), and asymptomatic 19% (n=21). According to presenting complaints, initial ONSD measurements were modestly higher in patients with dyspnea compared to those without ($p = 0.009$, 95% CI: 0.14–0.96, t-test). ONSD values did not differ significantly between the remaining symptom groups. Based on clinical evaluation, HE and HU were diagnosed in 27 (23.9%) and 86 (76.1%) participants,

respectively. The most common clinical presentations in patients diagnosed with HE were acute renal failure 23.3% (n=7), unstable angina pectoris 20.0% (n=6), acute ischemic stroke 16.7% (n=5), pulmonary edema 13.3% (n=4), hypertensive encephalopathy 10.0% (n=3), intraparenchymal hematoma 10.0% (n=3), and hypertensive retinopathy 6.7% (n=2). Multiple organ damage was detected in 10.0% (n=3) of patients. Gender distribution did not differ significantly between patients diagnosed with HE and HU. Age did not differ significantly between the HE and HU groups (p=0.065, t-test). The mean SBP at presentation was 200.00±12.02 mmHg in the HE group and 192.44±11.23 mmHg in the HU group (p=0.03, t-test). The mean DBP at presentation was 118.97±17.02 mmHg in the HE group and 113.27±16.83 mmHg in the HU group, and this difference was not significant (p=0.120, t-test). The mean ONSD at presentation was 4.88±0.76 mm in the HE group and 4.45±0.46 mm in the HU group, and it was significantly higher in the HE group (p=0.007, 95% CI: 0.12-0.73, t-test). When pre- and post-treatment SBP, DBP, and ONSD values were compared in all patients, a significant decrease was observed in all parameters following treatment (p<0.001, Table 1). Additionally, post-treatment ONSD values decreased significantly in both HE and HU groups (p<0.001, Table 2). The mean ONSD at presentation in hospitalized patients was 4.89±0.63 mm. In patients who did not require hospitalization, this value was 4.43±0.51 mm, and ONSD was significantly higher in hospitalized patients (p<0.001, t-test). A moderate positive correlation was identified between ONSD at presentation and age, SBP, DBP, and TOD (Age: r=0.603, p<0.001; SBP: r=0.653, p<0.001; DBP: r=0.526, p<0.001; TOD: r=0.323, p<0.001, Pearson correlation analysis) (Table 3). SBP at presentation showed a weak positive correlation with TOD (r=0.280, p=0.003, Pearson correlation analysis). ROC analysis was performed to evaluate the ability of ONSD to discriminate between patients with and without HE and to assess hospitalization requirement (Figure 3). An ONSD threshold value of 4.62 mm was identified as being associated with HE, while a threshold value of 4.57 mm was associated with hospitalization requirement (Table 4).

Figure 1: Probe Preparation and Measurement Technique for Optic Nerve Sheath Diameter (ONSD) Measurement Using Ocular Ultrasonography

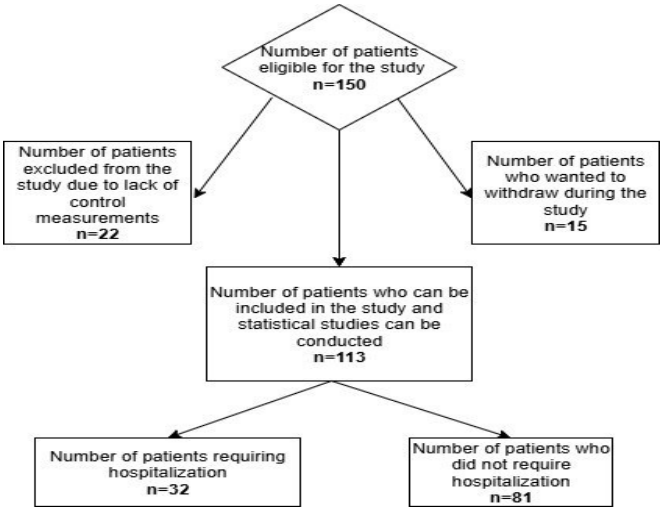

Figure 2: Patient flow chart

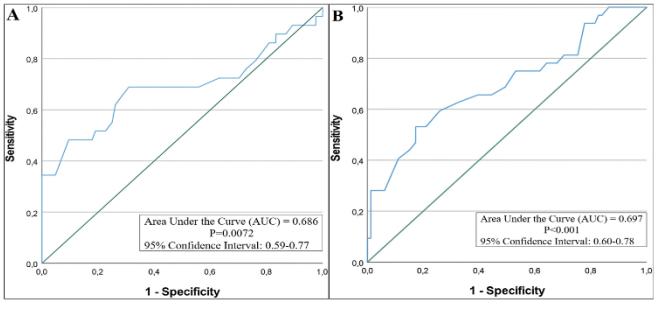

Figure 3: Figure 1. ROC curve analysis evaluating the ability of ONSD to discriminate between patients with and without hypertensive emergency **(A)** and to assess the requirement for hospitalization **(B)**.

Table I: Comparison of SBP, DBP and ONSD measurements of all patients 0. and 1. hour (n=113)

	0.Hour (Mean±SD)	1.Hour* (Mean±SD)	P (Paired t test)	95% CI
SBP	194.38±11.86	150.31±15.44	**<0.001**	41.20-46.93
DBP	114.73±16.99	85.53±11.94	**<0.001**	19.60- 32.15
ONSD	4.56±0.58	4.17±0.58	**<0.001**	0.32-0.44

SBP: Systolic Blood Pressure (mmHg), DBP: Diastolic Blood Pressure ONSD: Optic Nerve Sheath Diameter, SD: Standard Deviation, CI: Confidence Interval

Post-treatment measurements were taken 1 hour after reaching the target blood pressure P<0.05*

Table II: Comparison of 0th and 1st hour ONSD measurements of patients diagnosed with hypertensive emergency (n=27) and urgency (n=86)

	0.Hour (Mean±SD)	1.Hour* (Mean±SD)	P (Paired t test)	95% CI
HU	4.45±0.46	4.12±0.50	**<0.001**	0.27-0.39
HE	4.88±0.77	4.35±0.76	**<0.001**	0.37-0.70

HU: Hypertensive Urgency, HE: Hypertensive Emergency, SD: Standard Deviation, CI: Confidence Interval

** Post-treatment measurements were taken 1 hour after reaching the target blood pressure*

Table III: Correlation of all patients in terms of age, SBP, DBP, ONSD

r	Age	SBP	DBP	ONSD	EOD
Age	1	**0.658***	**0.449***	**0.603***	0.174
SBP	**0.658***	1	**0.785***	**0.653***	**0.280**
DBP	**0.449***	**0.785***	1	**0.526***	0.147
ONSD	**0.603***	**0.653***	**0.526***	1	**0.323**
TOD	0,174	**0.280**	0.147	**0.323**	1

*SBP: Systolic Blood Pressure (mmHg), DBP: Diastolic Blood Pressure (mmHg) ONSD: Optic Nerve Sheath Diameter, TOD: Target organ damage, r: Pearson Correlation Coefficient * P<0.05*

Table IV: Performance parameters of ONSD in diagnosing hypertensive emergency and hospitalization

Performance parameters	Hypertensive Emergency (95% CI)	Hospitalisation (95% CI)
Cut off Value	>4.6	>4.57
Sensitivity	68.97 (49.2-84.7)	65.00 (41.4-76.3)
Specificity	69.05 (58.0-78.7)	60.00 (51-68)
Positive Predictive Value	43.5 (34.0-53.5)	54.84 (40.54-68.38)
Negative Predictive Value	40.5 (31.3-51.6)	59.68 (51.13-67.67)
Positive Likelihood ratio	2.23 (1.49-3.33)	4.43 (2.3-8.2)
Negative Likelihood ratio	0.45 (0.26-0.79)	0.42 (0.25-0.60)
Area Under the Curve	0.686 (0.59-0.77)	0.696 (0.60-0.78)
P	**0.0072**	**<0.001**

ONSD: Optic Nerve Sheath Diameter, CI: Confidence Interval

DISCUSSION

IH is a critical condition associated with high morbidity and mortality, for which early diagnosis is of paramount importance[7,10-12]. Although the gold standard method for diagnosis is pressure measurement via intracranial catheter, its use is limited to select patients due to complications such as hemorrhage, infection, and catheter occlusion[8,13,14]. While imaging modalities such as CT and MRI are non-invasive methods, their utilization is constrained by factors including prolonged acquisition time, limited accessibility, and high cost[12-16]. In contrast, ONSD measurement with B-USG is a non-invasive, cost-effective, rapid, reproducible method that does not require patient transport and involves no radiation exposure[9,13-17]. The literature demonstrates a significant positive correlation between IH and ONSD, and it has been established that HT causes IH by inducing

damage to the blood-brain barrier vasculature[7,10,11]. The present study examined the relationship between ONSD and IH in hypertensive patients presenting to the emergency department and explored its associations with blood pressure parameters, target organ damage, and clinical severity. Da Costa and colleagues reported that chronic HT can affect fluid dynamics around the brain and optic nerve by causing permanent alterations in vascular structure[7]. Similarly, in our study, the finding that ONSD was significantly higher in patients with a prior history of HT compared to those newly diagnosed with HT (p=0.048) suggests that chronic HT may lead to IH and consequently ONSD elevation.

HE are clinical conditions requiring urgent diagnosis and treatment, characterized by the development of TOD with sudden and severe blood pressure elevation[2,3,5,6]. In these patients, symptoms such as severe headache, visual disturbances, chest pain, dyspnea, altered consciousness, and neurological deficits are frequently observed, and early diagnosis with rapid intervention is of vital importance[5,6]. Dyspnea can often be an indicator of serious TOD such as pulmonary edema or myocardial ischemia in HE and may be associated with elevated ONSD values, potentially reflecting IH[5,9,15]. In line with the findings reported by Danış et al., our results showed that patients presenting with dyspnea had significantly higher ONSD measurements than those without dyspnea (p=0.009), highlighting its potential clinical relevance[9]. The literature emphasizes the prognostic significance of dyspnea and cardiopulmonary complications in hypertensive crises, and it is noted that ONSD may demonstrate correlation with such systemic manifestations[5,9]. ONSD measurement performed at the bedside in hypertensive patients presenting to the ED with dyspnea can guide the emergency physician regarding TOD[9,15]. In our study, the finding that the frequency of HE diagnosis was similar according to gender (p=0.071) and that there was no significant difference between HE and HU groups in terms of age (p=0.065) indicates that these conditions occur in a demographically homogeneous population[1-3]. However, the findings that mean SBP at presentation was significantly higher in the HE group (200.00±12.02 mmHg vs. 192.44±11.23 mmHg, p=0.03), that there was no significant difference between groups in terms of DBP (p=0.120), and that mean ONSD at presentation was significantly higher in the HE group (4.88±0.76 mm vs. 4.45±0.46 mm, p=0.007) suggest that SBP and ONSD may serve as potential biomarkers in HE diagnosis. The observation of significant decreases in SBP, DBP, and ONSD values following treatment demonstrates that effective antihypertensive therapy in HE affects both blood pressure and ONSD, which reflects intracranial pressure. The literature reports that with rapid and controlled administration of intravenous antihypertensive agents in HE, SBP and DBP are reduced, and in parallel, non-invasive parameters such as ONSD also decrease[2,3,5,6]. Furthermore, the finding that ONSD values at presentation were significantly higher in patients requiring hospitalization supports the notion that ONSD is a potential biomarker in predicting disease severity and hospitalization need[9,12,17-19]. Supporting this diagnostic utility, recent literature has also demonstrated that ONSD measurement is an effective tool for identifying intracranial pressure changes in various clinical scenarios, including the evaluation of shunt dysfunction[20]. These findings demonstrate that ONSD measurement can be utilized as a complementary tool in monitoring treatment response and clinical decision-making processes[12,18,19,21]. In addition, current studies highlight the potential role of ONSD measurement as a bedside assessment method for evaluating patients with suspected

intracranial pressure alterations in emergency settings[9,15,17,20].

In our study, the identification of moderate positive correlations between ONSD values at presentation and SBP, DBP, and TOD demonstrates that ONSD is associated with TOD in HE. In our study, ROC analysis was performed to evaluate the performance of ONSD measurement in determining HE diagnosis and hospitalization requirement. As a result of the analysis, threshold values of 4.62 mm for HE and 4.57 mm for hospitalization requirement were identified, suggesting potential clinical relevance. These threshold values suggest that ONSD may serve as a practical and non-invasive adjunctive parameter for the early identification of HE and for supporting hospitalization decisions.

LIMITATIONS

Several constraints should be considered when interpreting the results of this study. Being performed in a single ED setting may restrict the extent to which the findings can be extrapolated to other populations or clinical environments. Furthermore, the relatively small sample size within some subgroups may have limited the robustness of subgroup-specific statistical analyses. As ONSD measurement is inherently operator dependent, it may also be affected by factors unrelated to IH. Lastly, the absence of longitudinal follow-up precluded assessment of the prognostic implications of treatment-related changes in ONSD.

CONCLUSION

In conclusion, bedside measurement of optic nerve sheath diameter using B-USG appears to be a feasible, rapid, and non-invasive adjunctive method that may support the assessment of clinical severity, hospitalization requirement, and treatment response in patients with HE presenting to the ED. While ONSD measurement should not replace standard clinical and diagnostic evaluation, it may provide complementary information to assist emergency physicians in clinical decision-making.

Ethics Committee Approval: The study was conducted with the approval of Afyonkarahisar Health Sciences University Non-Interventional Ethics Committee (Meeting Date: 03.02.2023, Decision No: 2023/2, Ethics Committee Code: 2011-KAEK-2). A signed informed consent form was secured from every individual who participated in the research. The Helsinki Declaration was followed as the guideline in this study. This study was derived from the medical specialty thesis of Dr. Hüseyin Aldemir.

Conflict of Interest: The author(s) declare that there is no financial conflict of interest related to this article.

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